Enhancing sustainability of the railway infrastructure through efficient energy management policies

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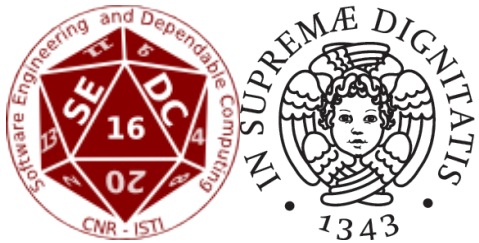

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11th international green and sustainable computing conference

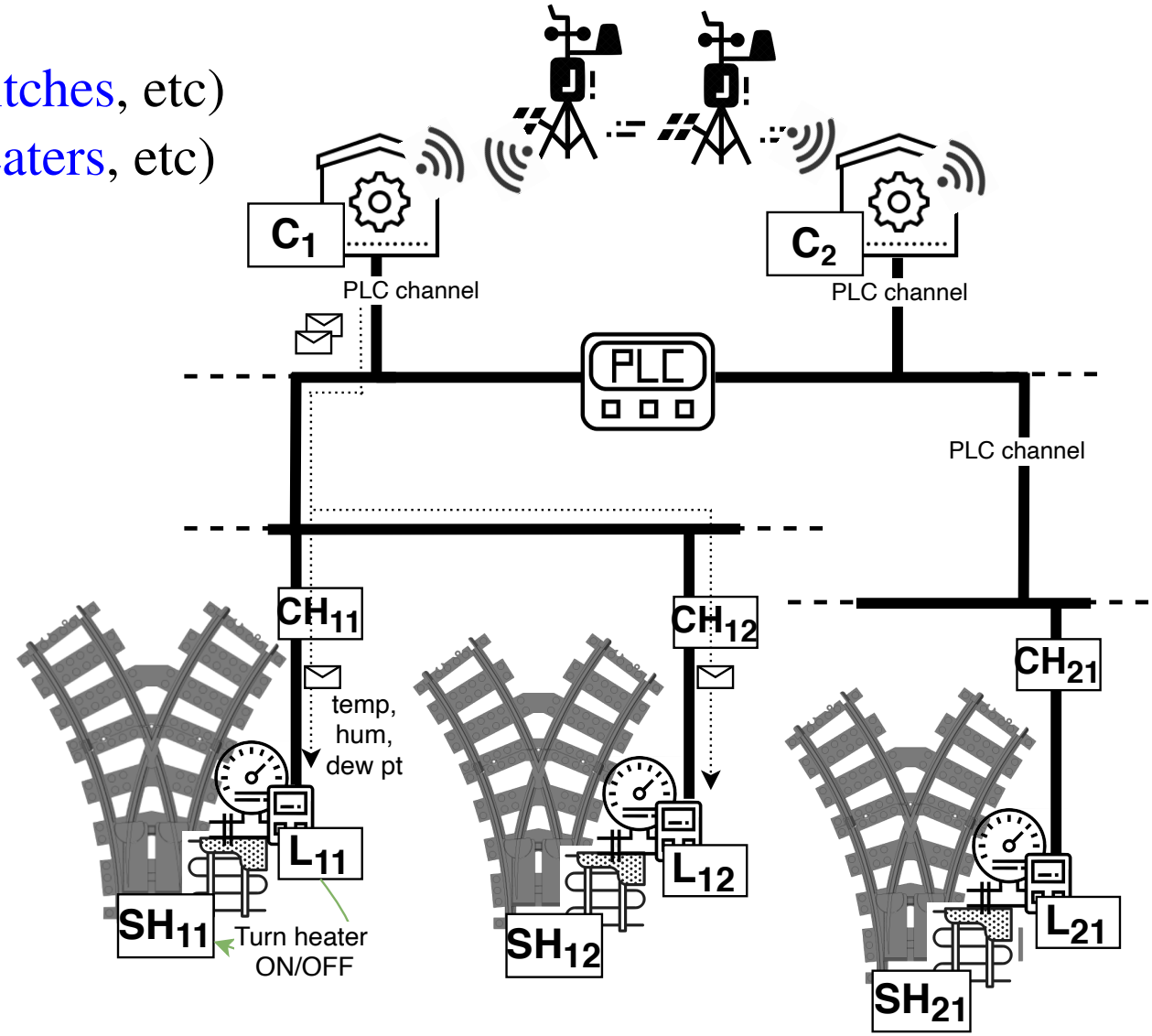
- Motivation & Background
- Definition of new policies
- Brief description of the model
- Evaluation campaign
- Conclusion and future work

Motivation and background

Motivation and context

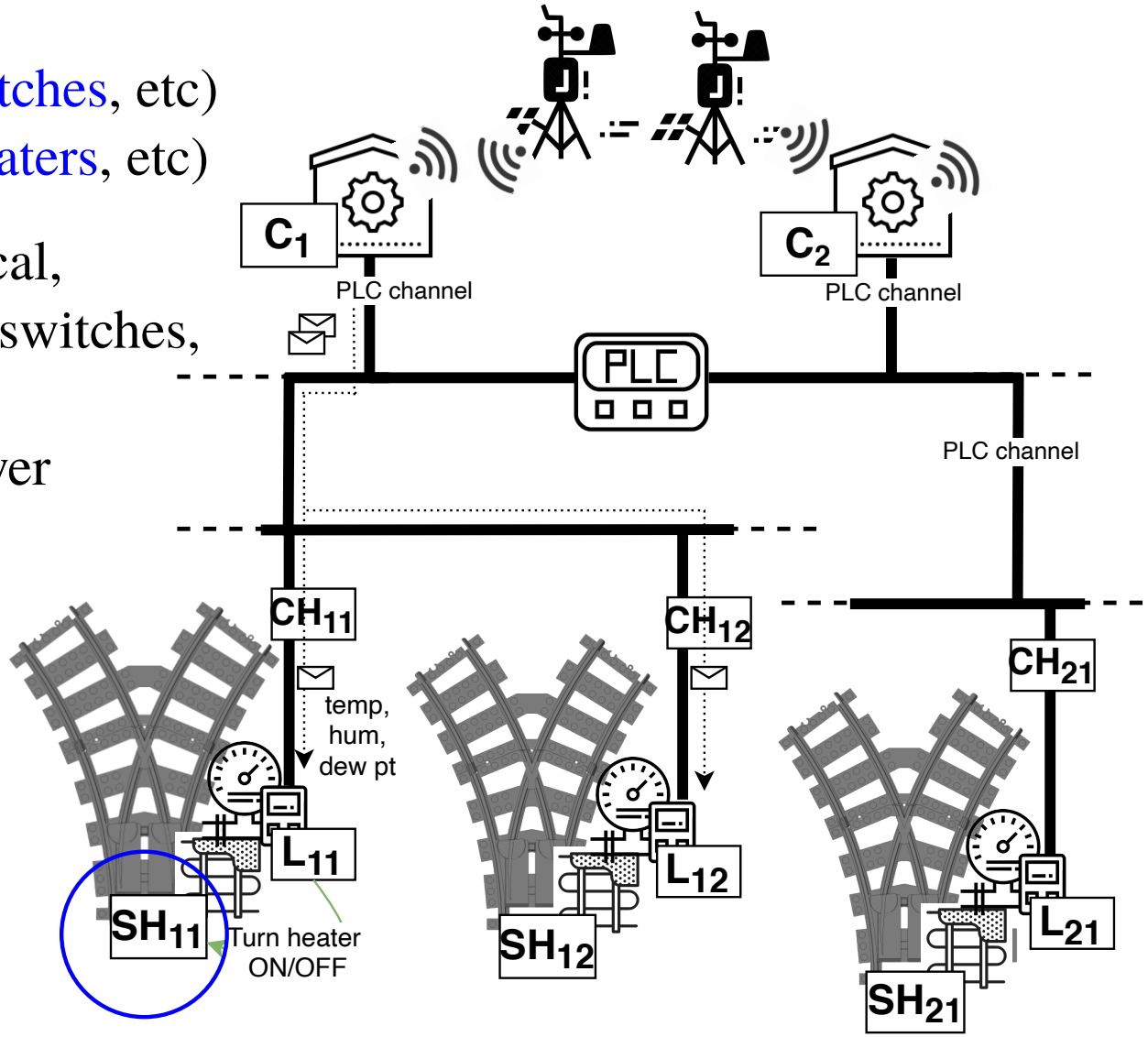
- Increasingly, there is pressure on energy saving in all sectors, triggered by environmental and economical needs
- Although traditionally a critical infrastructure, the railway transportation system is urging attention to cautious energy usage
- The heating system for railroad switches is among the most relevant energy-consumption equipment within the railway system (10-15 M€/year in Sweden)
- However, saving in energy should not impair dependability: a trade-off is needed
- The Internet of Things computing paradigm is expected to enable the implementation of novel control strategies, exploiting heterogeneous data and the fusion with data collected from external systems

Two infrastructures:
railroad (rail lines, switches, etc)
power (power lines, heaters, etc)



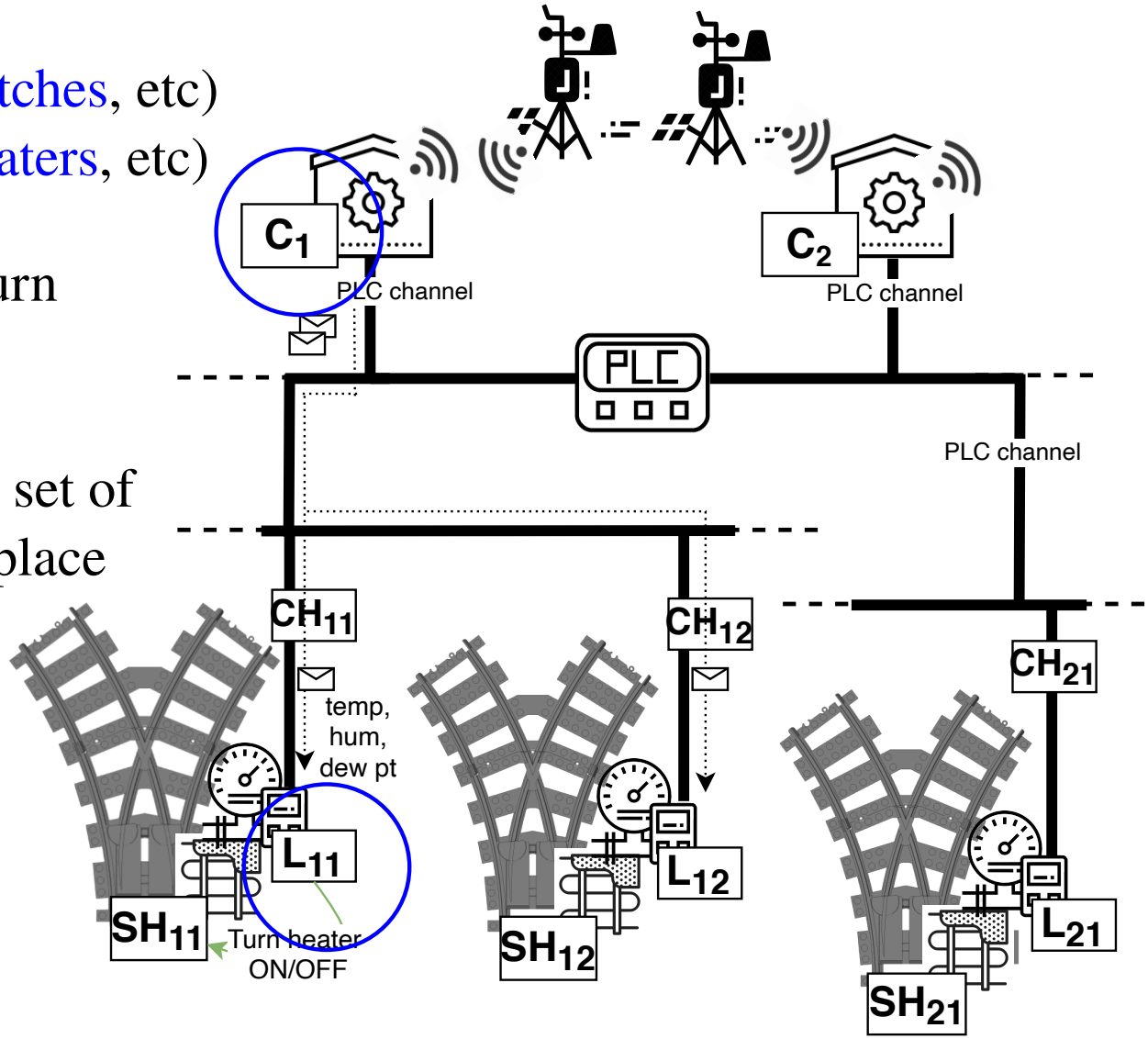
Two infrastructures:
railroad (rail lines, switches, etc)
power (power lines, heaters, etc)

switch heaters are critical,
prevent freezing of the switches,
but if always turned on
consume too much power



Two infrastructures:
railroad (rail lines, switches, etc)
power (power lines, heaters, etc)

for deciding when to turn
the switch heaters on,
a set of coordinators,
each one supervising a set of
local controllers, is in place



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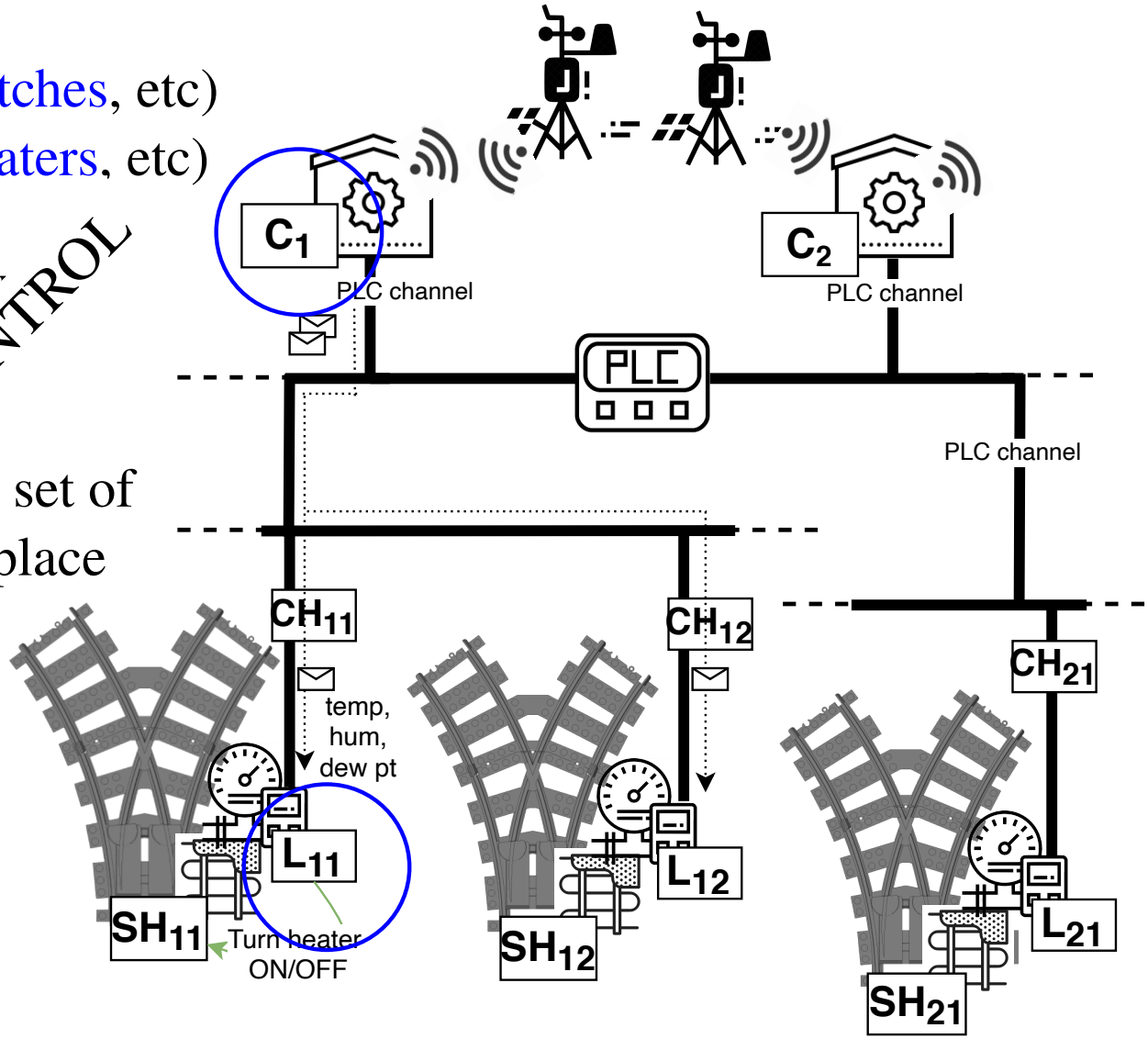
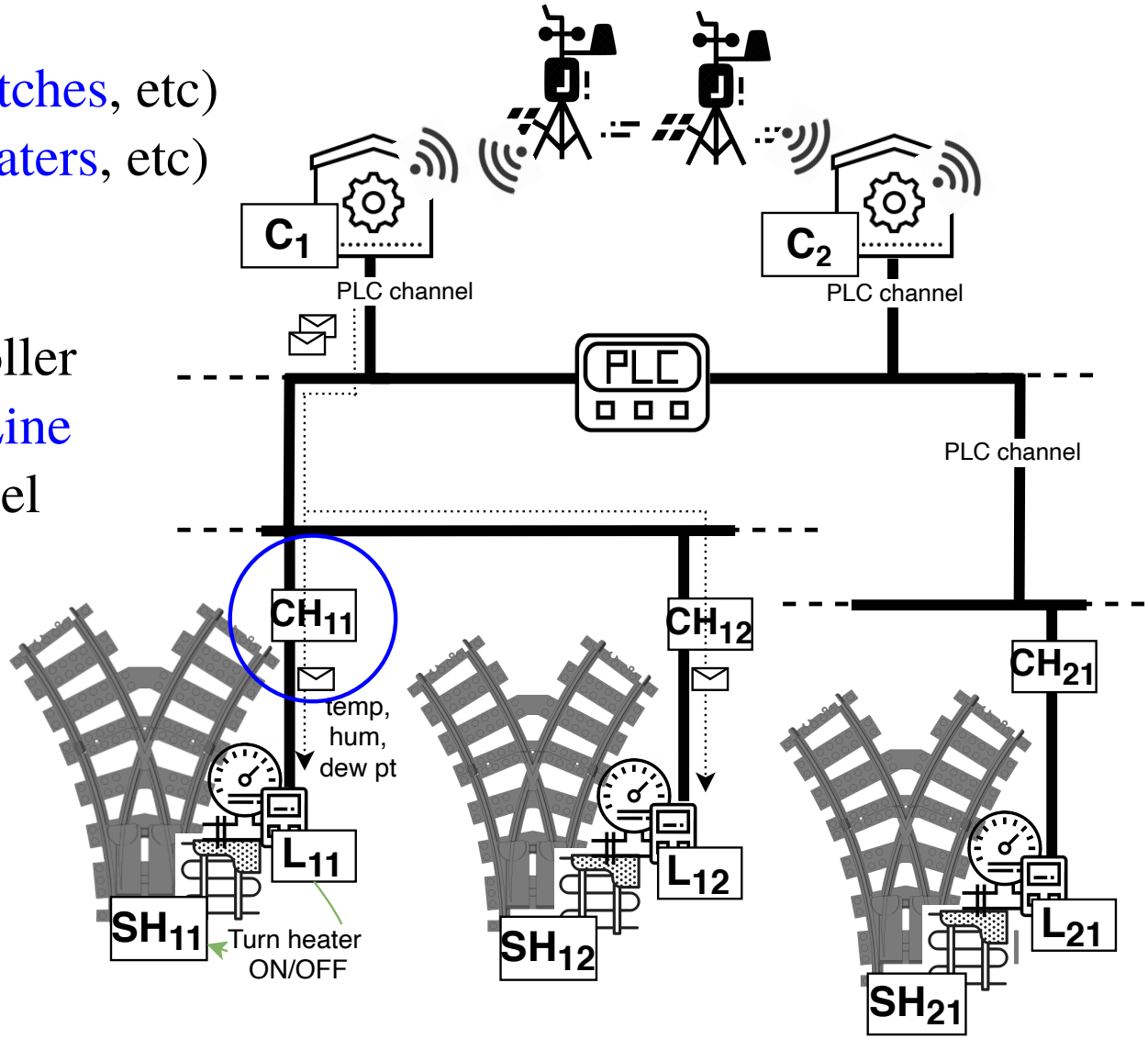
HIERARCHICAL CONTROL



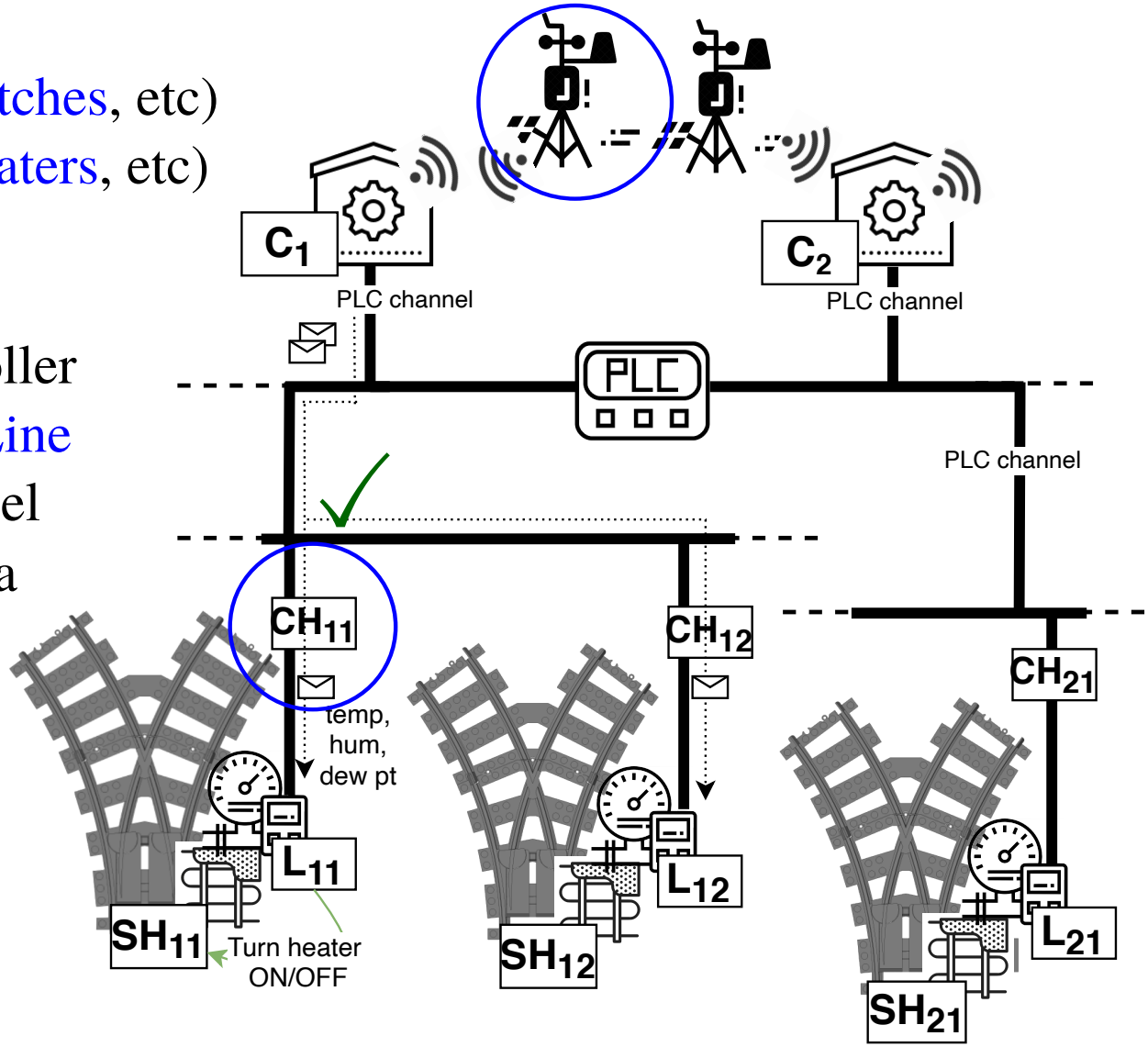
Two infrastructures:
railroad (rail lines, switches, etc)
power (power lines, heaters, etc)

coordinator and controller talk through a Power Line Communication channel



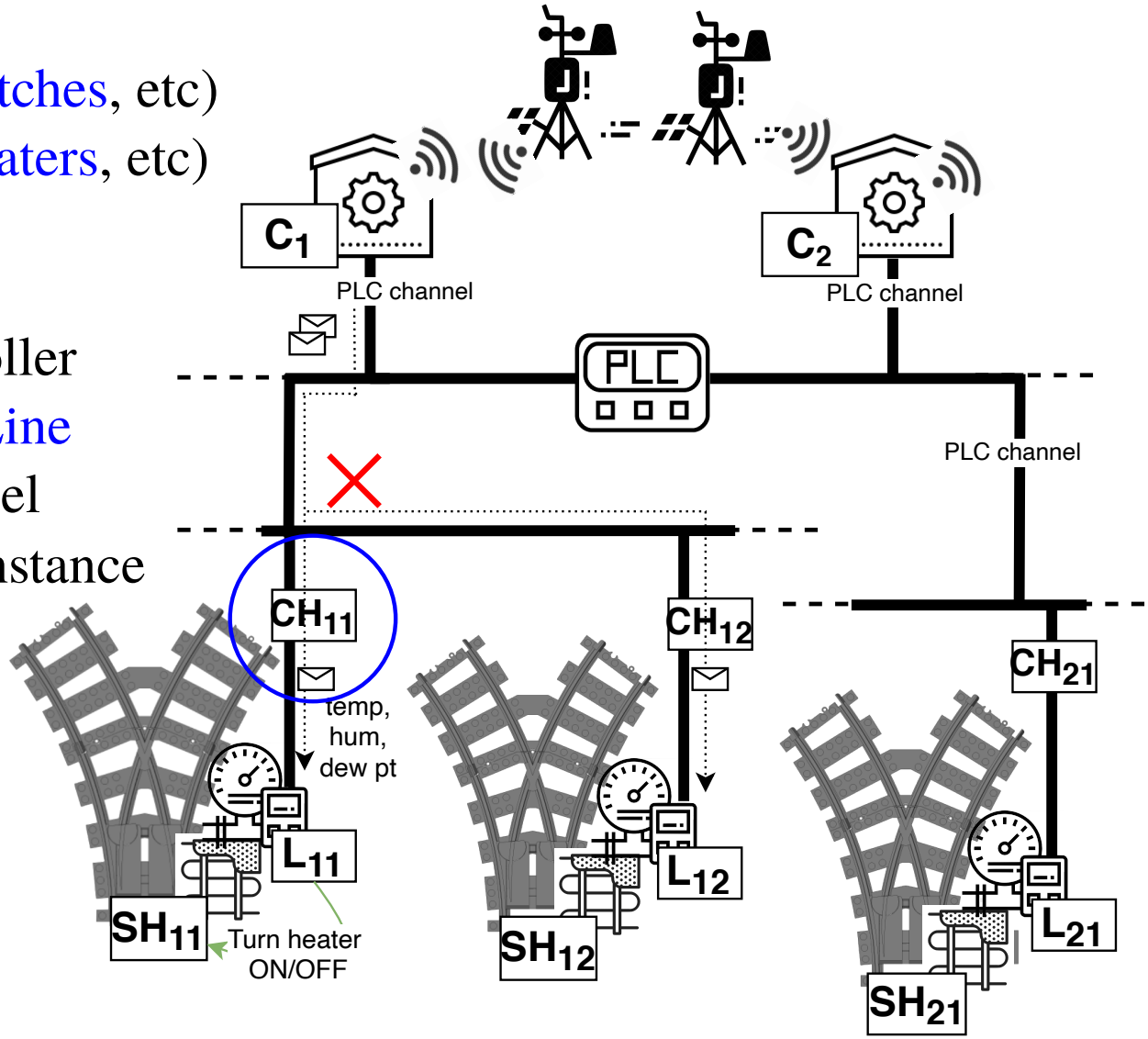
Two infrastructures:
railroad (rail lines, switches, etc)
power (power lines, heaters, etc)

coordinator and controller talk through a Power Line Communication channel
controllers receive data from weather stations and, when the PLC is working, everything is fine



Two infrastructures:
railroad (rail lines, switches, etc)
power (power lines, heaters, etc)

coordinator and controller talk through a Power Line Communication channel
the PLC can fail, for instance due to adverse weather conditions, so local policies have to be defined



Background

- the coordinators periodically receive from the weather stations the value of dew point (temperature to which air must be cooled to become saturated with water vapor)
- local controllers are equipped with temperature sensors
- when the PLC is working, the coordinator
  - receives from local controllers the temperature they measure
  - send them the dew point
  - *decide to turn on* the switch heater *only if the temperature is below the dew point and a threshold*
- the failure of the channel interrupts this protocol. Depending on the PLC topology, *a number of local controllers may become isolated from the coordinator* due to a single channel failure

Contribution

Outline of the contribution

- Focus on the management policies of the railroad switch heating system
- Definition of algorithms to improve energy efficiency wrt current practice
- Definition of a modeling framework to analyze the behaviour of the policies both in terms of *energy efficiency* and *unavailability* in a variety of climate conditions/failure events/switch heater configurations
- Evaluation campaign on a representative case study

Basic policy, the one currently in place

- the local controller considers no information except the temperature measured by its sensor at the moment the turn on/off decision has to be taken (no past information is retained, no prediction on the future is made)
- if the temperature is below a given threshold then the local controller turns on the switch heater
- otherwise it turns off the switch heater

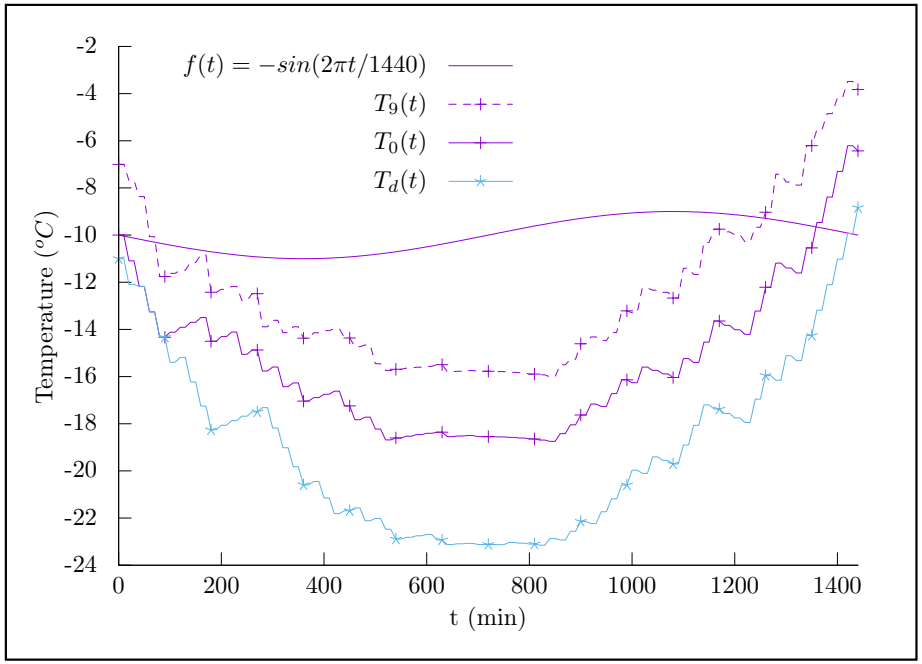
Memory-based policy

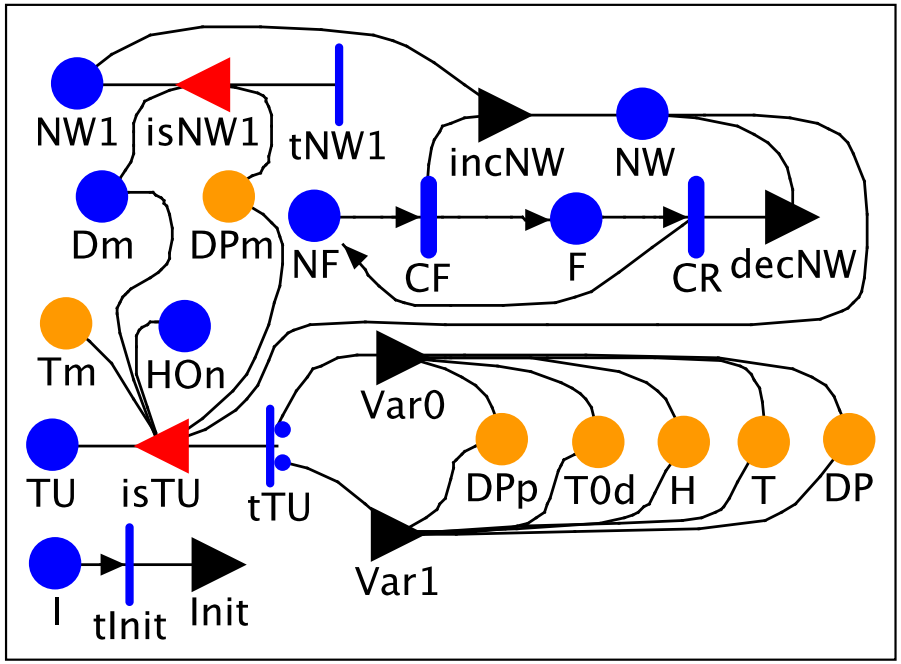
- when the channel is working, the local controller stores in its local memory the value of dew point that it receives periodically from its coordinator
- in case of channel failure, the local controller uses the *last stored value of dew point* for at most Δm time units
- after Δm time units, the local controller switches to the *basic policy* because the retained dew point is considered too old to be useful
- in a geographical location characterized by slowly changing weather conditions, it is expected that this policy brings significant benefits in terms of energy consumption

Prediction-based policy

- the local controller maintains in memory *only* recent values of temperature and uses them, possibly together with other information on seasonal trends, to perform *local prediction of future temperature values*
- when the channel fails, the local controller exploits its temperature prediction to decide on whether to turn on/off the switch heater, instead of *comparing the actual temperature with a fixed temperature threshold*
- improvements in energy consumption are expected when the prediction shows a future temperature that is increasing

Model and results

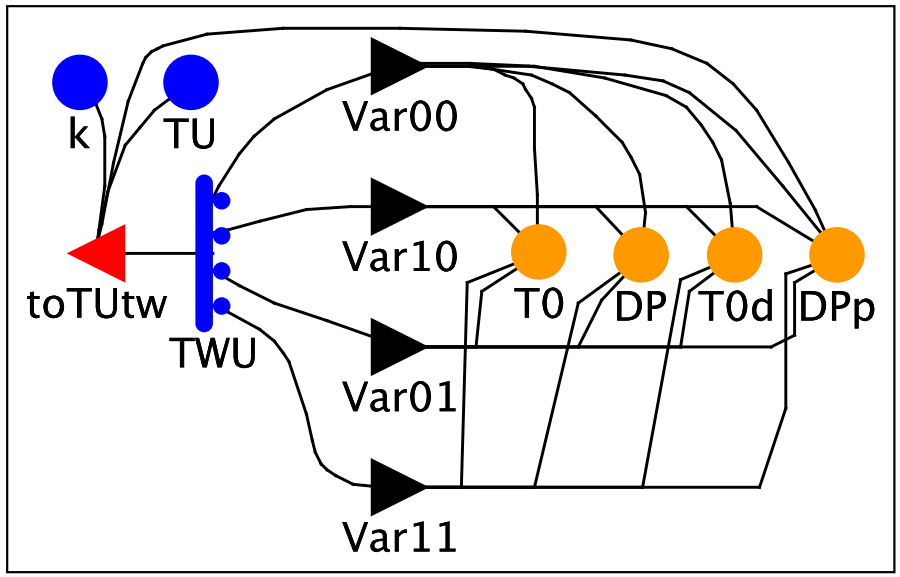




Weather: pure jump compound guided stochastic process

PLC failure and recovery: Continuous Time Markov Chain

Formalism: Stochastic Activity Networks



Case study

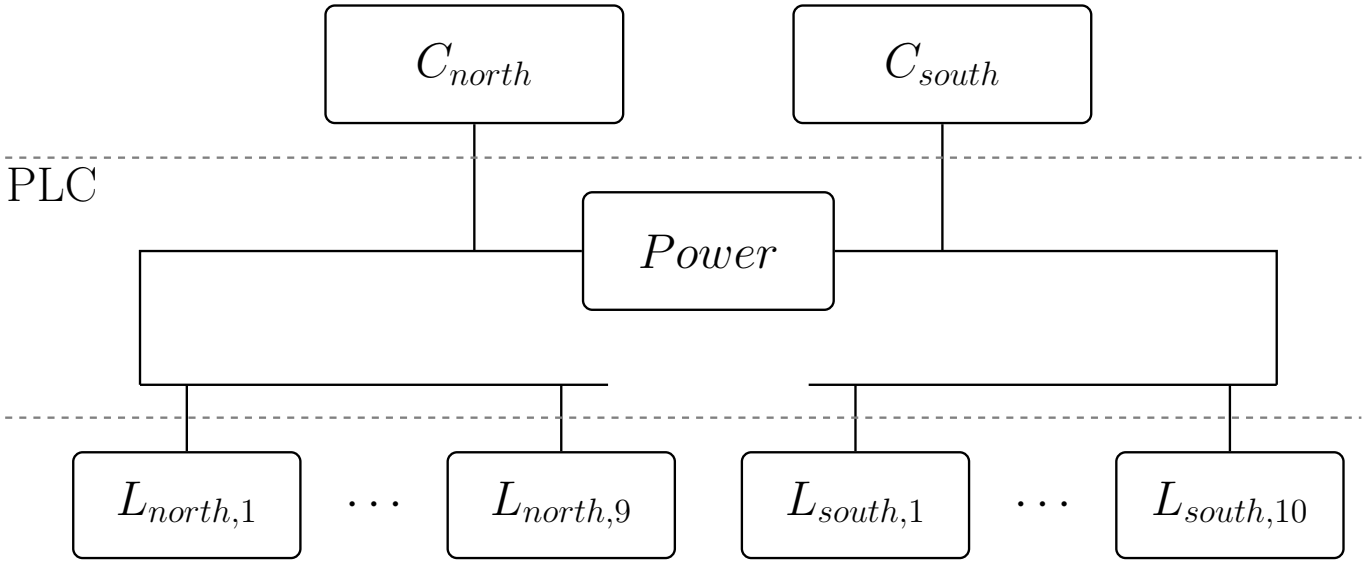
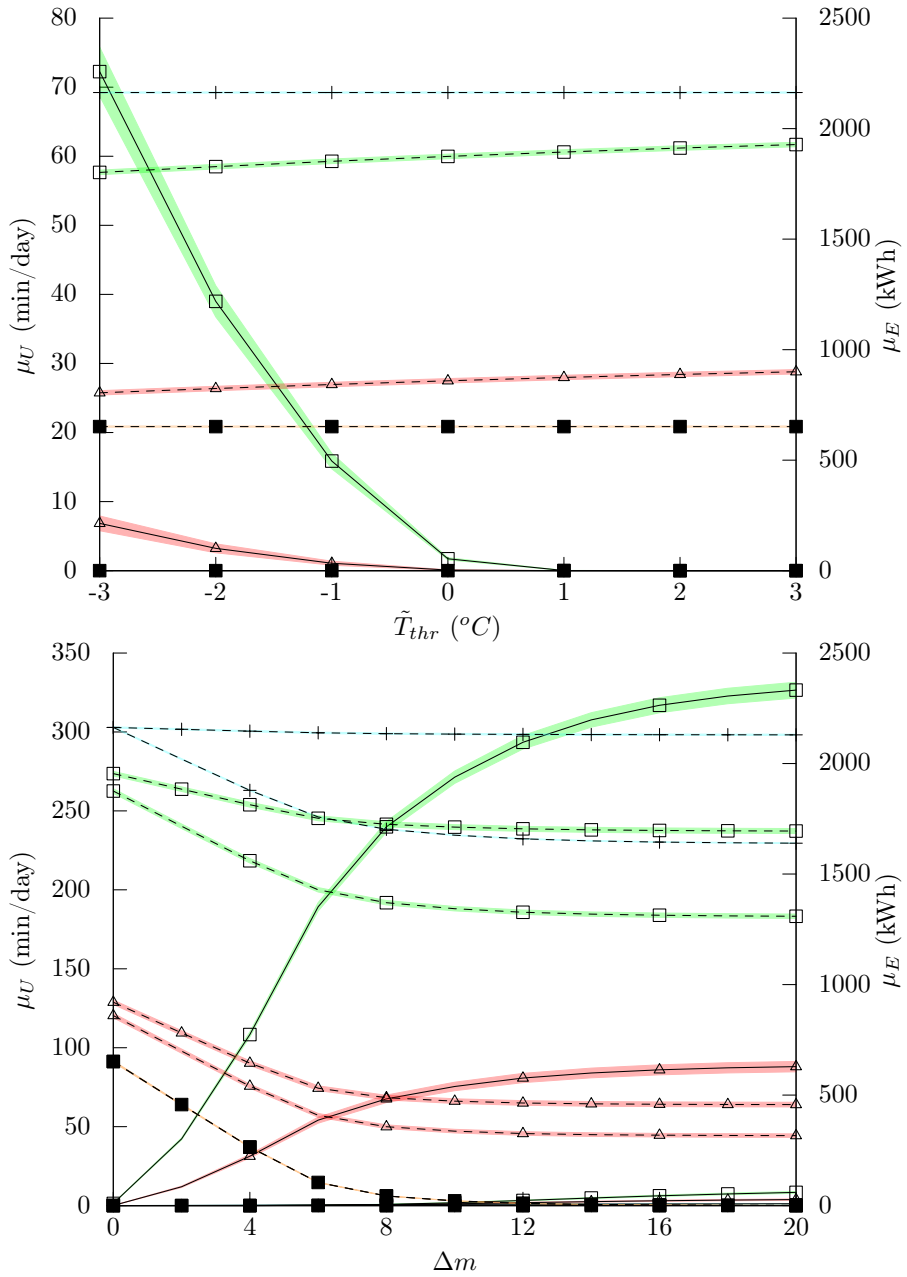


Figure: Logical architecture of the case study PLC.

Prediction-based policy:

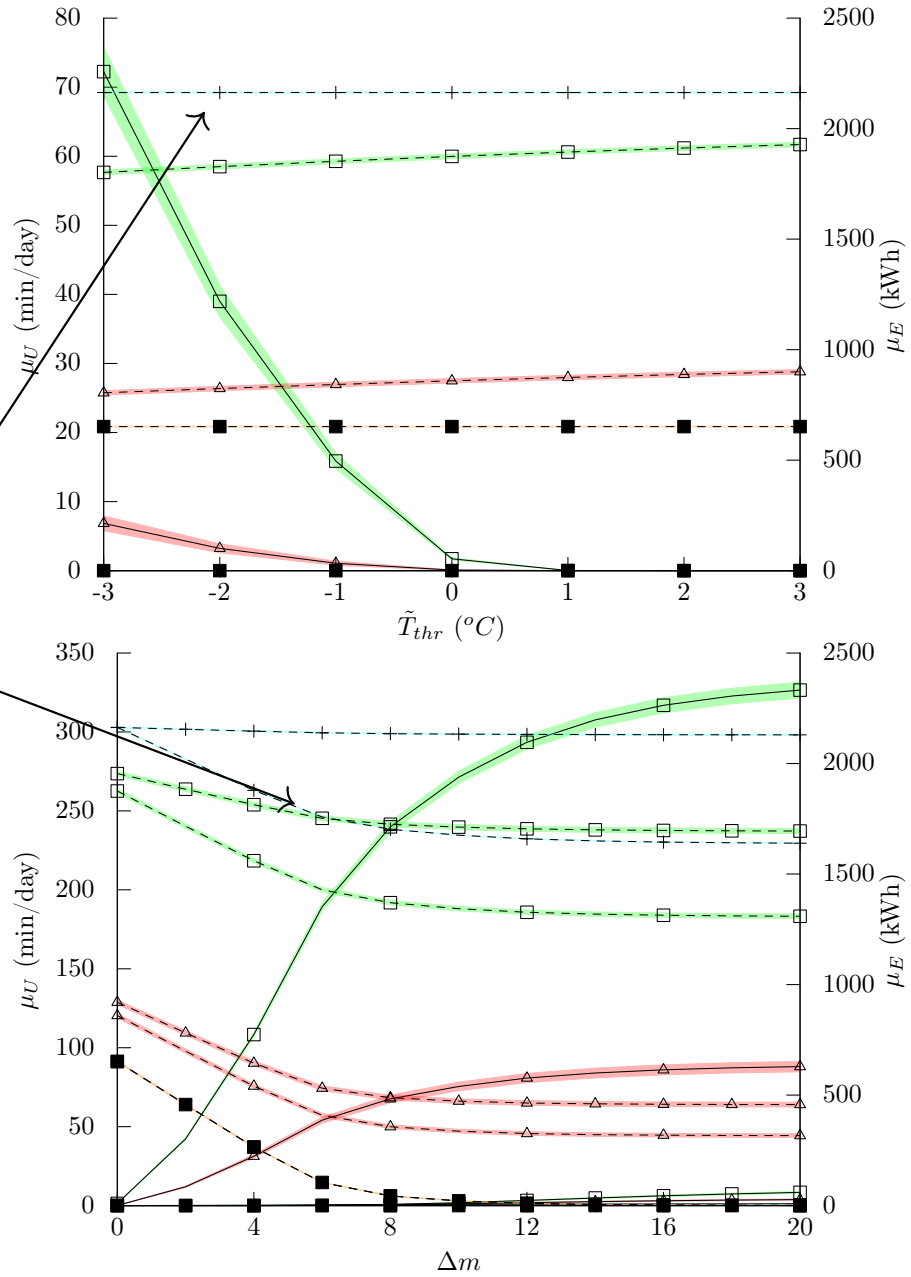
Memory-based policy:



Prediction-based policy:

Expected Energy

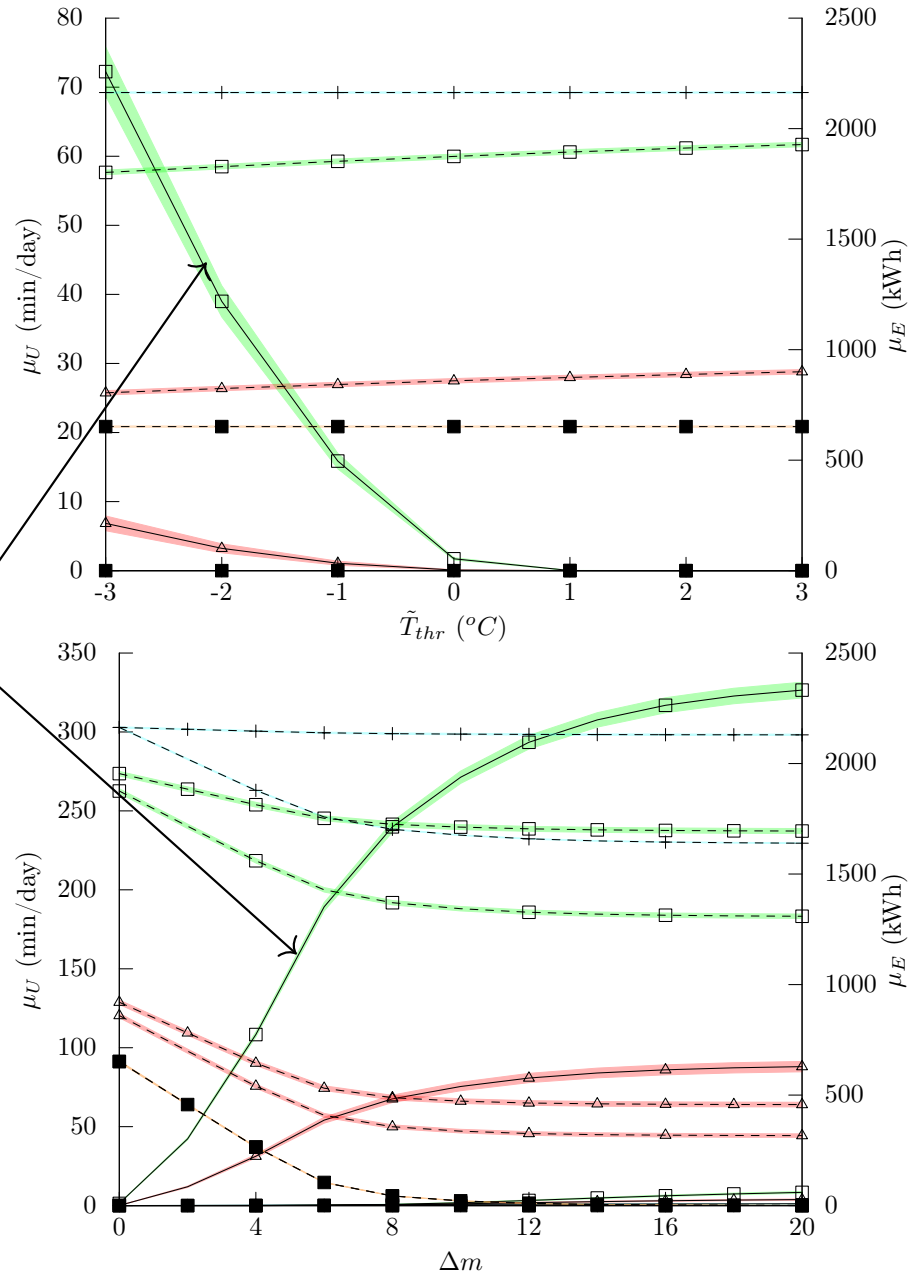
Memory-based policy:



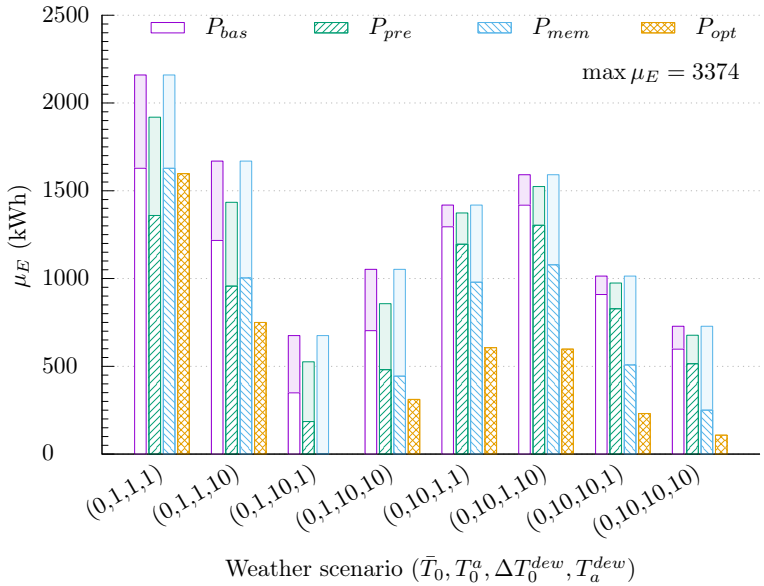
Prediction-based policy:

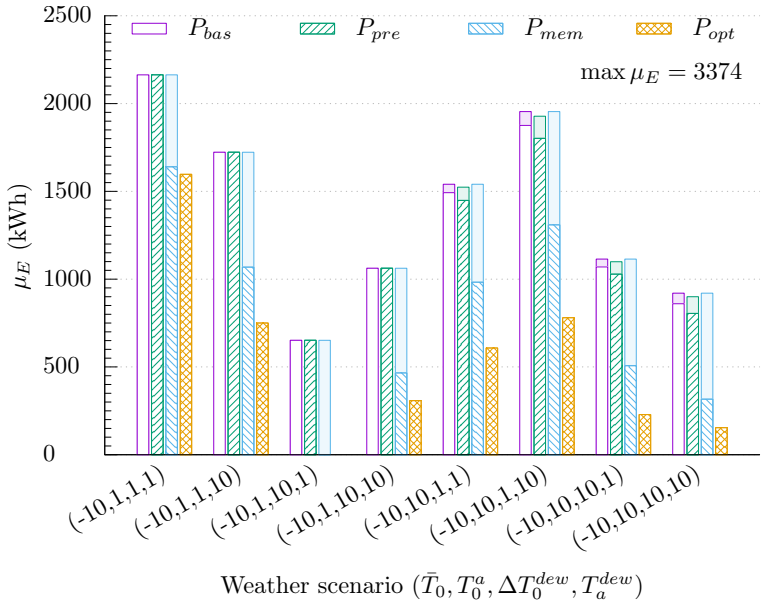
Expected Unavailability

Memory-based policy:

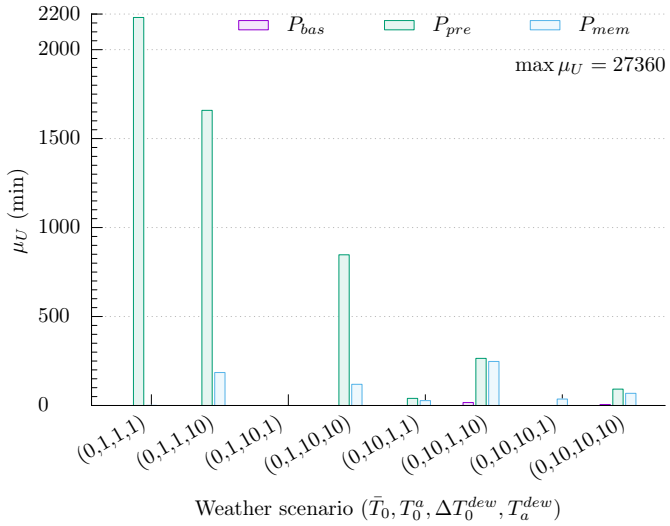


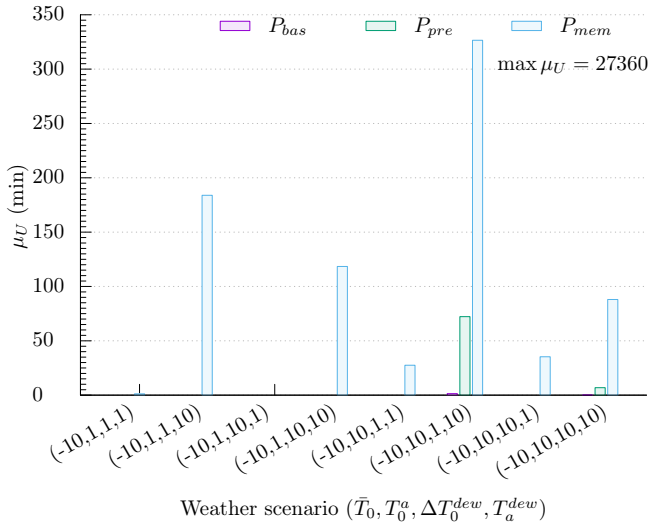
Energy





Unavailability





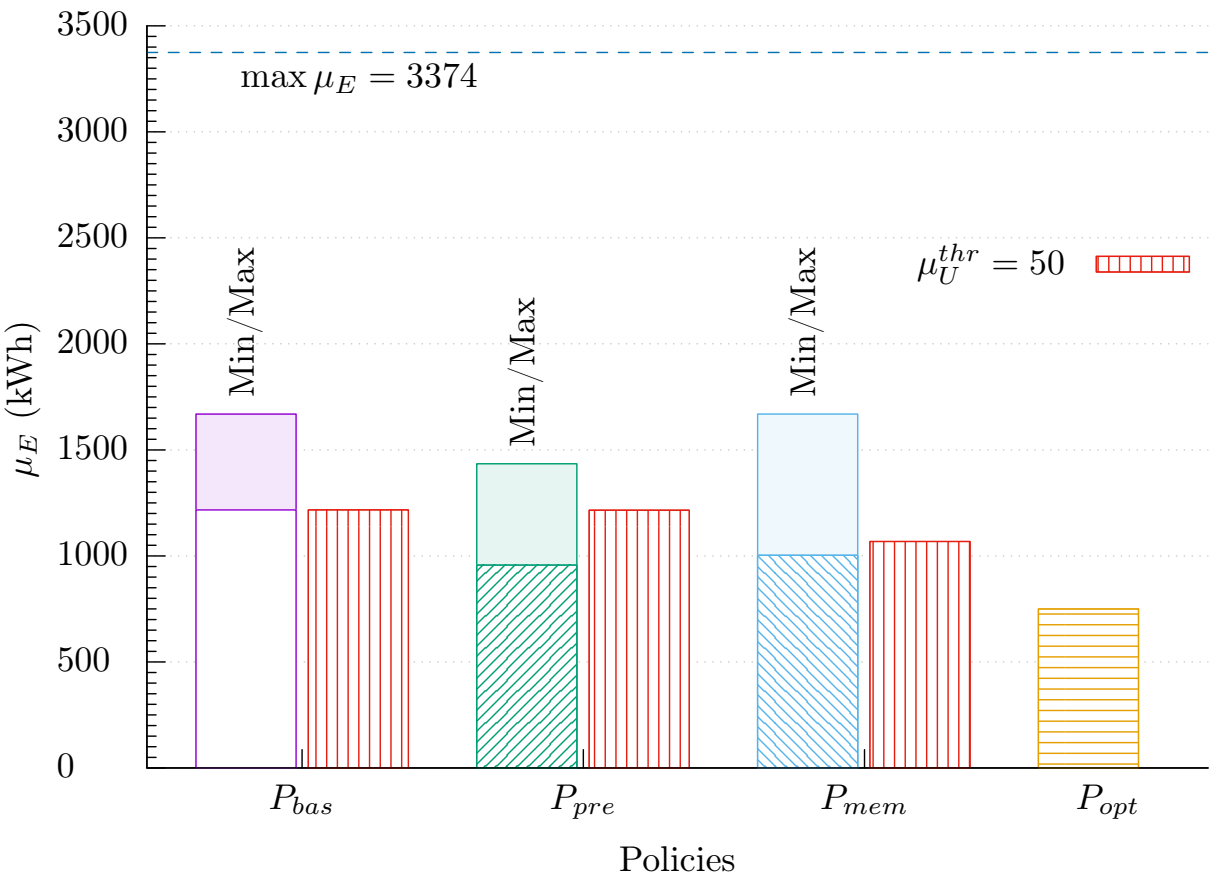


Figure: Energy consumption without unavailability constraints (minimum and maximum) and when the Unavailability is at least 50.

Conclusion and future work

- investigate the impact of parameters kept constant so far
- consider other topology configurations, inducing different dependency among failures of communication channels
- further enhance the energy management policies by taking into account also the traffic on the railway tracks close to the switches

Thank you
Questions?