Fast Choreography of Cross-DevOps Reconfiguration with Ballet

Multi-Site OpenStack Case Study

Jolan Philippe, Hélène Coullon, Antoine Omond, Charles Prud'Homme, Issam Raïs

April 8th, 2024

STACK, IMT Atlantique
SeMaFoR project

DevOps deployment and reconfiguration

Responsible for **development**

DevOps team

Run tests | Package app | Build image Docker | Push artifact to repo | Deploy to server

Continuous integration + Continuous deployment

Responsible for **operations**

$\Rightarrow$ Continuous deployment then **reconfiguration**

Cross-DevOps reconfiguration

Responsible for **development** of A

DevOps team

Run tests on A → Package A → Build image for A → Push A to repo → **Deploy A**

Responsible for **operations** on A

Responsible for **development** of B which uses A

DevOps team

Run tests on B → Package B → Build image for B → Push B to repo → **Deploy B (after A?)**

Responsible for **operations** on B (using A)

Case study: Deploy or update OpenStack with Galera cluster of MariaDB

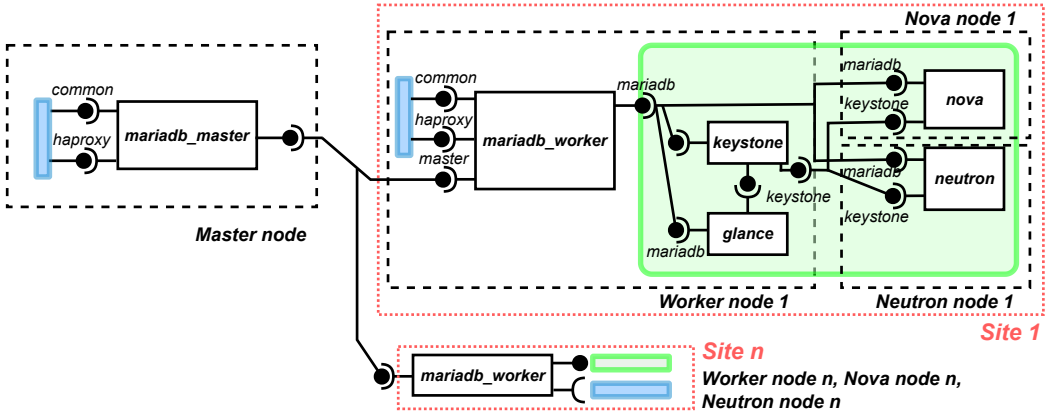


Figure 1: Assembly of a multi-site OpenStack with a Galera cluster of distributed MariaDB databases.

Approach

Naive solution

Using a centralized tool on top of all DevOps teams is not suitable for scale and fault tolerance reasons.

Decentralized solution

Make a plan for each DevOps team, and execute them concurrently.

Muse (Sokolowski et. al.) covers cross-DevOps decentralized reconfiguration with planning, but inefficient because of the fixed life cycles (i.e., on-off mode for resources).

Ballet overview

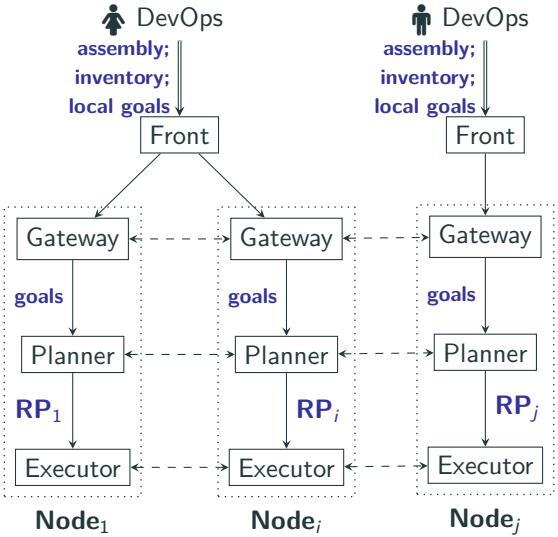


Figure 2: Ballet overview

- Decentralized tool (one instance of Ballet on each node)
- Declarative input
- Automatic planning
- Efficient reconfiguration

Gateway

Global knowledge building of reconfiguration goals

Planner

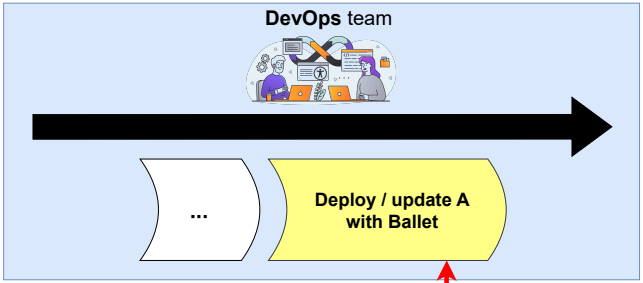
Decentralized inference of reconfiguration plans (RPs)

Executor

Coordinated execution of RP

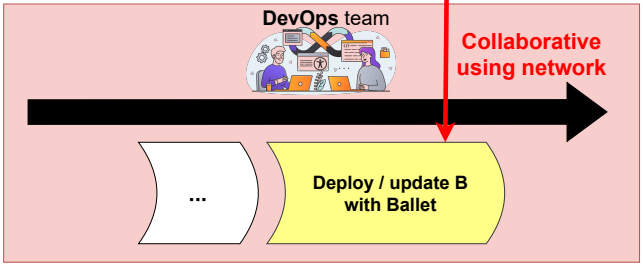
Ballet's usage

Responsible for **development** of A and A's life cycle



Responsible for **operations** on A

Responsible for **development** of B and B's life cycle



Responsible for **operations** on B (using A)

Developers' concern

Life-cycle and ports

Simple language to define component

- **Places**: milestones in reconfiguration
- **Transitions**: reconfiguration actions (can be concurrent) associated to a general behavior
- **Ports**: dependencies in the reconfiguration process between components

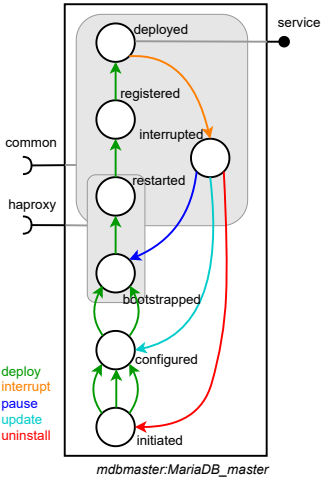


Figure 3: Visual representation of a component for MariaDB

Developer's concern

Listing 1: Control component MariaDB master in PYTHON

```
class MariaDB_Master(Component):
    def create(self):
        self.places = [ "initiated", "configured", "bootstrapped", "restarted",
                        "registered", "deployed", "interrupted"]
        self.transitions = {
            "configure0": ("initiated", "configured", "deploy", self.configure0),
            "configure1": ("initiated", "configured", "deploy", self.configure1),
            "configure2": ("initiated", "configured", "deploy", self.configure2),
            ...
        }
        self.dependencies = {
            "service": (DepType.PROVIDE, ["deployed"]),
            "haproxy": (DepType.USE, ["bootstrapped","restarted"]),
            ...
        }
        self.initial_place = 'initiated'
        self.running_place = 'deployed'

    def configure0(self):
      # concrete actions
```

DevOps' concern

Reconfiguration goals

Declarative language for defining reconfiguration goals

- **Behavior goal**: Specify a behavior that must be executed
- **Port goal**: Specify a port status (active, inactive)
- **State goal**: Specify a component state (specific, running, initial)

Case study reconfiguration

behaviors:
- ***component***: *mariadb_master*
  behavior: *update*

components:
- ***forall***: *running*

Listing 2: Language to define reconfiguration goals for DevOps usage

```
<goals> ::= behaviors: <bhvr_list>
            ports: <port_list>
            components: <comp_list>
<bhvr_list> ::= ...
<bhvr_item> ::= - forall: <bhvr_name>
              | - component: <comp_name>
                  behavior: <bhvr_name>
<port_list> ::= ...
<port_item> ::= - forall: <port_status>
              | - component: <comp_name>
                  port: <port_name>
                  status: <port_status>
<comp_list> ::= ...
<comp_item> ::= - forall: <comp_status>
              | - component: <comp_name>
                  status: <comp_status>
```

Ballet execution

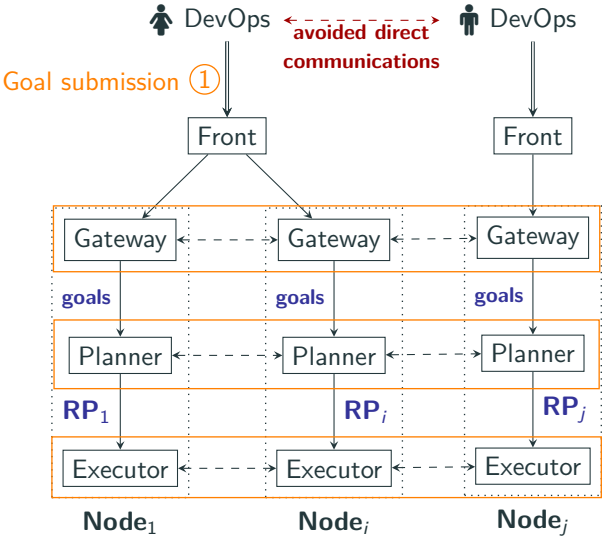


Figure 4: Ballet execution

Ballet execution

Outline

For clarity reasons:

1. (Skip gateway since there is no scientific challenge)
2. Start with the execution
3. Followed by the planning

Execution language: Concerto-D (Antoine Omond's thesis)

Reconfiguration programs are plans which can

1. Create assemblies of components (software system)
2. Make this assembly evolve at runtime
3. Interact with the life cycle of components

The used language propose instructions for:

Add/remove a component instance to the current assembly

Connect/disconnect two component instances with compatible ports

Push behavior to the behavior queue on a component instance

Wait for a given component instance to execute a behavior

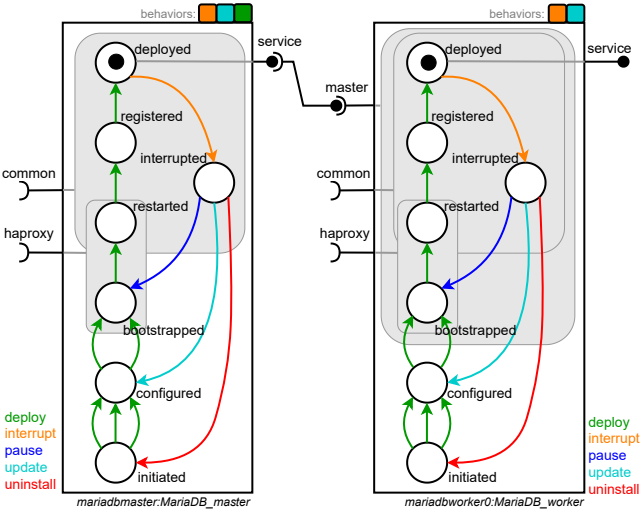
Decentralized execution: Concerto-D

mariadb_master's RP

pushB(master, interrupt)
pushB(master, update)
pushB(master, deploy)

mariadb_worker0's RP

pushB(worker, interrupt)
pushB(worker, update)
wait(master, interrupt)
pushB(worker, deploy)



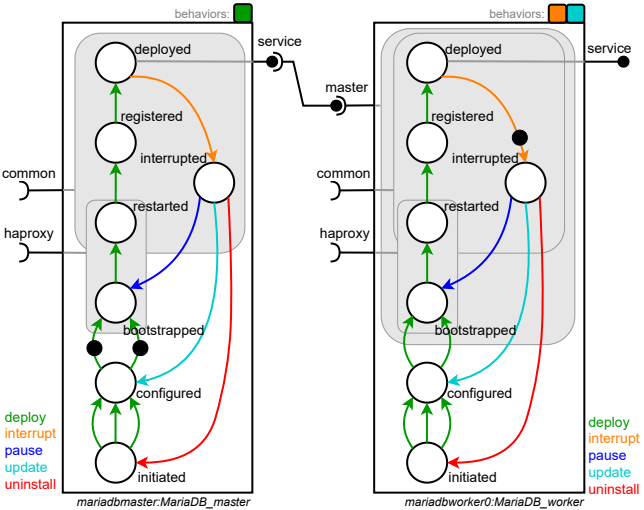
Decentralized execution: Concerto-D

mariadb_master's RP

pushB(master, interrupt)
pushB(master, update)
pushB(master, deploy)

mariadb_worker0's RP

pushB(worker, interrupt)
pushB(worker, update)
wait(master, interrupt)
pushB(worker, deploy)



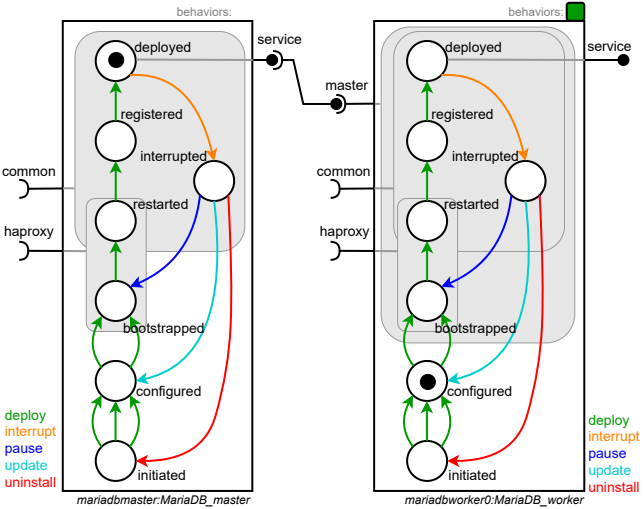
Decentralized execution: Concerto-D

mariadb_master's RP

pushB(master, interrupt)
pushB(master, update)
pushB(master, deploy)

mariadb_worker0's RP

pushB(worker, interrupt)
pushB(worker, update)
wait(master, interrupt)
pushB(worker, deploy)



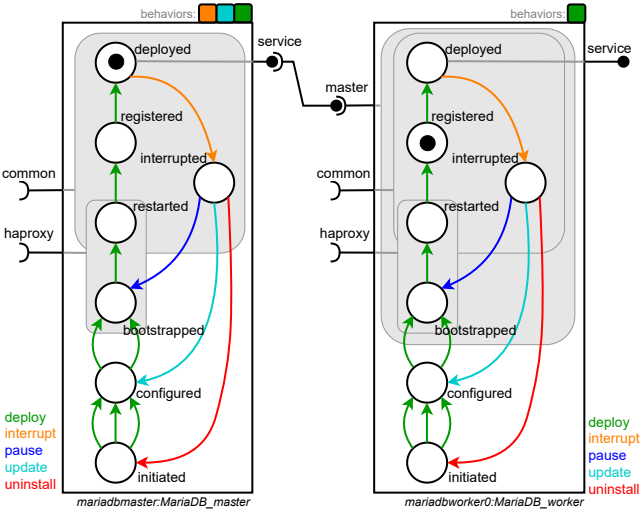
Failing example

mariadb_master's RP

pushB(master, interrupt)
pushB(master, update)
pushB(master, deploy)

mariadb_worker0's RP

# No wait master's interrupt
pushB(worker, interrupt)
pushB(worker, update)
pushB(worker, deploy)



Approach for Ballet's planner

Main challenge: Infer synchronization barriers (i.e., wait instructions)

Local resolution

- **Purpose**: Find a sequence of behavior to execute
- **Hint**: Constraint programming approach

Constraint propagation

- **Purpose**: Inferring wait instructions (*i.e.*, synchro. barrier)
- **Hint**: Propagation based on Gossip algorithm
- **Hint**: Consensus using Paxos-like approach

CP for local planning: Find a word in an automaton

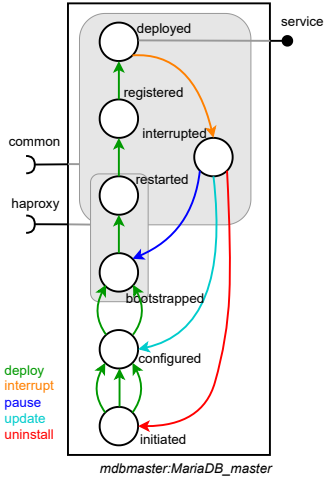
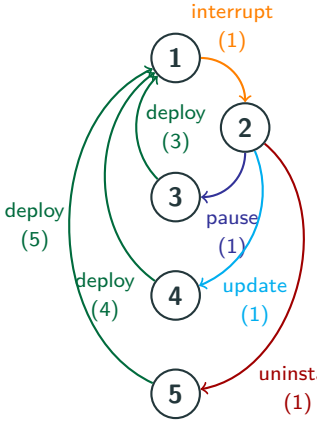


Figure 5: *MariaDB_master* control component



state	1	2	3	4	5
common	✓	✓	×	×	×
haproxy	×	×	✓	×	×
service	✓	×	×	×	×

Figure 6: Automaton representation of *Mariadb_master* component's life cycle with its matrix for ports statuses.

Message inference

Case study reconfiguration

behaviors:

- ***component***: *mariadb_master*
  behavior: *update*

components:

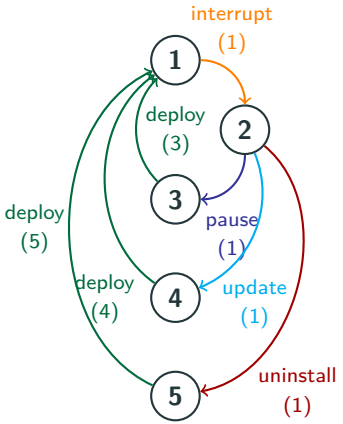
- ***forall***: *running*

CP Result

Sequence := [interrupt, update, deploy]

States := [1, 2, 4, 1]

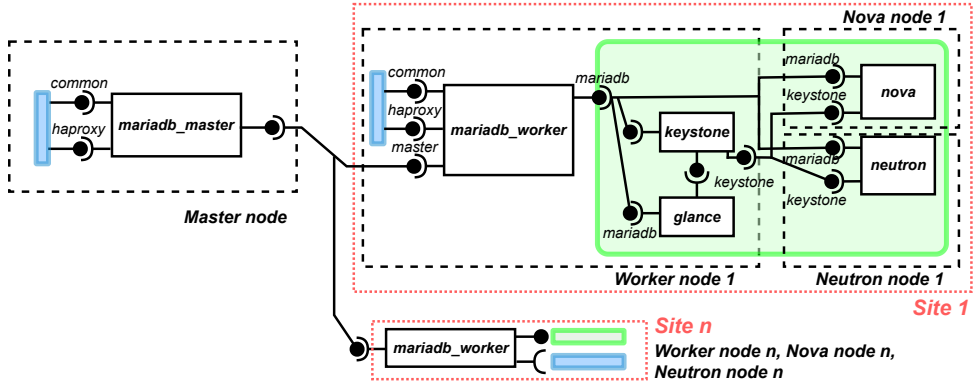
Ports statuses := common: [✓, ✓, ×, ✓]
haproxy: [×, ×, ×, ×]
service: [✓, ×, ×, ✓]



- "Components using **master**'s **service** must disconnect until **interrupt** ends"

⇒ Message: (master, service, disconnect, interrupt)

Constraint propagation



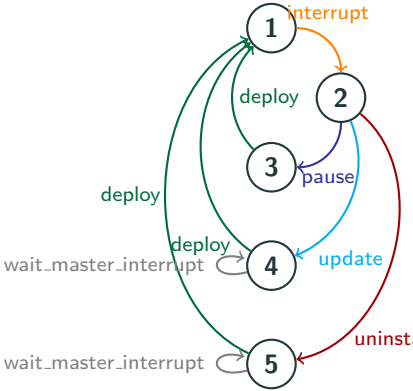
Propagated constraint (gossip + consensus) from mariadb_master for master's service

- mariadb_master ⇒ mariadb_worker
- mariadb_worker ⇒ keystone; glance; nova; neutron
- keystone ⇒ glance; nova; neutron

Enriched CP Model

Enriched CP problem

- Enriched automaton with synchronization instruction
- Additional constraint to have synchro. barrier in local plan



state	1	2	3	4	5
common	✓	✓	×	×	×
haproxy	×	×	✓	×	×
master	✓	✓	✓	×	×
service	✓	×	×	×	×

Figure 7: Enriched automaton representation of *Mariadb_worker*.

Experiments

Deployment and update of OpenStack with Galera cluster of MariaDB with $n \in [1, 2, 5, 10]$ sites, that is a total of $7 + 11 * n$ components.

Metric of interest

- For both the planner and the executor: Execution time
- For the planner: Inferred constraints, inferred actions, number of communications

Setup

- Results on $1 + 3 * n$ nodes Gros (Nancy) of Grid'5000
- Comparison to Muse (decentralized reconfiguration)
- Reproducible example on Grid'5000

Experimental results

Sc.	# Sites	Ballet			Muse	Gain
		Planning	Execution	Total		
Deploy	1	1.69s	306.02s	307.71s	536.57s	42.7%
	2	1.78s	306.09s	307.86s	536.69s	42.6%
	5	1.77s	306.19s	307.97s	537.09s	42.7%
	10	2.02s	306.14s	308.19s	538.13s	42.7%
Update	1	3.36s	416.84s	420.20s	555.56s	24.4%
	2	4.39s	416.92s	421.31s	555.70s	24.2%
	5	6.05s	417.17s	423.22s	556.08s	24.0%
	10	5.97s	417.46s	423.43s	556.77s	24.0%

Table 1: Comparison of time for planning and executing a deployment and an update of the `MariaDB_master` instance with Ballet and Muse.

Experimental results

Sc.	#Sites	#Constraints	#Instructions	#Messages
Deploy	n	$7 + 11 * n$	$7 + 11 * n$	0
	1	18	18	0
	2	29	29	0
	5	62	62	0
	10	117	117	0
Update	n	$3 + 20 * n$	$8 + 11 * n$	$9 * n$
	1	23	19	9
	2	43	30	18
	5	103	63	45
	10	203	118	90

Table 2: Results of the planning phase for the *deploy* and *update* scenario when varying the number of `Mariadb_workers` in a Galera cluster.

Conclusion

Contributions

- Ballet as a DevOps reconfiguration tool [1] (Ballet code and benchmarks available [2])
- Infer reconfiguration actions
- Efficient execution of actions

Target applications

- Multi-site OpenStack
- CPS with sensors

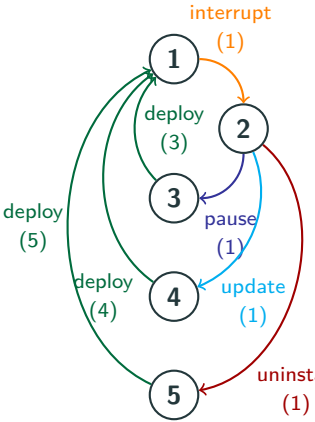
Perspectives

- Extend our constraint propagation to other problems (e.g., placement or reconfiguration)
- Formalization and reasoning for correctness
- Integrate planner and executor solutions to SeMaFoR solution

[1] Jolan Philippe, Antoine Omond, Hélène Coullon, Charles Prud'Homme, Issam Raïs. Fast Choreography of Cross-DevOps Reconfiguration with Ballet: A Multi-Site OpenStack Case Study. SANER 2024 - IEEE International Conference on Software Analysis, Evolution and Reengineering, Mar 2024, Rovaniemi, Finland.
[2] https://zenodo.org/records/10472116

Backup

CP Model



state	1	2	3	4	5
common	✓	✓	×	×	×
haproxy	×	×	✓	×	×
service	✓	×	×	×	×

Figure 9: Automaton representation of *Mariadb_master* component's life cycle with its matrix for ports statuses.

- $\textsc{Regular}(B, \Pi, s_{init}, S_{goal})$
- $s_{i+1} = inc_{\Pi}[s_i][b_i],\ \forall i \in 1..m$
- $\textsc{Count}(b, B, >, 0)$
- $status(p, s_{m+1}) = \Gamma_p$

where

$\Gamma_p \in \{\texttt{active}, \texttt{inactive}\}$

$c_i = cost(s_i, b_i),\ \forall i \in 1..m$

$C = \textsc{Sum}([c_i \mid i \in 1..m])$

Planner time

#Sites	Solving	Communications	Total
1	1.58 (0.06)	1.78 (0.44)	3.36 (0.43)
2	1.53 (0.13)	2.85 (1.62)	4.39 (1.72)
5	1.59 (0.06)	4.47 (0.92)	6.05 (0.91)
10	2.61 (0.17)	0.26 (0.01)	5.97 (0.63)

Table 3: Average duration in seconds (and standard deviation) to calculate the plans for the *update* scenario.

Gossip + Protocol

https://docs.google.com/presentation/d/18asPwHJ4HOZqAlmQqLEI5V-hX38_robjgia62bNtrig/edit?usp=sharing

Full execution with failure

https://docs.google.com/presentation/d/1pe4HXdohWJyxwJHHbdmIitxnkCEN_UEdfBWqZRvZQbc/edit?usp=sharing

Cyber Physical System (CPS) performance

https://docs.google.com/presentation/d/
1WwMoAma8trummqHhtNLrDV-AL7t4WSIZ7PMY5ZI-Jk0/edit?usp=sharing