Current research on dependability aspects of TSN at UIB

Inés Álvarez Vadillo

Julián Proenza, Manuel Barranco, Alberto Ballesteros

Universitat de les Illes Balears

Outline of the presentation

Work on TSN

- Time redundancy of frames
- Mixing time and spatial redundancy
- Design a dependable network architecture
- Model checking of AVB’s SRP using Uppaal

Work on FTT to be adapted to TSN

- Dynamic fault-tolerance in the system
- Dependability evaluation

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Introduction

- TSN devises the use of spatial redundancy to increase reliability

- IEEE 802.1Qca amendment to Path Control and Reservation. Creation of multiple paths.

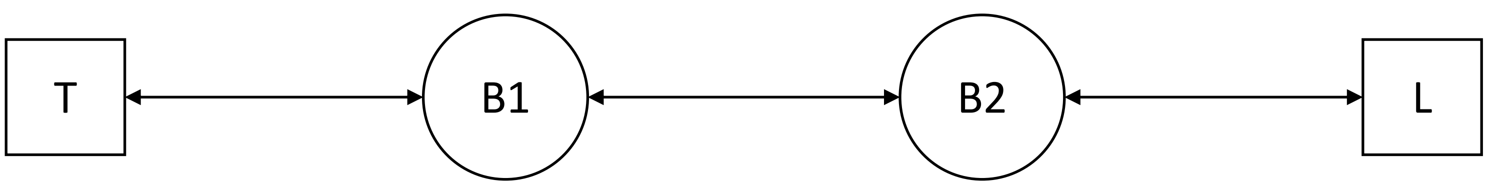
- IEEE 802.1CB standard for Frame Replication and Elimination for Reliability. Send frames through multiple paths in parallel.

Time redundancy of frames: current state

- Time redundancy to tolerate temporary faults
- We proposed the Proactive Transmission of Replicated Frames mechanism
- Transmit several replicas in a preventive manner
- We proposed three different approaches

Time redundancy of frames: current state

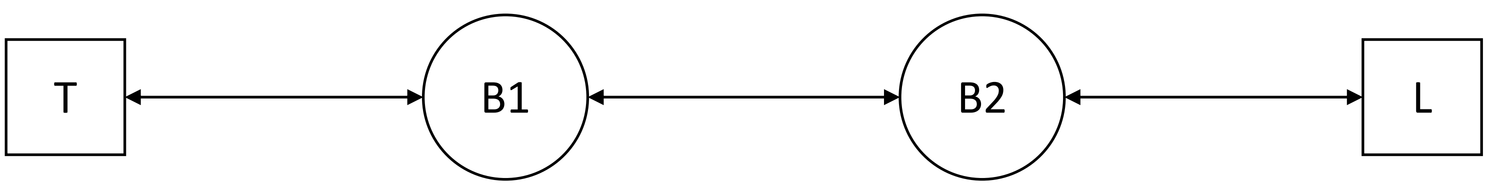
End-to-end estimation and replication



Time redundancy of frames: current state

End-to-end estimation and replication

k=3



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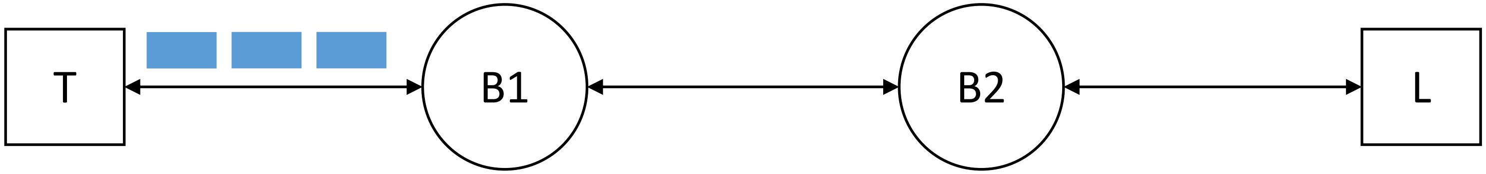

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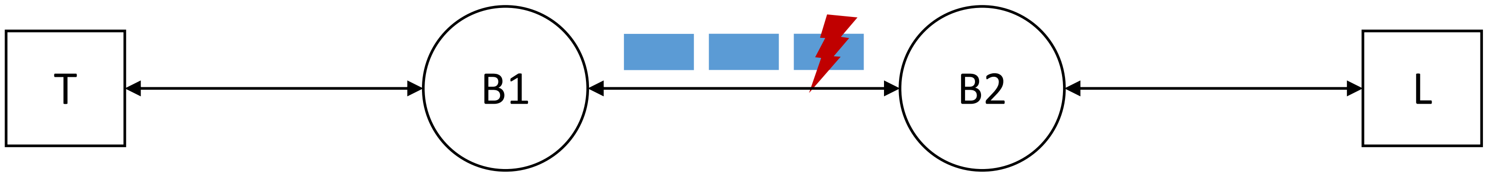

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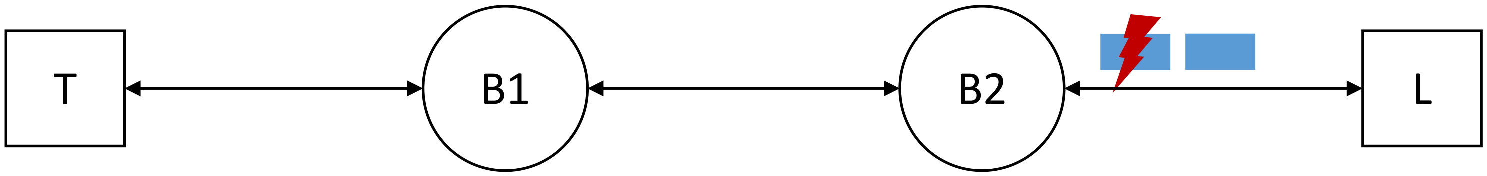

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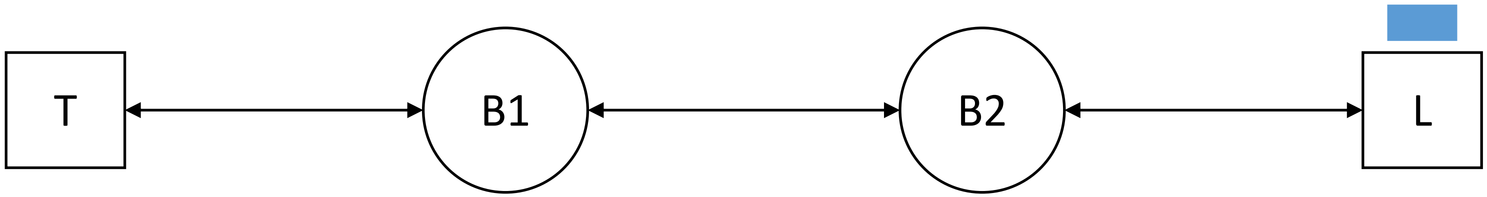
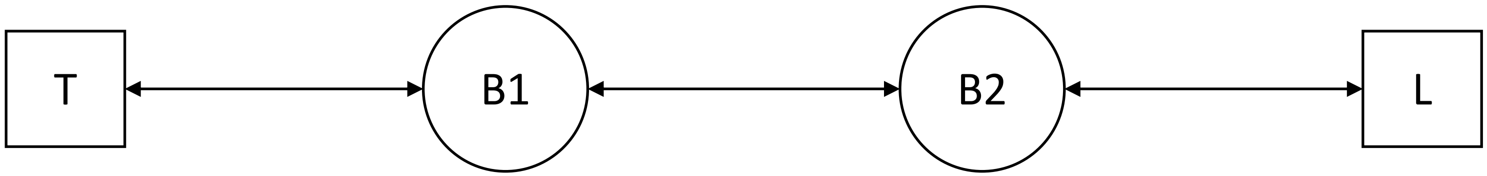


Time redundancy of frames: current state

End-to-end estimation, link-based replication



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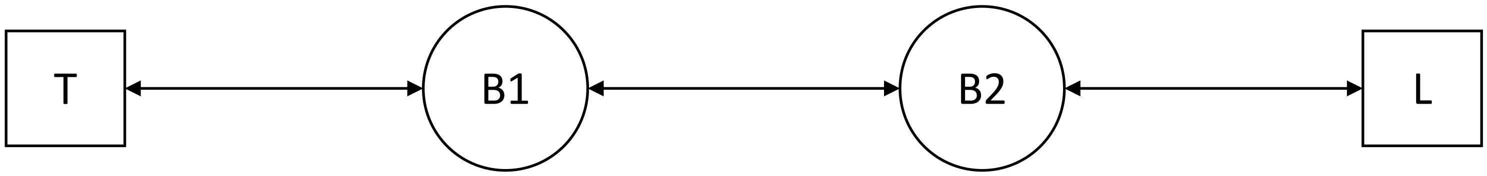

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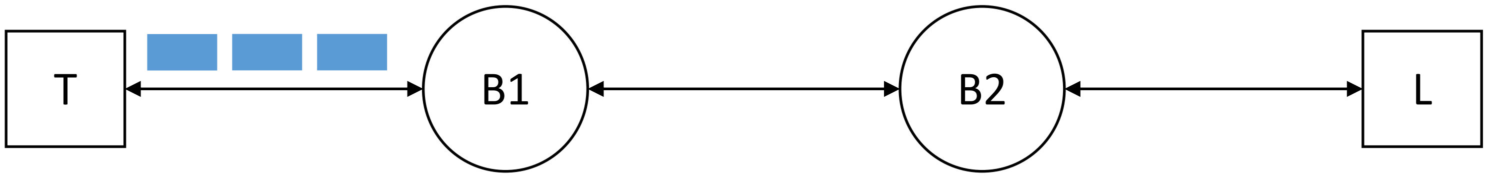

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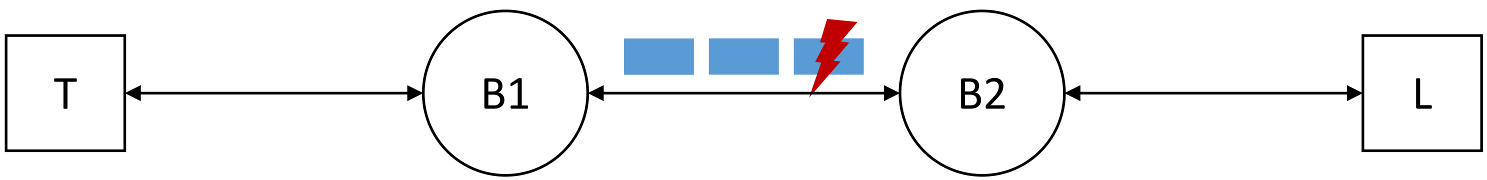

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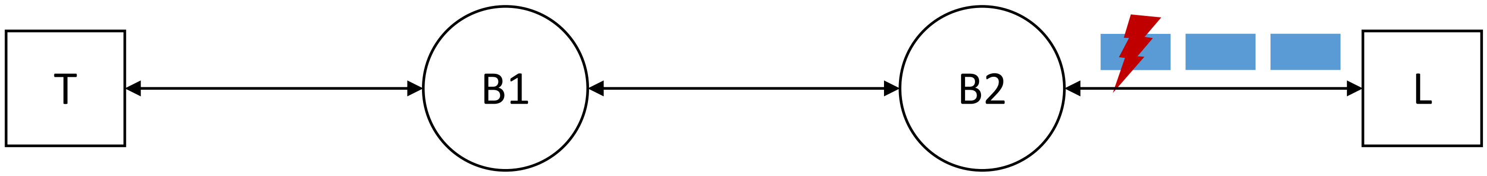

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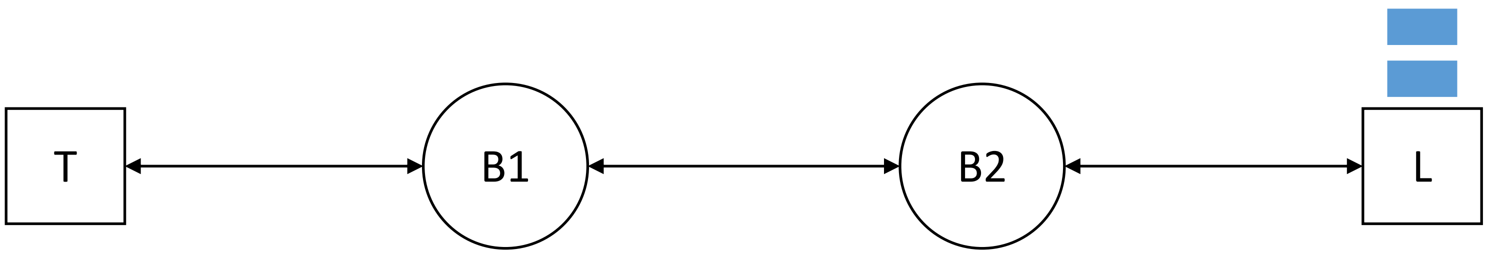

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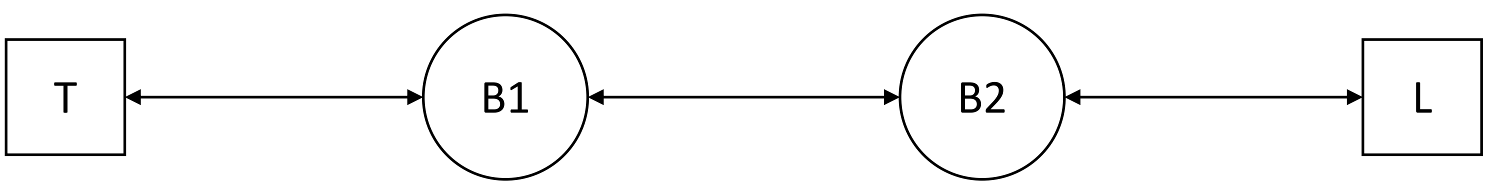

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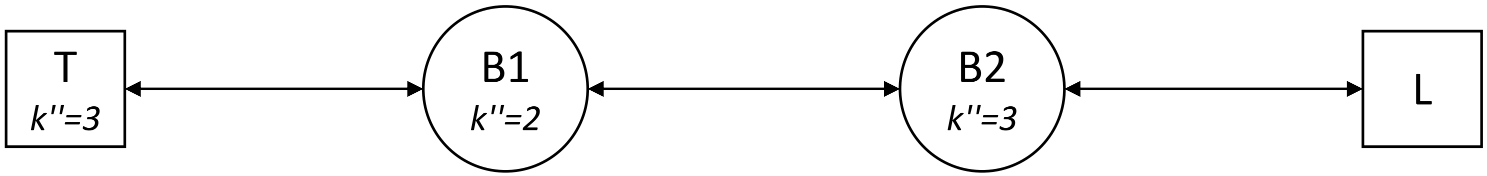

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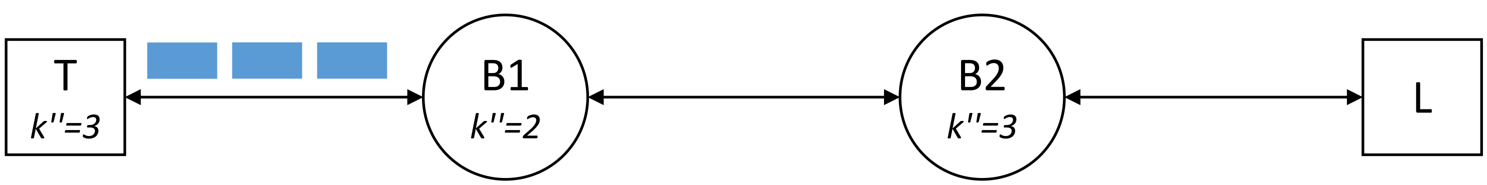

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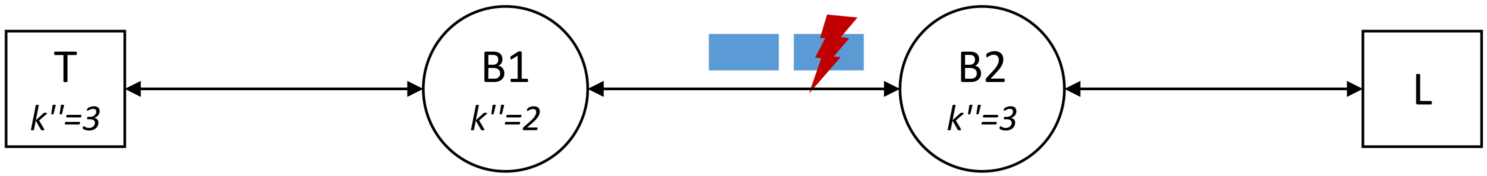

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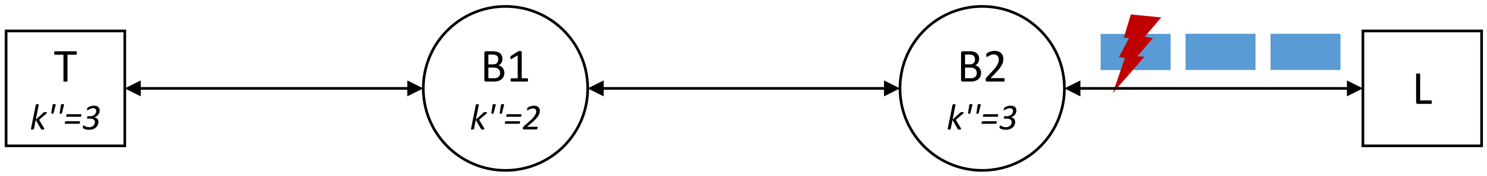
Link-based estimation and replication



Time redundancy of frames: current state

Link-based estimation and replication

State of the work

- Compared with OMNeT++
  - Exhaustive fault injection
  - Case study
- Want to carry out a reliability analysis
- Want to implement a real prototype

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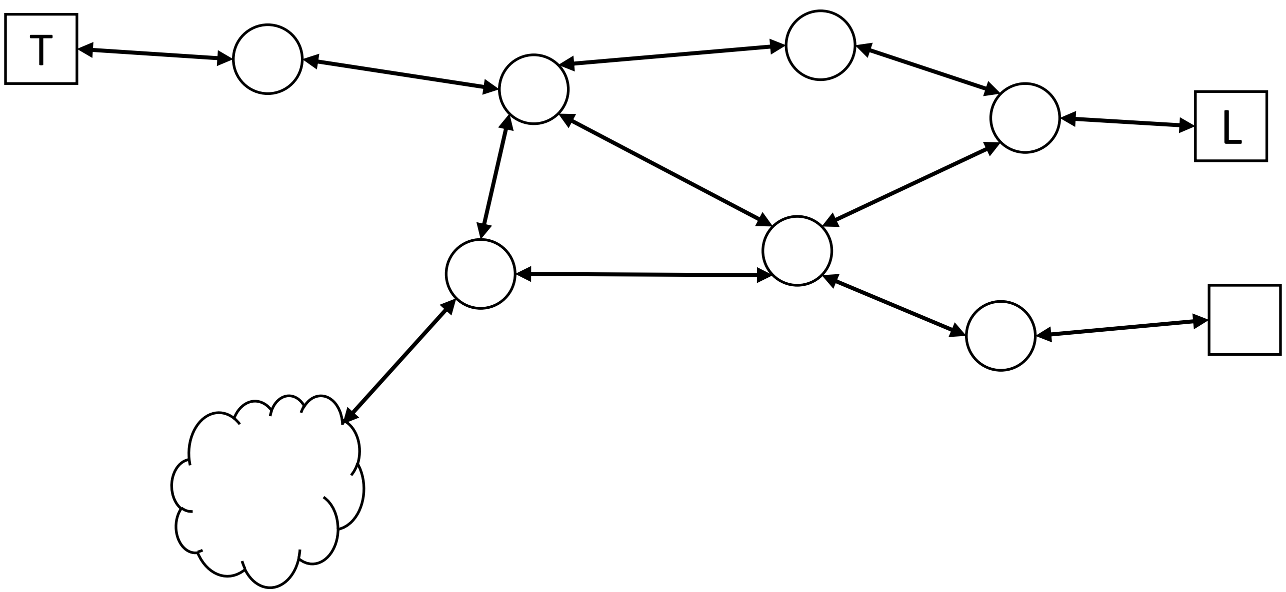
Mixing time and spatial redundancy

Starting point



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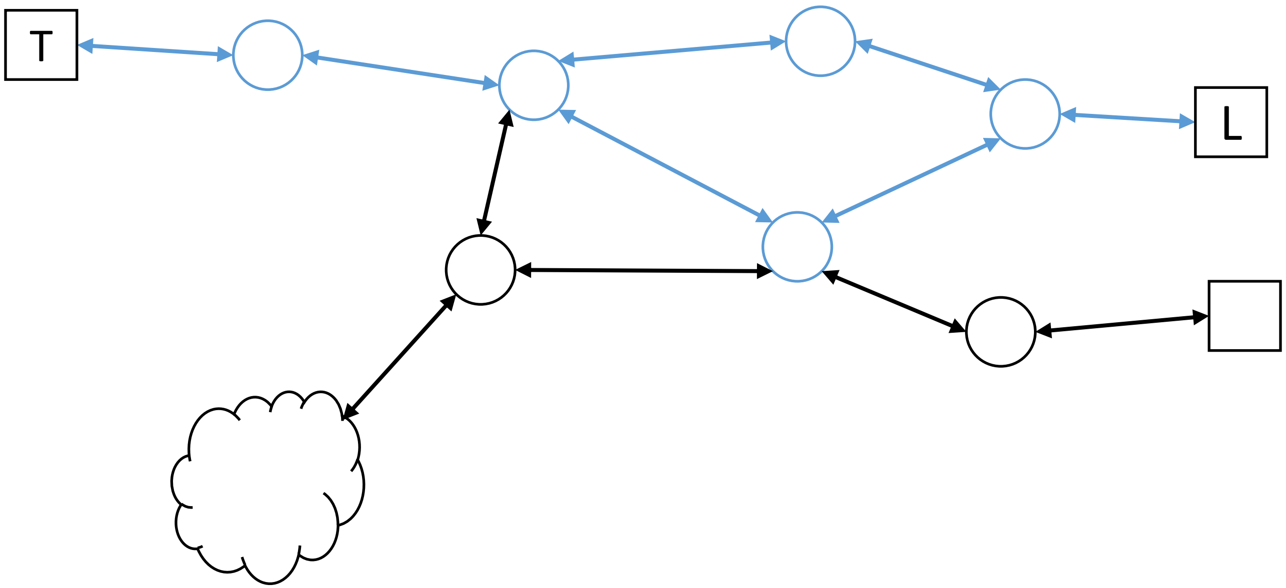
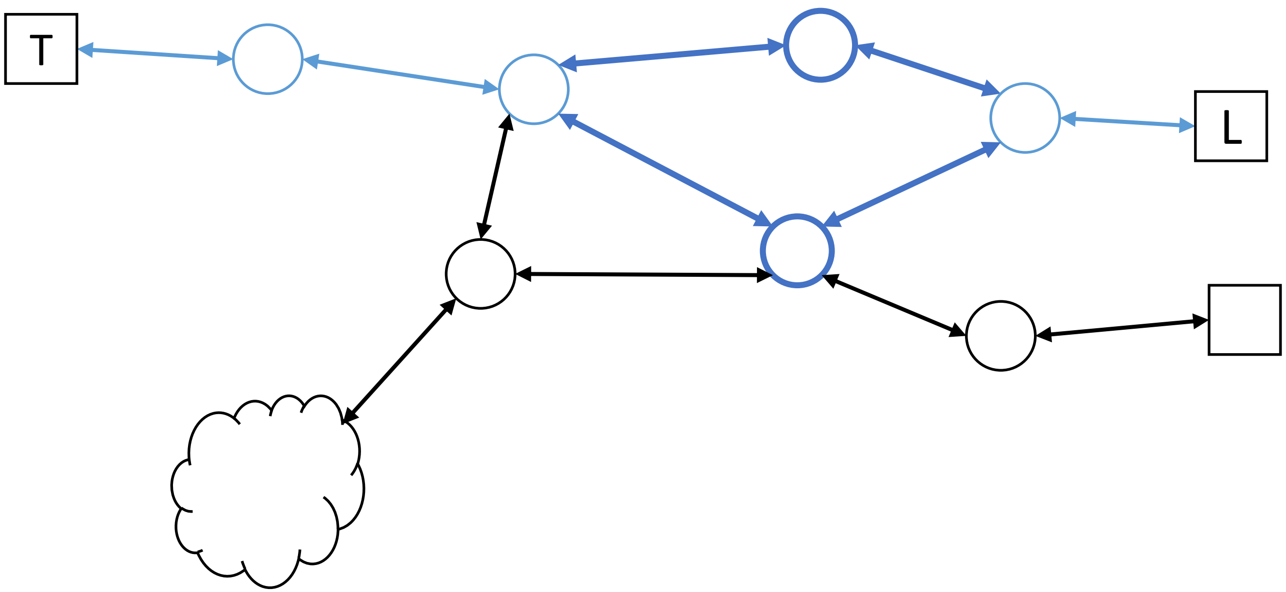


Mixing time and spatial redundancy

Detect spatial redundancy



Mixing time and spatial redundancy

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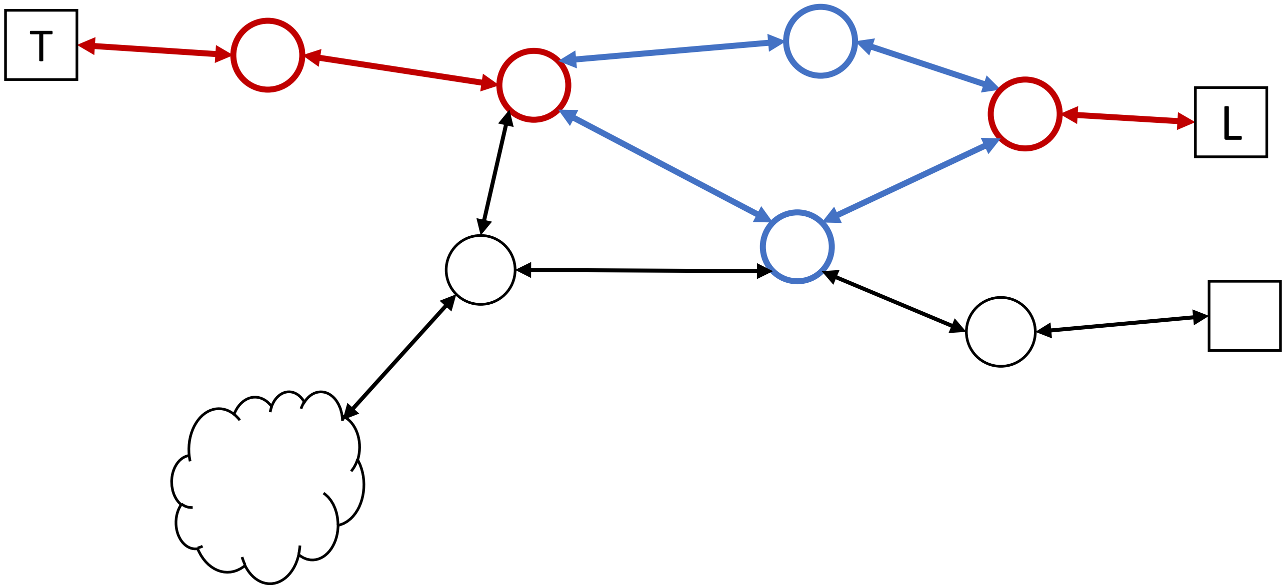
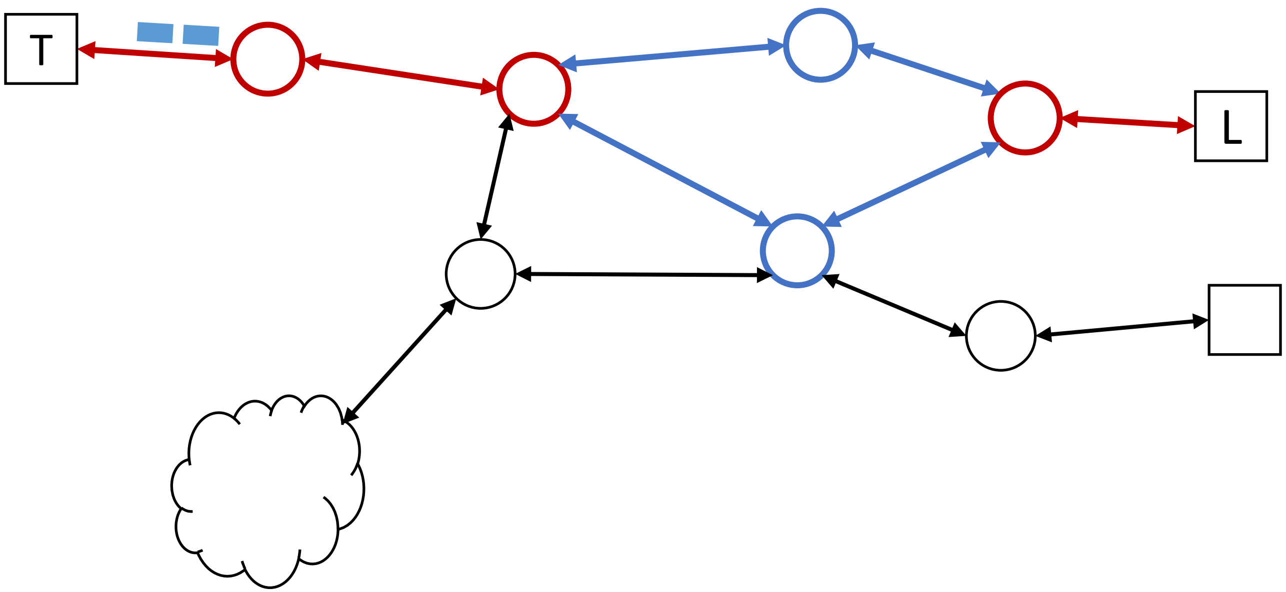


Mixing time and spatial redundancy

Decide on the level of replication



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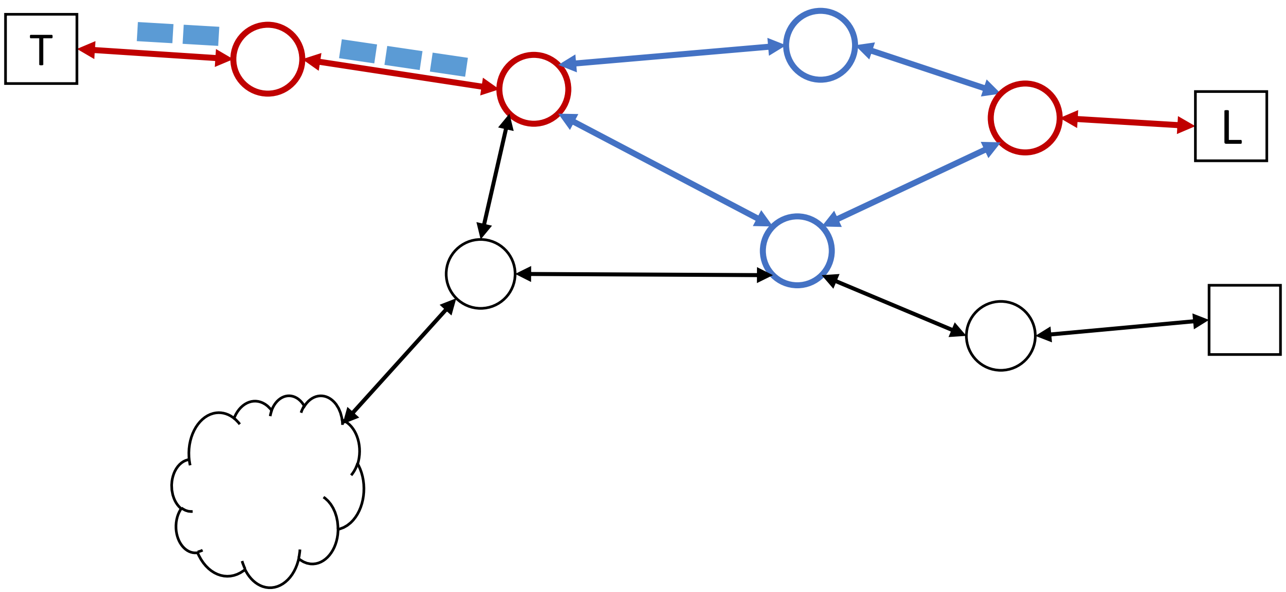

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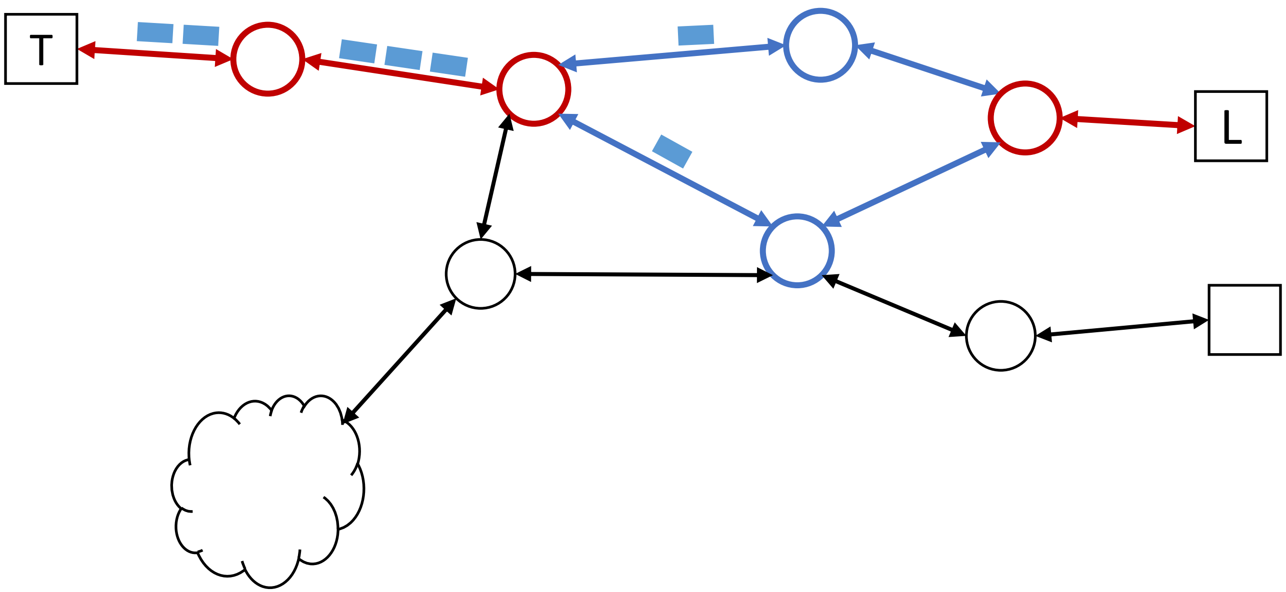

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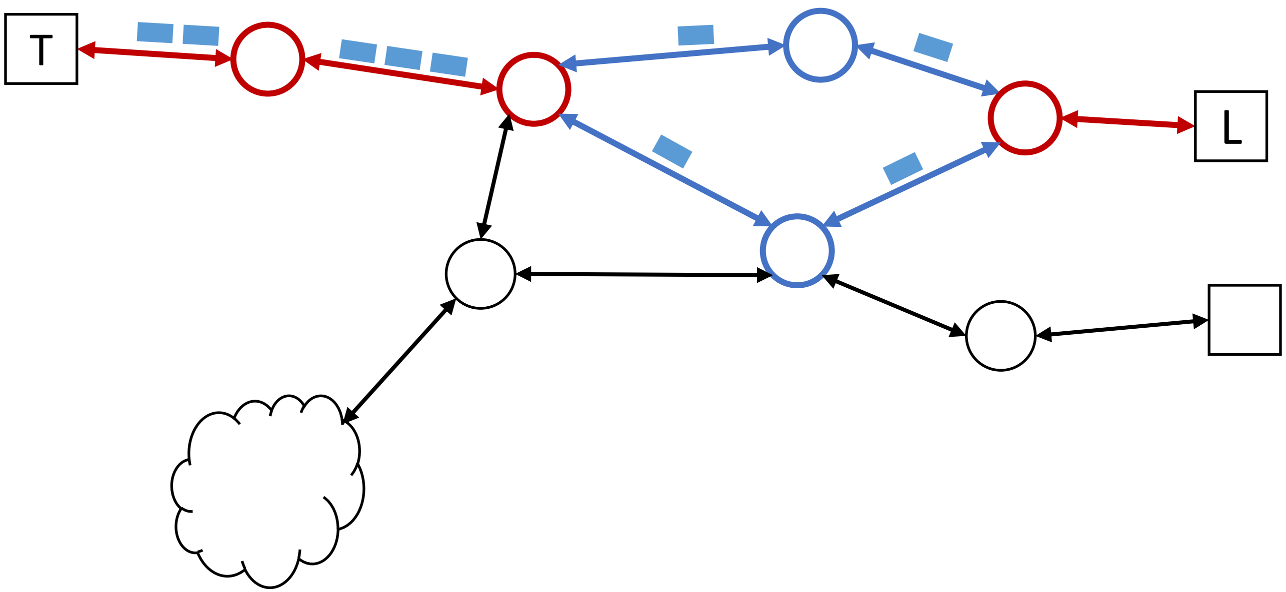

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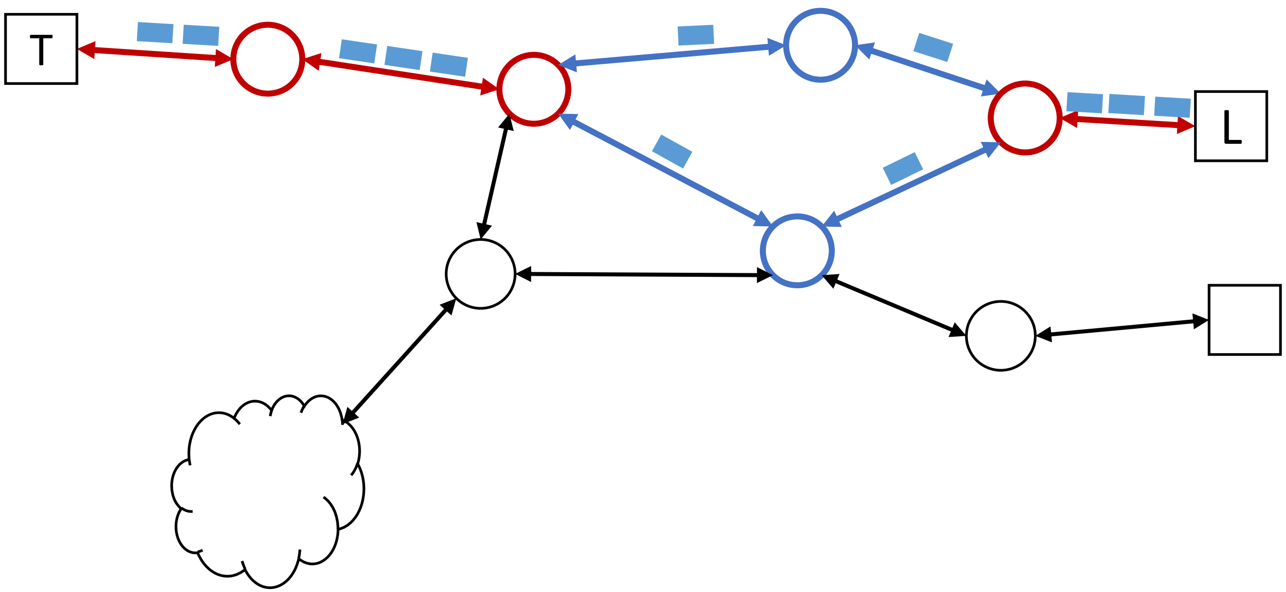

Next steps

- We want this to be dynamic and autonomous.
- Design the mechanisms to extract information from the network and make decisions.
- Mix both mechanisms using simulation to measure the gain in reliability and bandwidth consumption.
- Develop a real prototype.

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Design a dependable architecture

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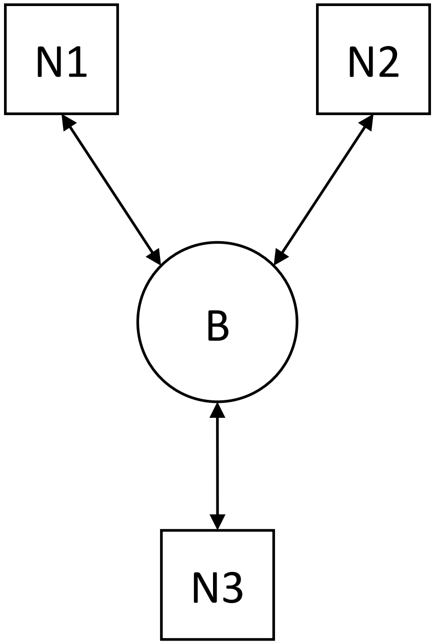

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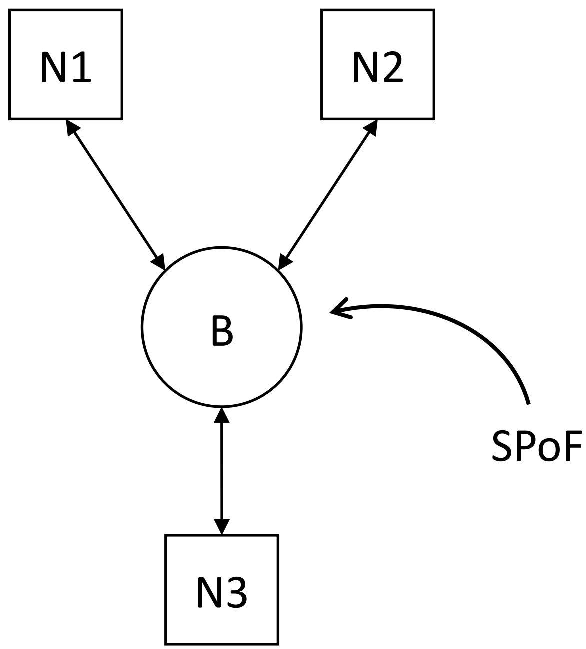

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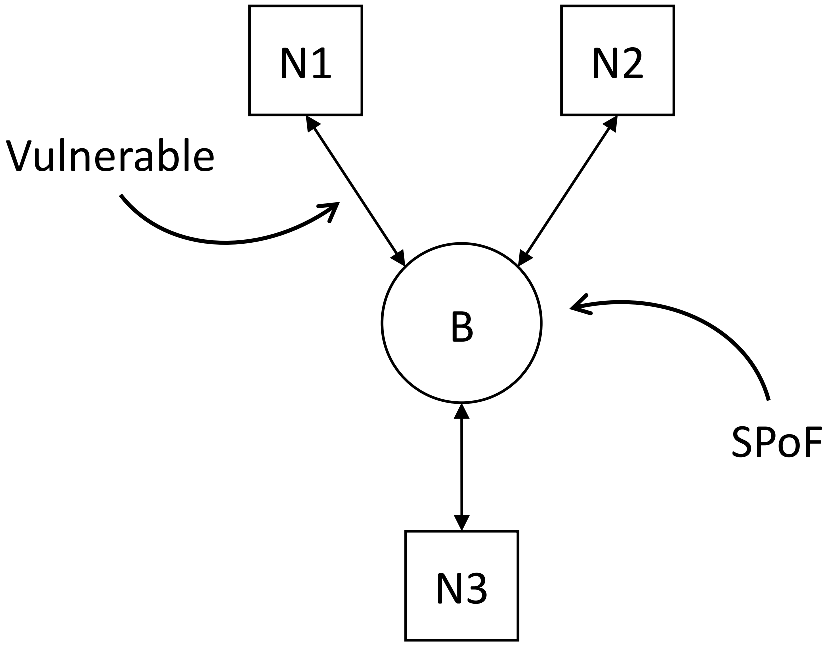
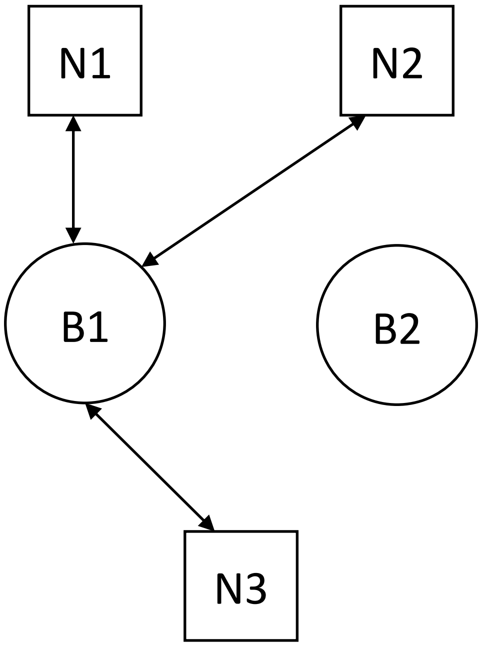


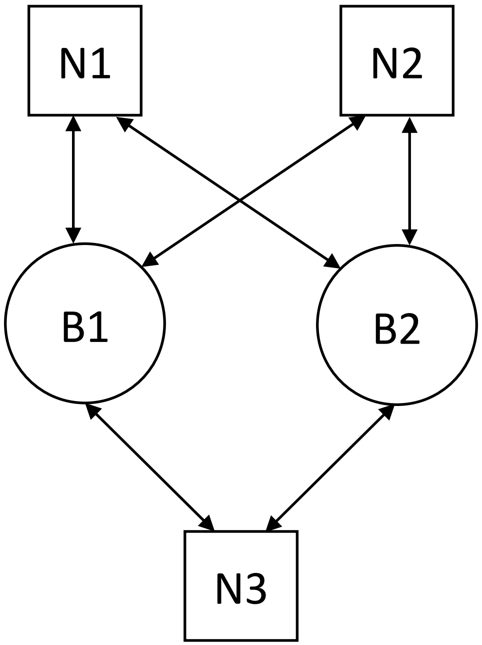
Design a dependable architecture

Eliminate SPoF



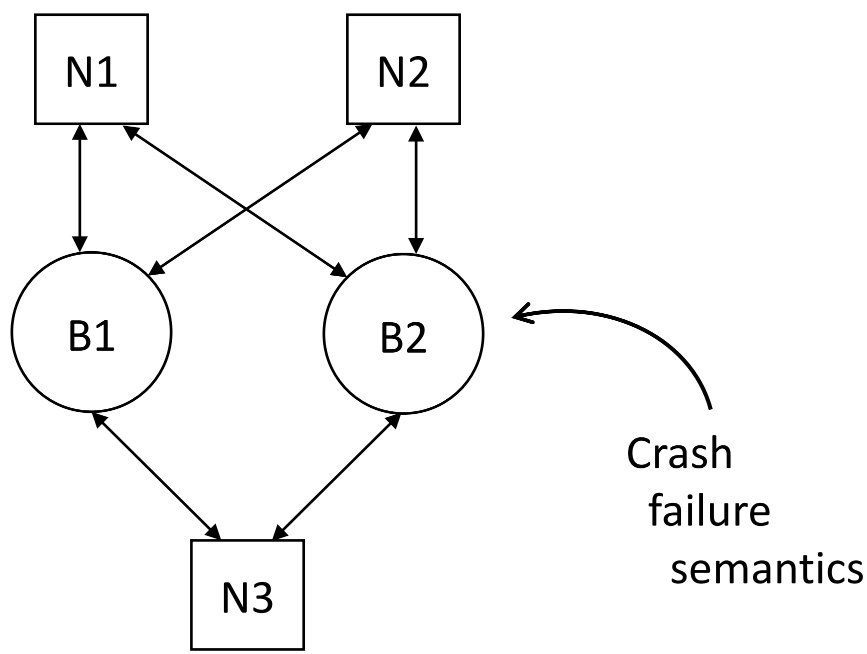
Design a dependable architecture

Add redundant paths



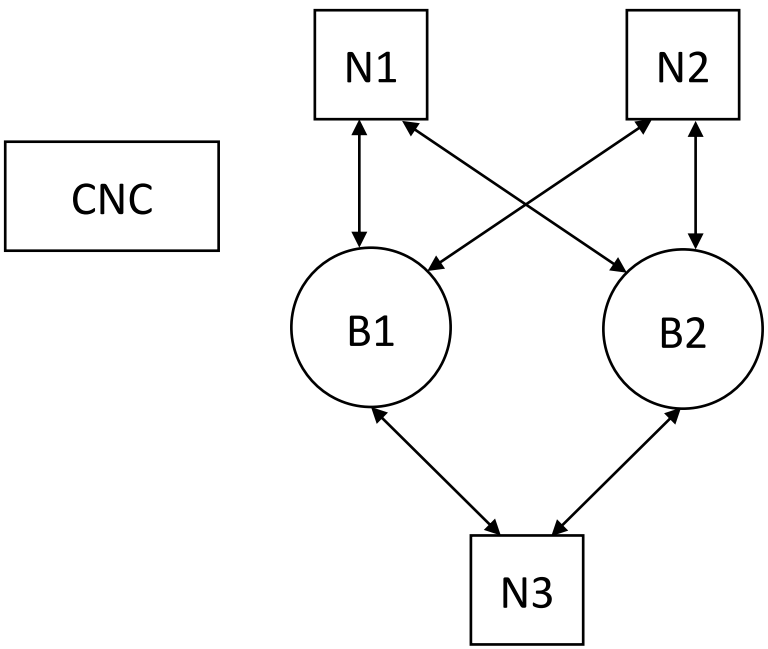
Design a dependable architecture

Restrict the failure semantics



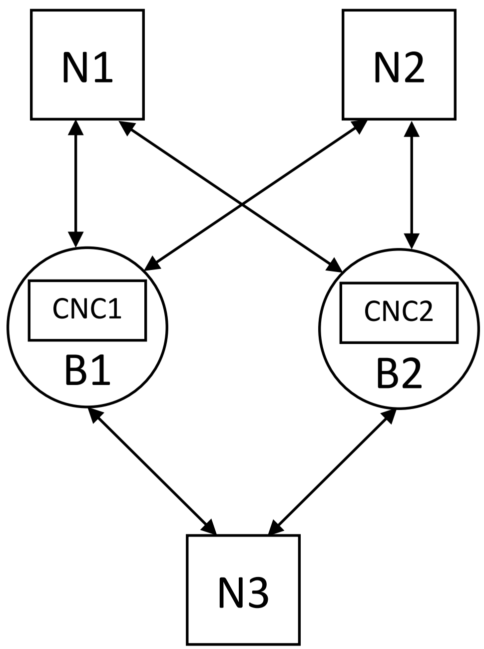
Design a dependable architecture

What should we do if we want a CNC?



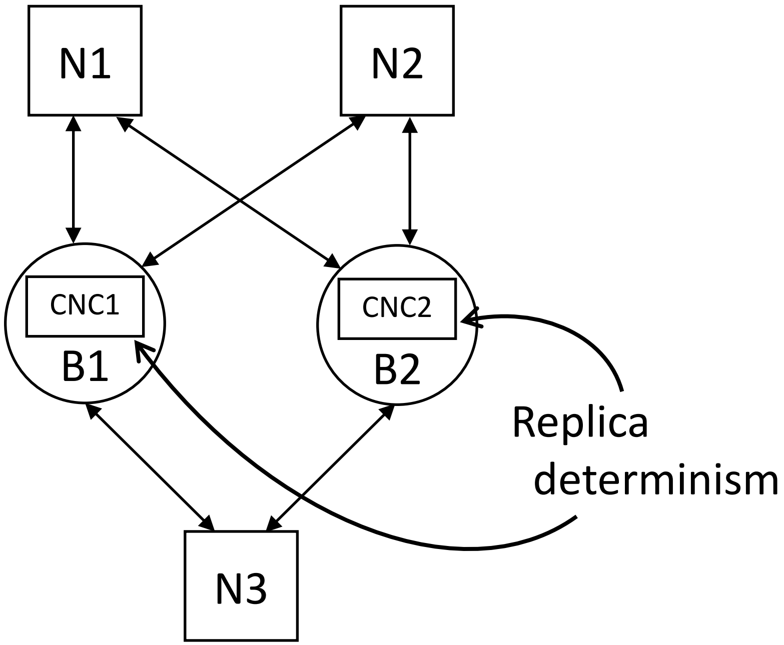
Design a dependable architecture

Introduce CNC in Switches



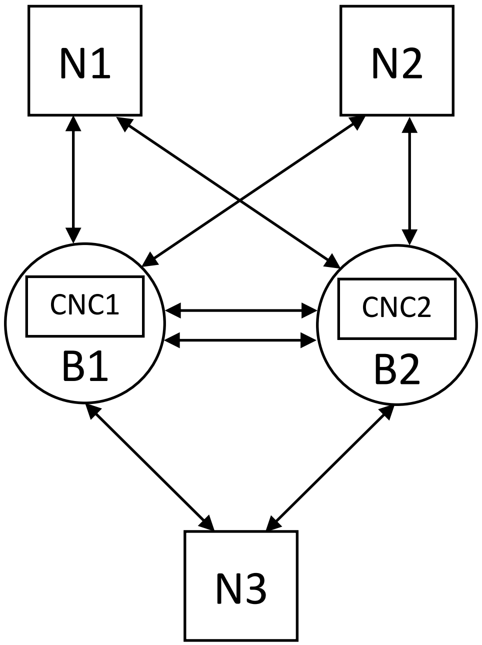
Design a dependable architecture

Introduce CNC in Switches



Design a dependable architecture

Include interlinks for the CNCs to communicate



Design a dependable architecture

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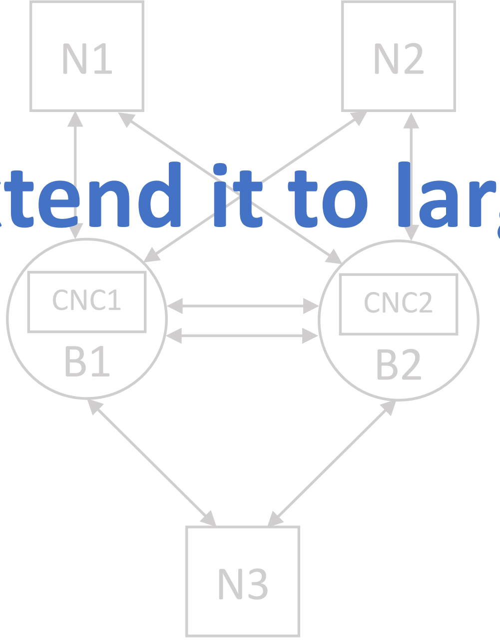

How can we extend it to larger networks?

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- Dynamic fault-tolerance in the system
- Dependability evaluation

Introduction

- We are modelling the AVB version of SRP using Uppaal.
- SRP operation in talker, bridges and listeners.
- Through the development we detected consistency and reliability issues.
- How will the issues detected affect TSN’s SRP?

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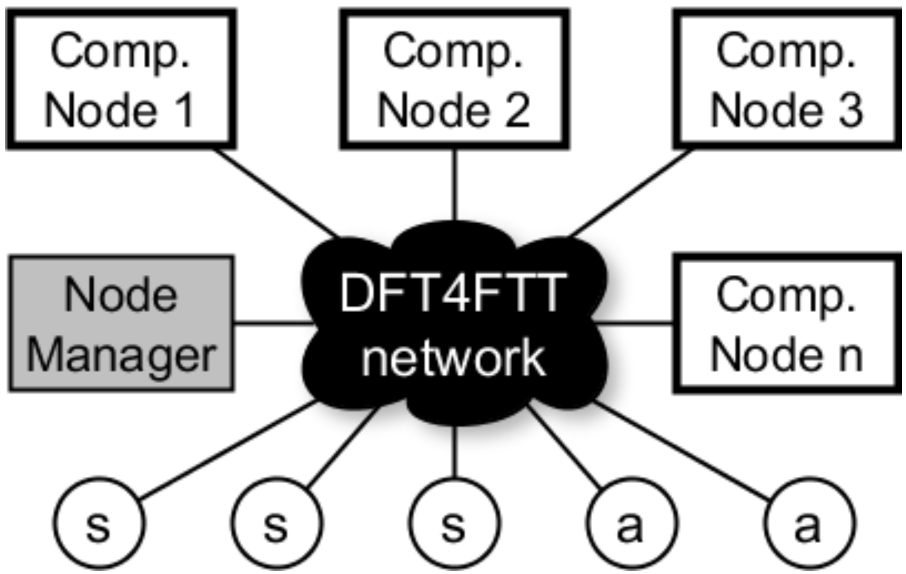
Introduction

- In our previous project we built a highly dependable distributed architecture based on FTT-Ethernet.
- We implemented fault-tolerance for the network and the nodes to increase the overall reliability of the system.
- GOAL: We want to build a self-reconfigurable infrastructure for critical adaptive distributed embedded systems.
- Include dynamic fault-tolerance mechanisms that can adapt

Dynamic fault-tolerance in the system

At the **node level**, our architecture
is composed of **various components**



Dynamic fault-tolerance in the system

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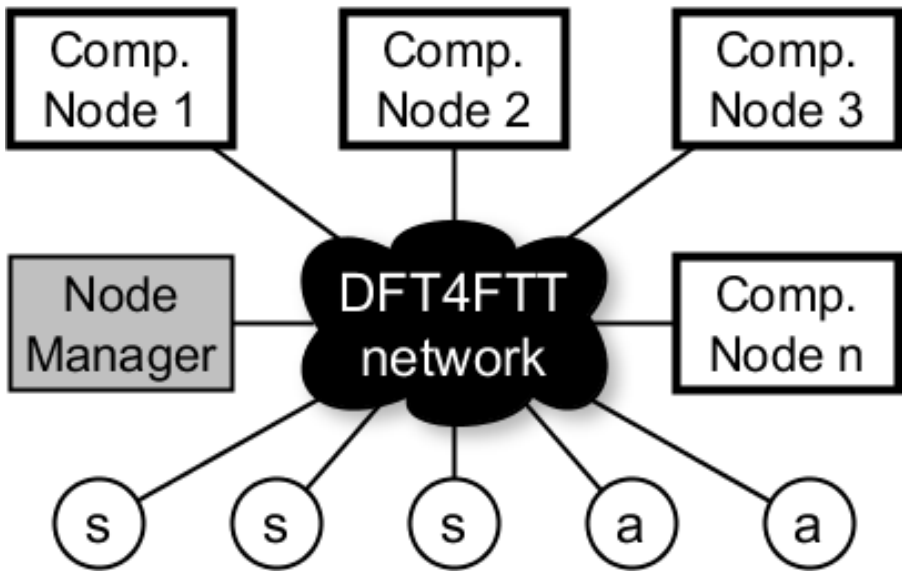

Tasks can be dynamically assigned to the nodes

Dynamic fault-tolerance in the system

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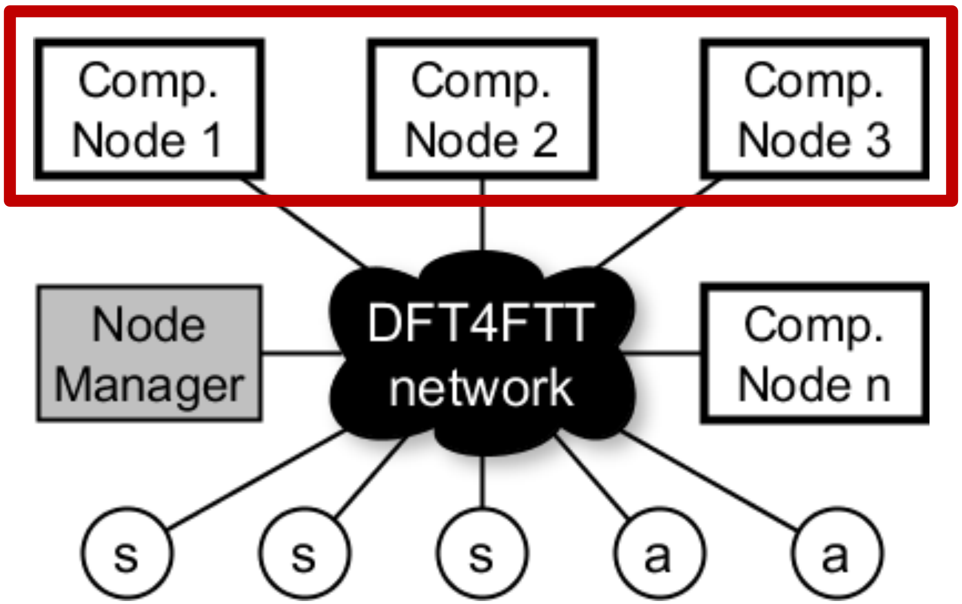

Tasks can be dynamically assigned to the nodes
E.g. any set of nodes can be configured for TMR

Dynamic fault-tolerance in the system

Potential change triggers

- Human commands
- Phase of the mission
- Environment
- State of the architecture

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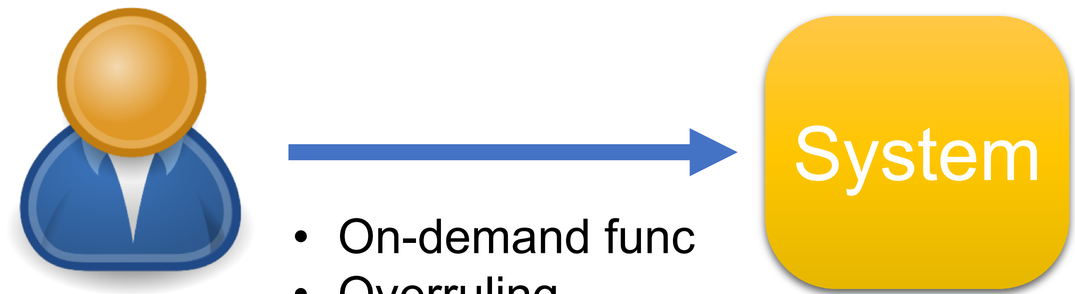

- On-demand func
- Overruling
- …

Dynamic fault-tolerance in the system

Potential change triggers

- Human commands
- **Phase of the mission**
- Environment
- State of the architecture

Phases in a commercial flight

- Engine start and warm-up
- Taxi
- Takeoff
- Climb to 45 kft
- Cruise
- Descent
- Landing
- Taxi
- Shutdown

Dynamic fault-tolerance in the system

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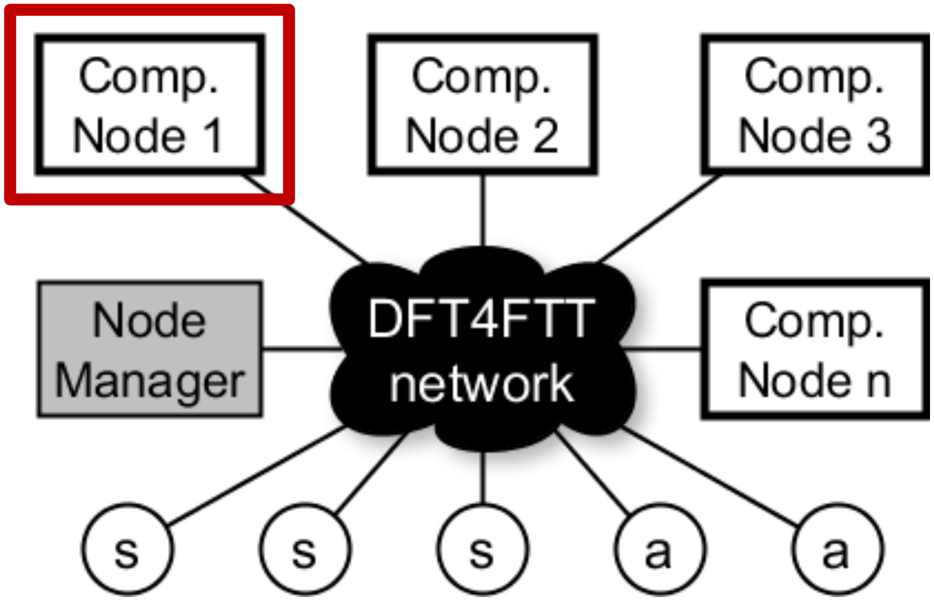

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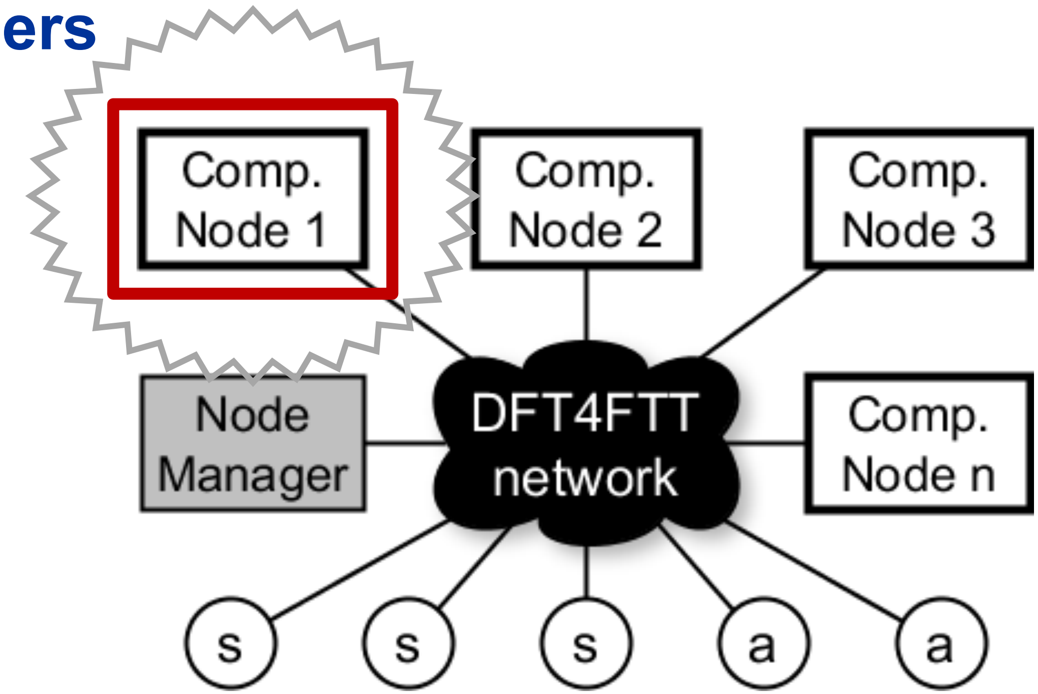

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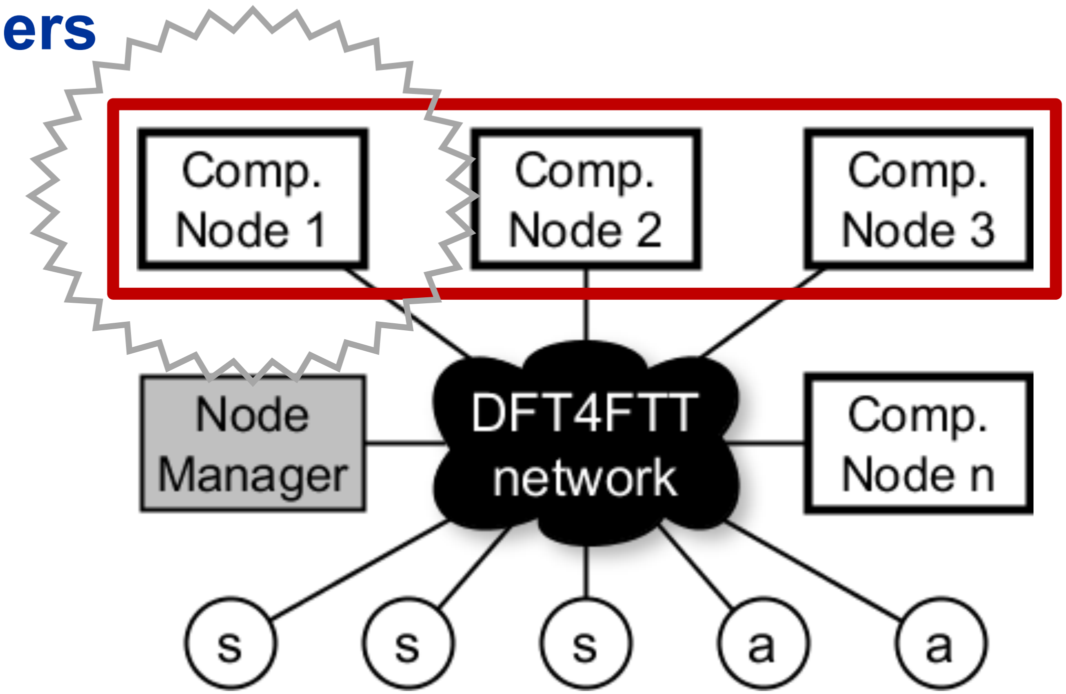

More hostile environment more replication

Dynamic fault-tolerance in the system

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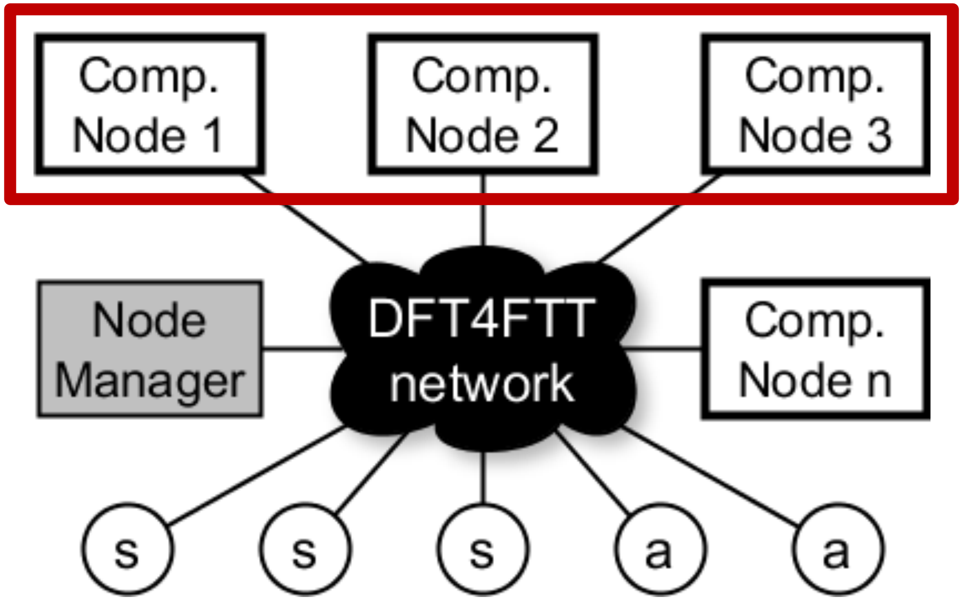

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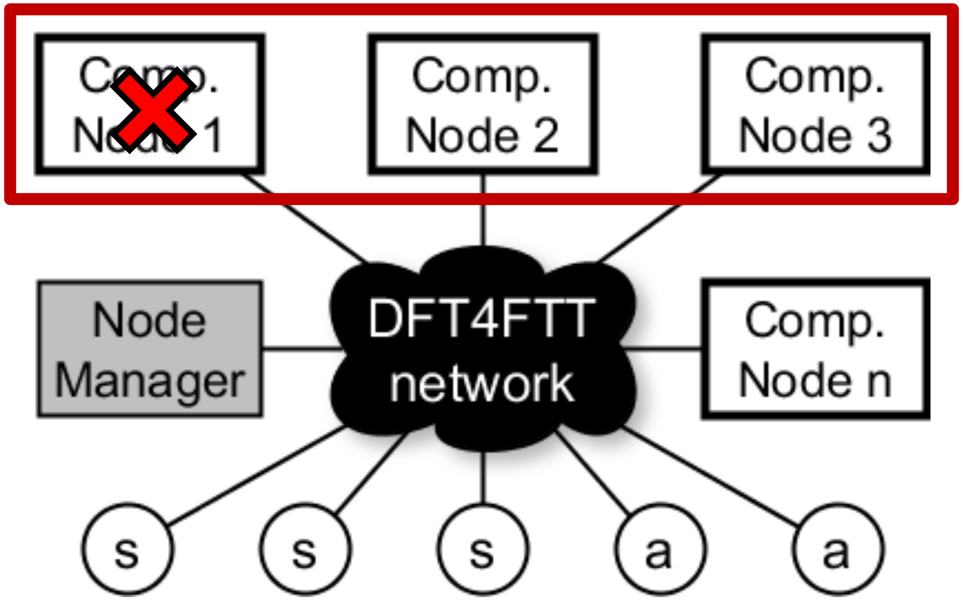

When one node is faulty it can be replaced for **redundancy preservation**

Dynamic fault-tolerance in the system

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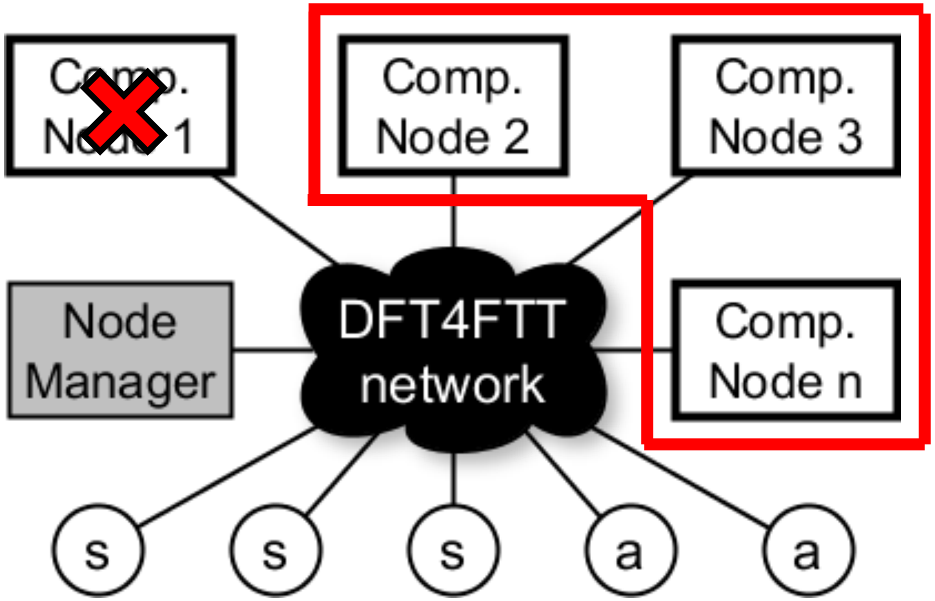

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Dynamic fault-tolerance in the system

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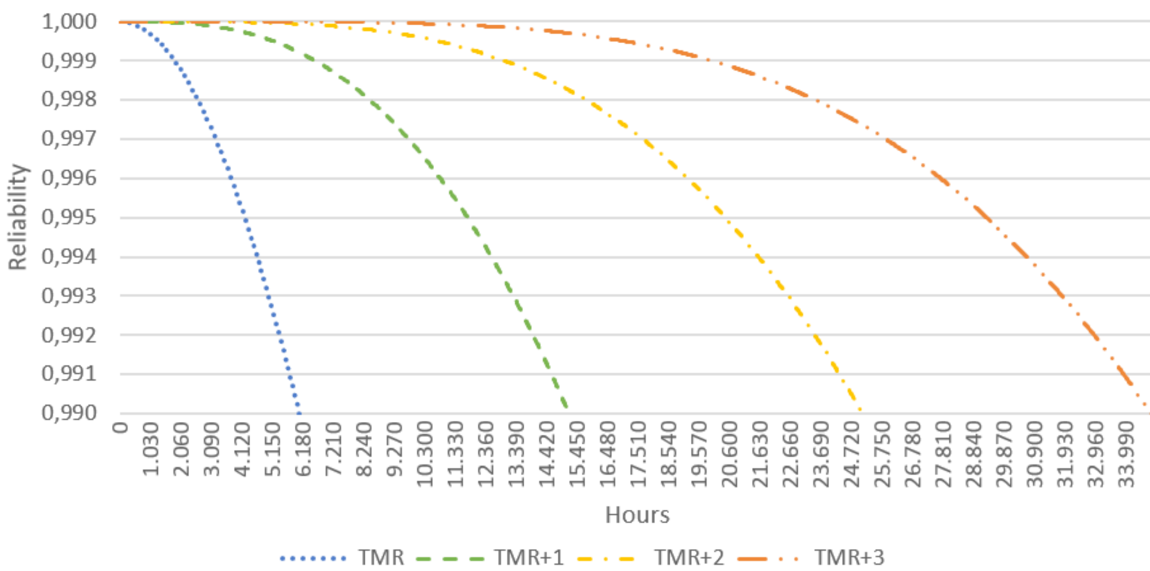


When one node is faulty it can be replaced for **redundancy preservation**

This seriously increases reliability

Dynamic fault-tolerance in the system

Changing the configuration

State
of the system

Fulfilment?

Requirements
of the system

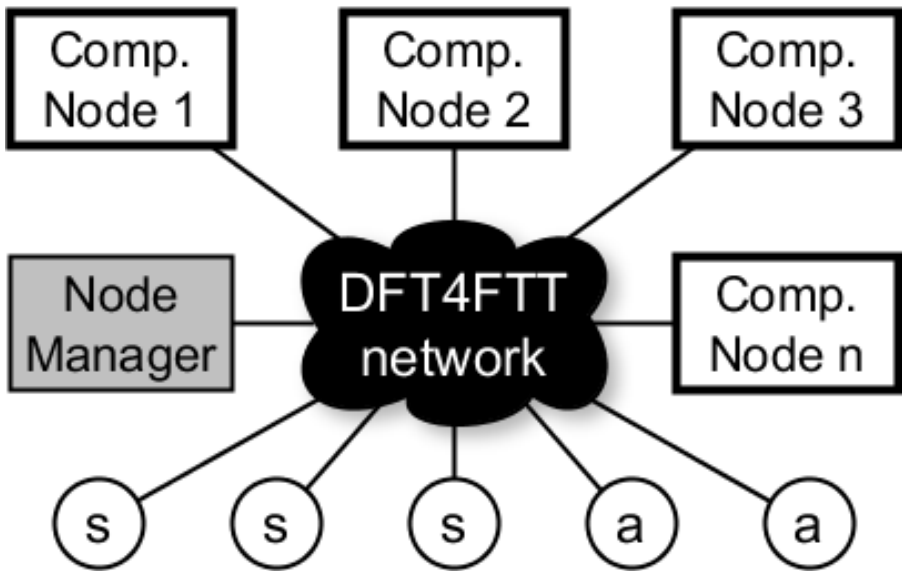
Configuration change

List of tasks

RT requirements
R(t) requirements

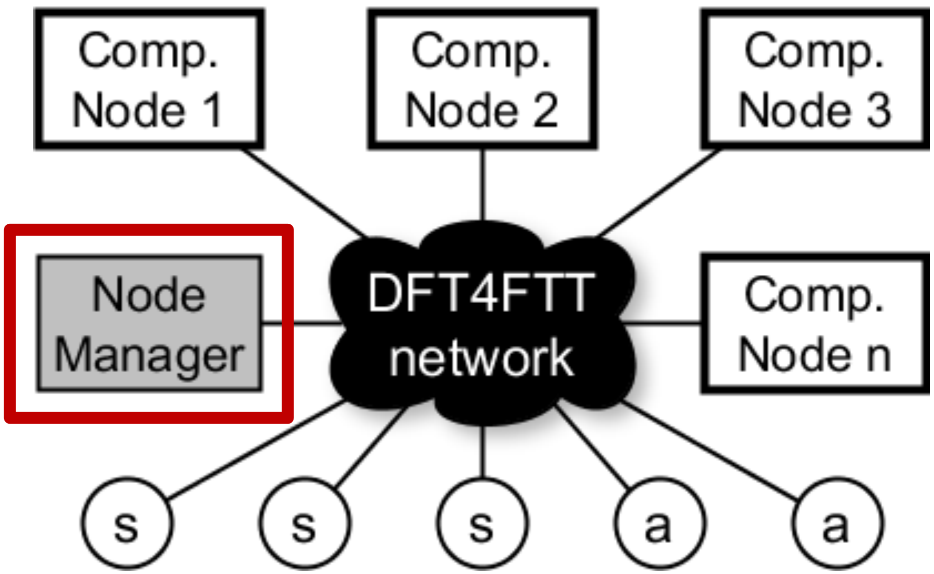
Dynamic fault-tolerance in the system

Performing changes



Dynamic fault-tolerance in the system

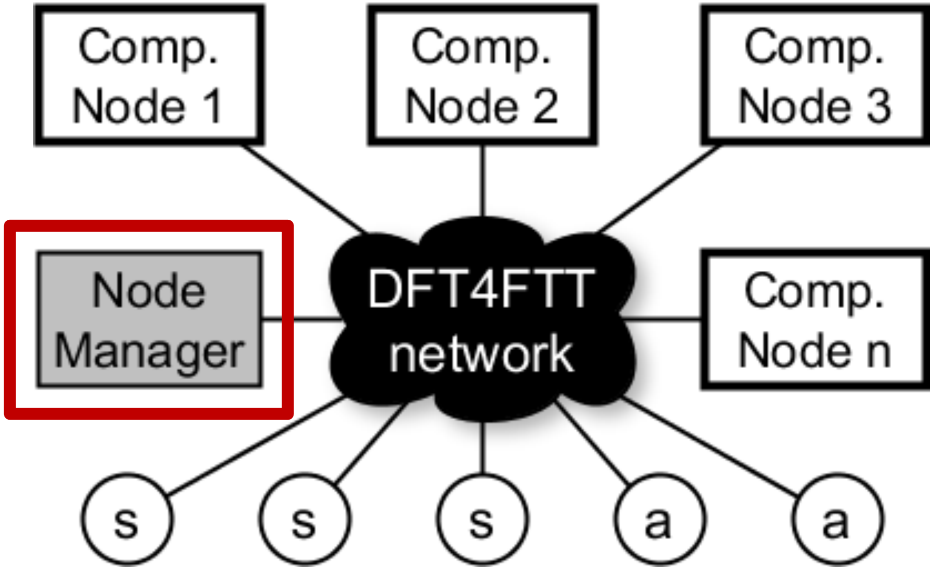
Performing changes



Dynamic fault-tolerance in the system

Performing changes

- Monitoring
- Decision
- Conf change



Next steps

- Extend this work to TSN-based systems.

- We would like to integrate the node manager operation with the Centralised Network Configurator.

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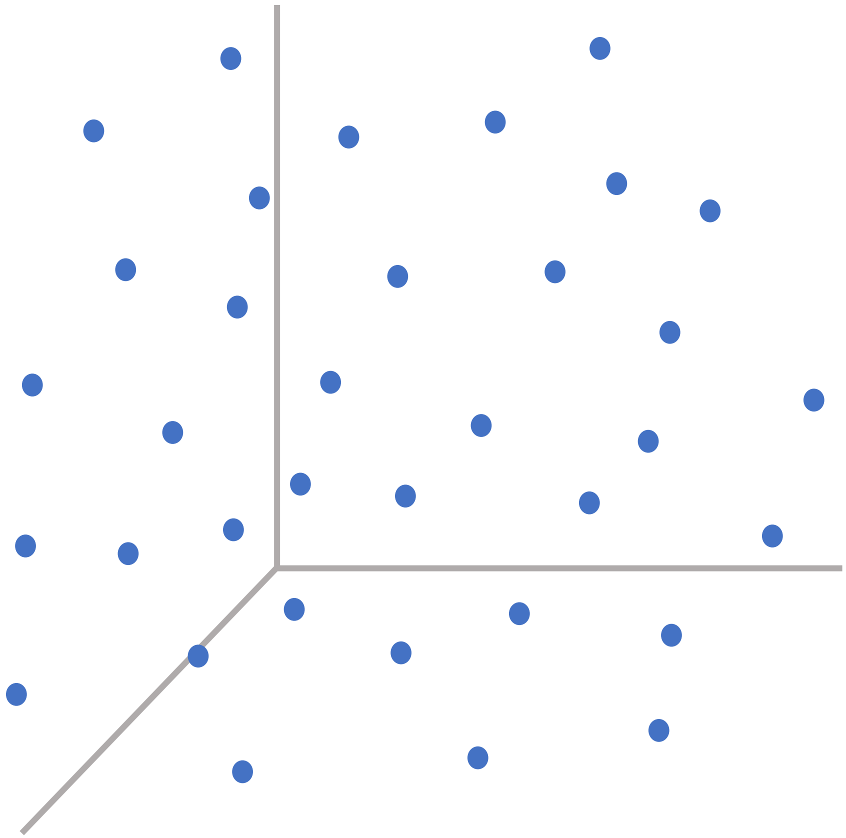
Introduction

- Explore the design space for the communication subsystem of FTTRS.
- Graph-based modelling of the network.
- Generate all networks that meet a set requirements.
- Find the one with the highest reliability for the given requirements.

Introduction



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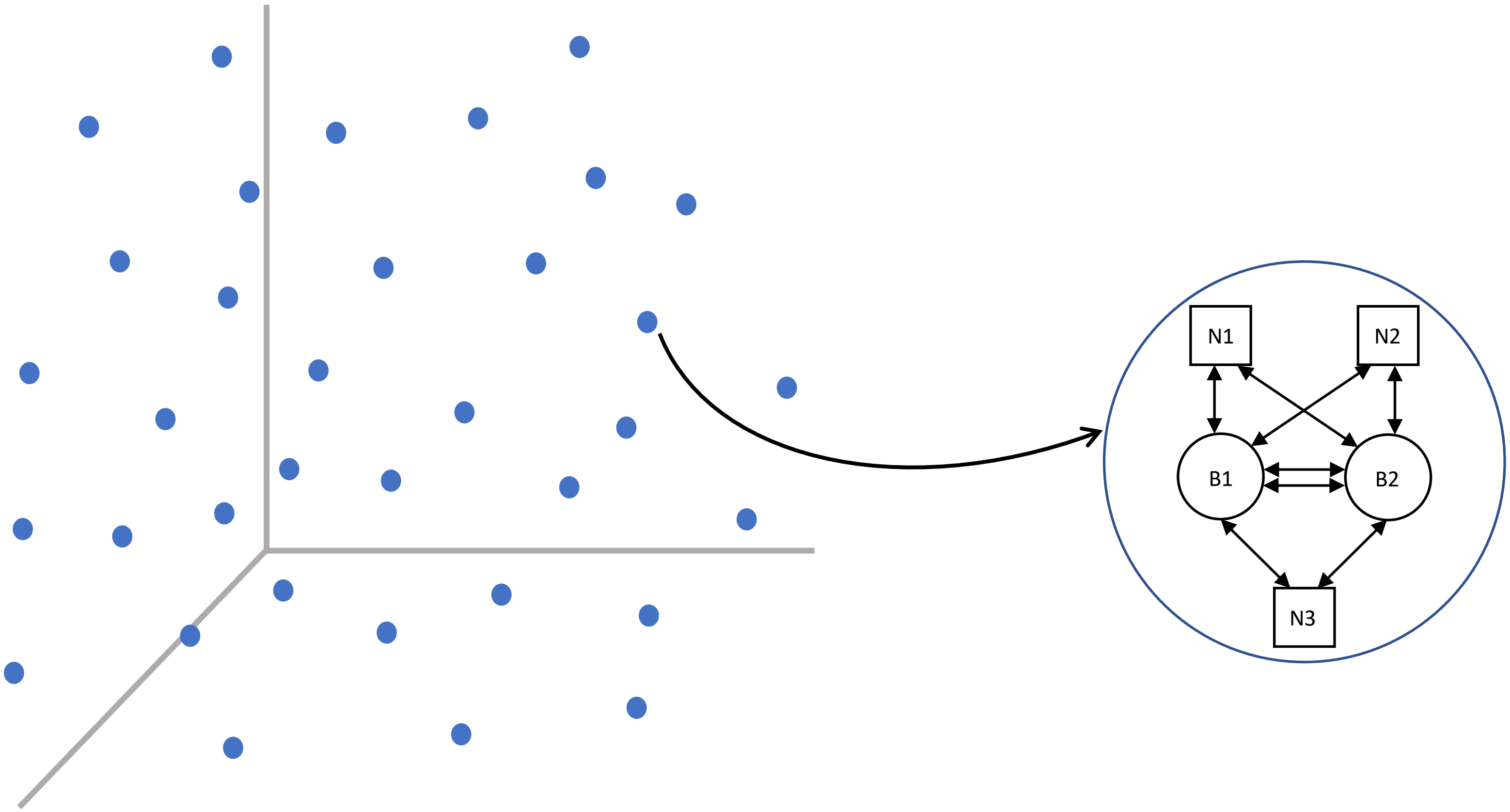
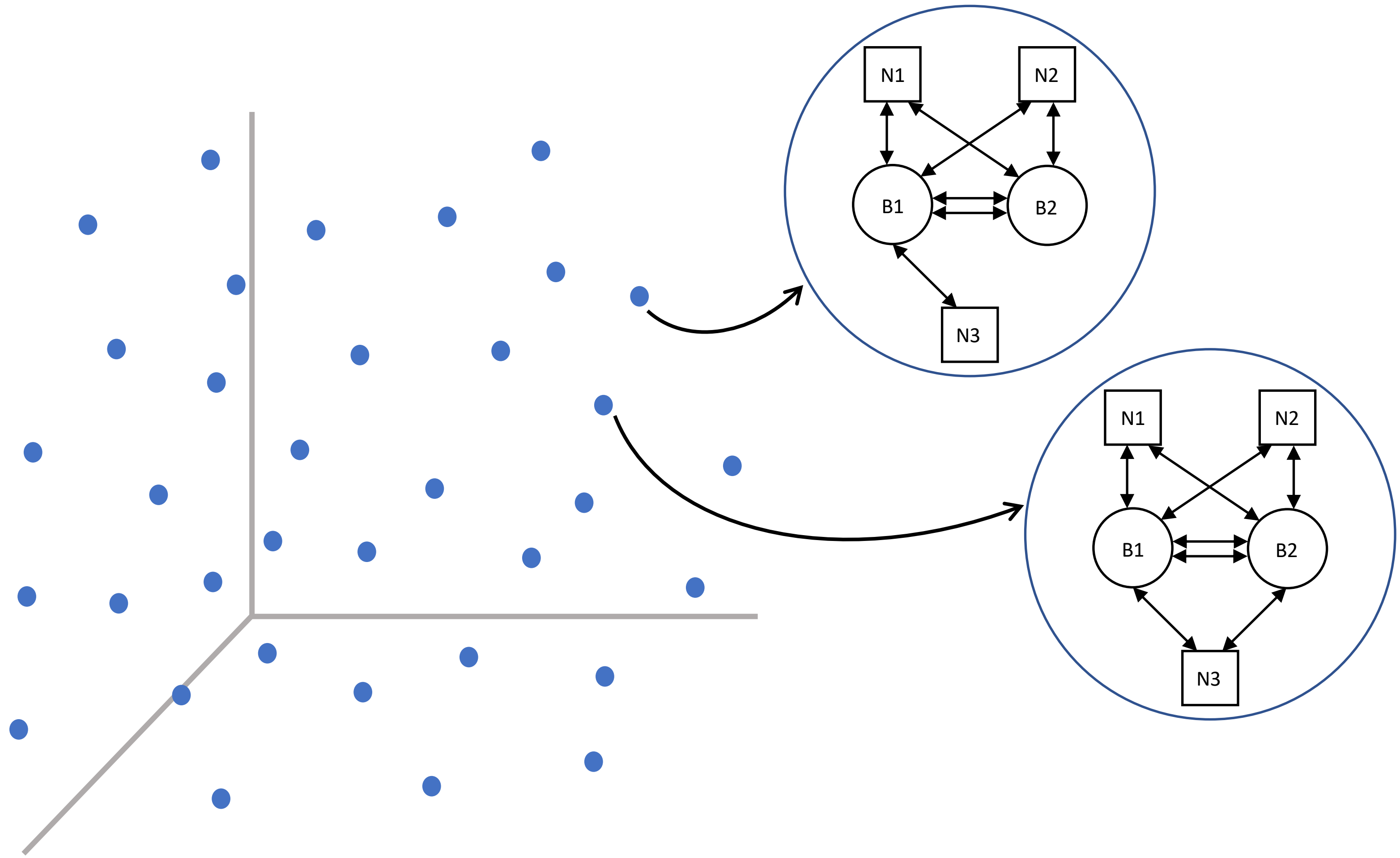
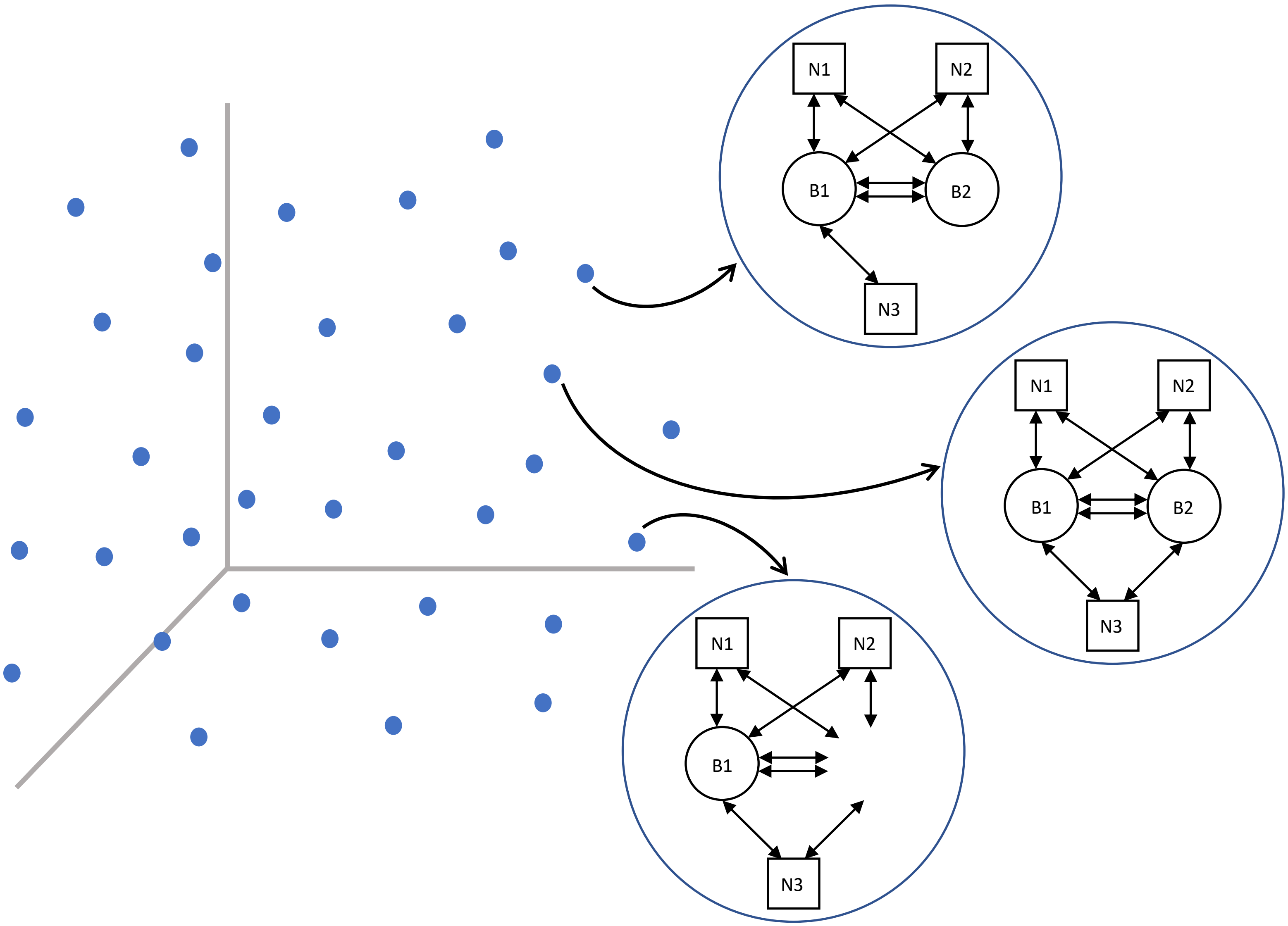


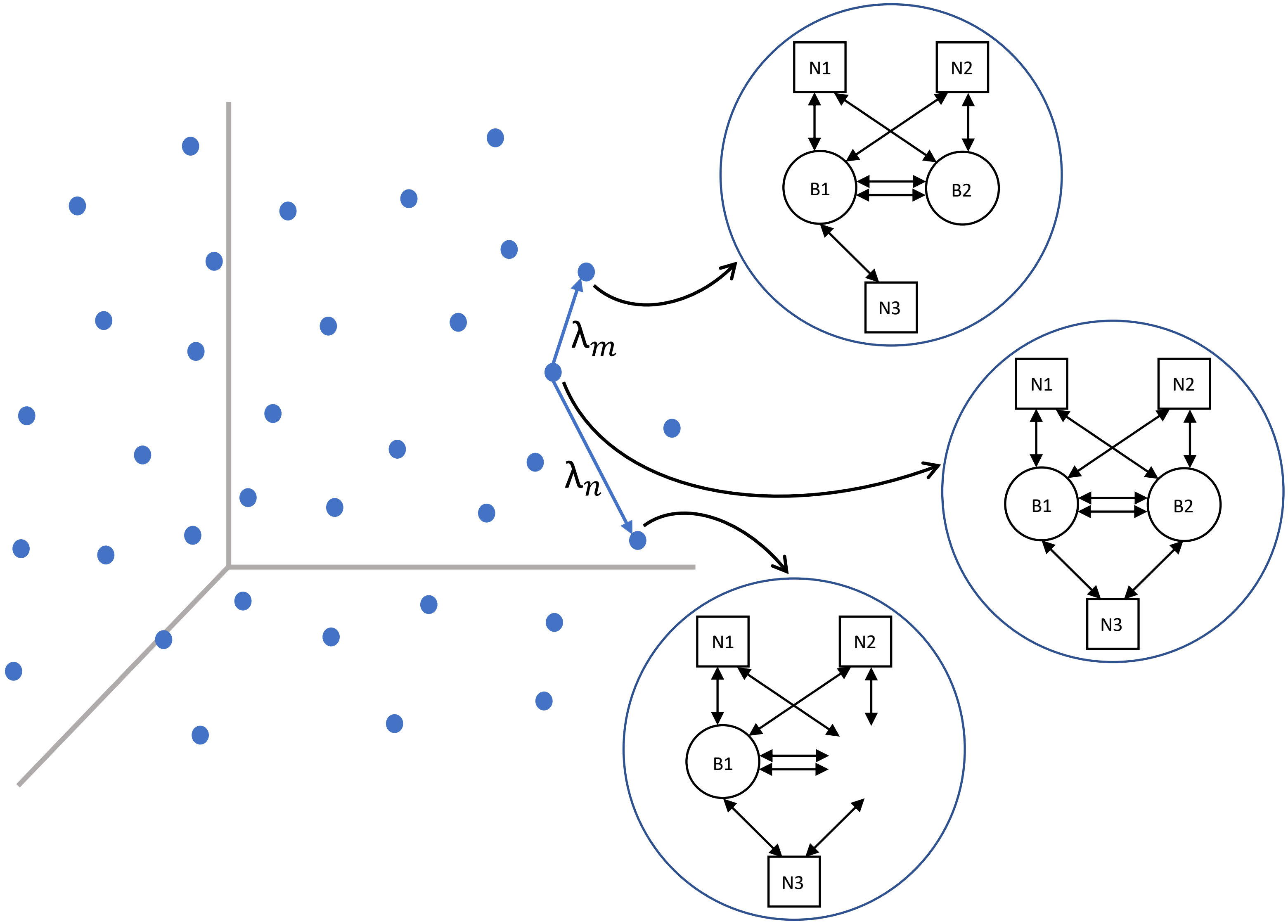
Introduction



Introduction



Introduction



Next steps

- Complete the implementation of the algorithms.
- Extend the work to support the dependability evaluation of TSN networks.
- Extend the work to support temporary faults.

Current research on dependability aspects of TSN at UIB

Inés Álvarez Vadillo

Universitat de les Illes Balears