Reliability in Time Sensitive Networking:

Overview, current efforts and future work

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Universitat de les Illes Balears

Outline of the presentation

Introduction to TSN

- What is Time Sensitive Networking?
- Why Time Sensitive Networking?
- Which services does Time Sensitive Networking provide?
- What is the current state of Time Sensitive Networking?

Our ongoing work in TSN

- The problem
- Our solution
- Open issues and current work

Future work in TSN

- Overview of key aspects
- Can we do in TSN what we did in FTT?
- Increase reliability of TSN itself

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Introduction

What is Time Sensitive Networking?

- TSN is a set of around 60 standards
- Aims at providing standard Ethernet with additional services:
  - Hard Real-Time
  - Reliability
  - Flexibility
  - Configurability

Introduction

What is Time Sensitive Networking?

- TSN is a set of around 60 standards

We will focus on layer 2 standards

- Aims at providing standard Ethernet with additional services:
  - Hard Real-Time
  - Reliability
  - Flexibility
  - Configurability

Introduction

Why Time Sensitive Networking?

- Growing interest in connecting all kind of devices
- Internet of Things and Cyber-Physical Systems
  - Automotive
  - Smart grid
  - Smart homes
- Standard Ethernet appealing (bandwidth, cost, internet…)

Introduction

Why Time Sensitive Networking?

- Standard Ethernet lacked adequate services for this change:
  - No real-time services to support the transmission of certain types of traffic.
  - No services for adaptivity (changes in the environment)

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Why Time Sensitive Networking?

- Standard Ethernet lacked adequate services for this change:
  - No real-time services to support the transmission of certain types of traffic.
  - No services for adaptivity (changes in the environment)
- IEEE proposed Audio Video Bridging (1st generation TSN)

Introduction

Why Time Sensitive Networking?

- Audio Video Bridging provides:
  - Clock synchronization
  - Resource reservation (bandwidth)
  - Traffic shapers (credit-based shaper)
- Support for soft real-time traffic and changes in the network
  - Now we have flexibility!!

Introduction

Why Time Sensitive Networking?

- Interest in increasing connection also in industry
  - IIoT and Industry 4.0
- IIoT and Industry 4.0 need flexibility and **configurability**
  - Flexibility to transmit several types of traffic and adapt existing services to changes in the environment.
  - Configurability to add new services or modify the system **on-line**.
- Industry needs hard real-time and high reliability

Introduction

Why Time Sensitive Networking?

- AVB can not provide:
  - Hard real-time
  - High reliability
  - Configurability
- Many industrial solutions, but with problems:
  - Don’t cover all the aspects
  - No interoperability guarantee
  - No standard

Introduction

Why Time Sensitive Networking?

Time Sensitive Networking aims at standardizing all mentioned services, guaranteeing interoperability with other technologies.

Introduction

Which services does Time Sensitive Networking provide?

- Hard and soft real-time:
  - Credit based shaper (AVB)
  - Time-aware shaper
  - Cyclic queueing and forwarding
  - Asynchronous traffic shaper
  - Stream filtering and policing
  - Frame preemption
  - Timing and synchronization

Introduction

Which services does Time Sensitive Networking provide?

- Flexibility:
  - Stream reservation protocol
  - Automatic attachment to provider backbone bridging services
- Reliability:
  - Path control and reservation (multiple paths)
  - Frame replication and elimination for reliability
  - Link-local registration protocol

Introduction

Which services does Time Sensitive Networking provide?

- Configurability:
  - YANG data model
  - LLDP YANG data model
  - YANG Data Models for Scheduled Traffic, Frame Preemption, and Per-Stream Filtering and Policing
  - YANG Data Model for Connectivity Fault Management

Introduction

What is the current state of Time Sensitive Networking?

Standard	Status	Standard	Status
Qbu	Standard	Qcr	Task group
Qbv	Standard	CS	Task group
Qca	Standard	Qcj	PAR approved
Qch	Standard	Qcp	PAR approved
Qci	Standard	ABcu	Editor’s draft
CB	Standard	Qcw	Editor’s draft
AS-Rev	Task group	Qcx	Editor’s draft
Qcc	Working group		

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Current work

- Our work focuses on industrial systems
- These systems are highly critical
- TSN relies in the natural spatial redundancy of the network to provide reliability
- That is, TSN tolerates both permanent and **transient** faults using spatial redundancy

Current work

- Nevertheless, using this approach has drawbacks:
  - We may not count with a high level of spatial redundancy (cars, domotic…)
  - Spatial redundancy is expensive
  - If we use spatial redundancy for transient faults it may not be available to tolerate permanent faults
- Transient faults are more common than permanent ones

Current work

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- Transient faults are more common than permanent ones
- Thus, we propose to use time redundancy to tolerate transient faults

Current work

- Existing protocols that provide time redundancy
  - Higher layer protocols
  - Rely on ACKs or NACKs

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- We propose **proactive replication of frames**
  - Transmit each frame several times to ensure that at least one copy will reach the receiver even in presence of faults

Current work

- Existing protocols that provide time redundancy
  - Higher layer protocols
  - Rely on ACKs or NACKs
- We propose **proactive replication of frames**
  - Transmit each frame several times to ensure that at least one copy will reach the receiver even in presence of faults
- Let’s remember that industrial applications have hard real-time and high reliability requirements…

Current work

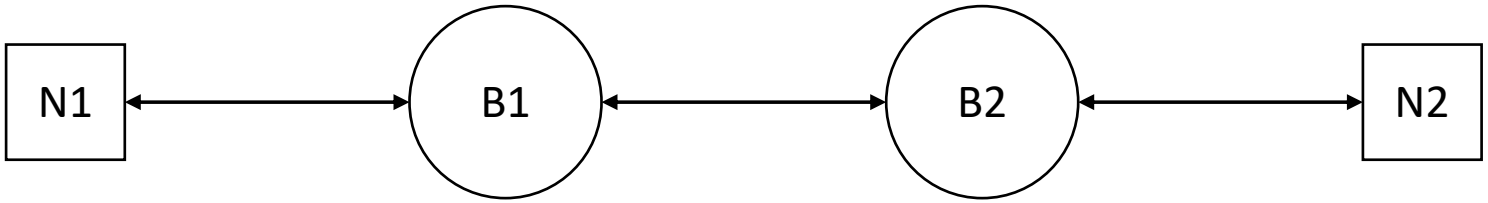
- Why **proactive replication of frames**?
  - ACKs and NACKs are single points of failure, since they can be affected by transient faults.
  - Time for retransmissions based in ACKs or NACKs can exceed deadlines of control applications.
  - In the worst case scenario, the overhead produced by said schemes is higher than by proactive replication.

Current work

- How **proactive replication of frames**?
- We proposed three different approaches:
  - End-to-end estimation and replication
  - End-to-end estimation, link-based replication
  - Link-based estimation and replication

Current work

End-to-end estimation and replication



Current work

End-to-end estimation and replication

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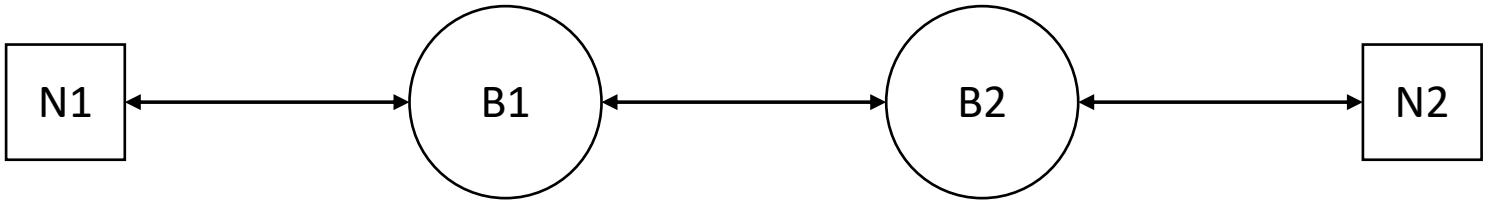

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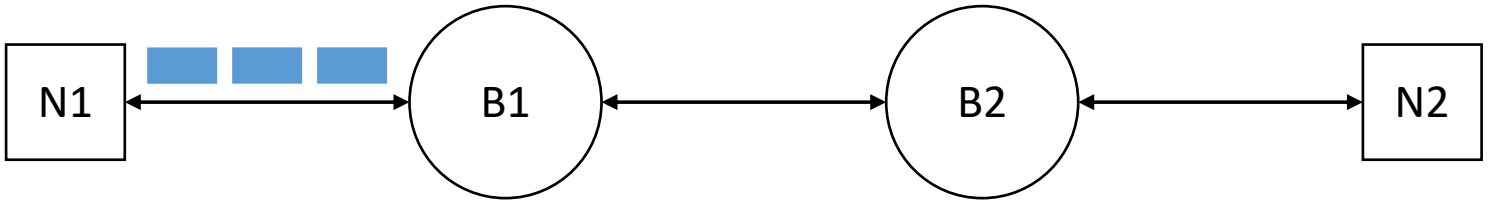

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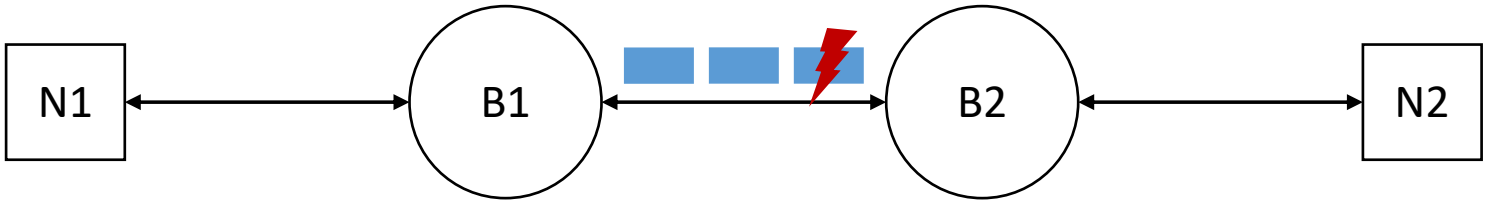

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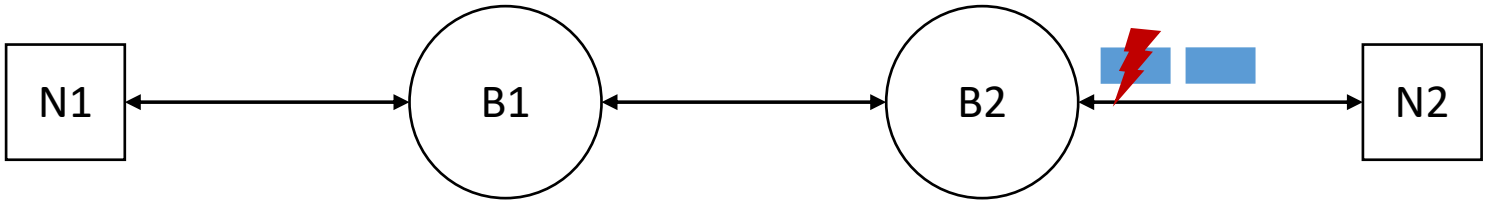

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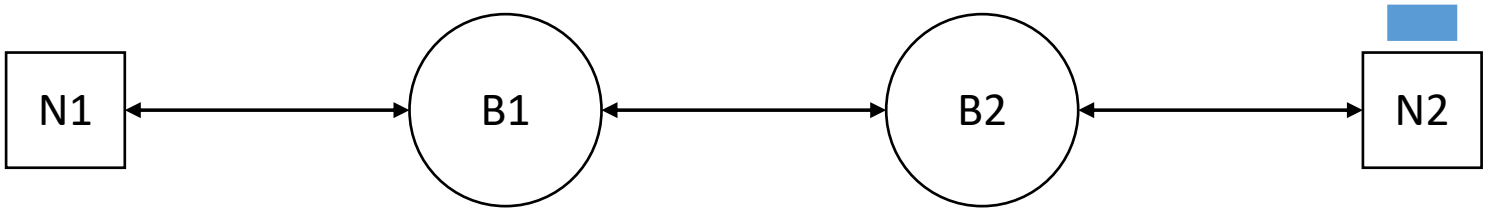
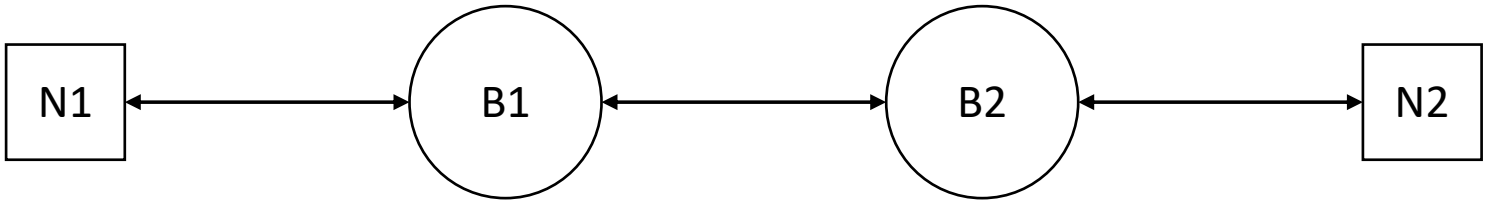


Current work

End-to-end estimation, link-based replication



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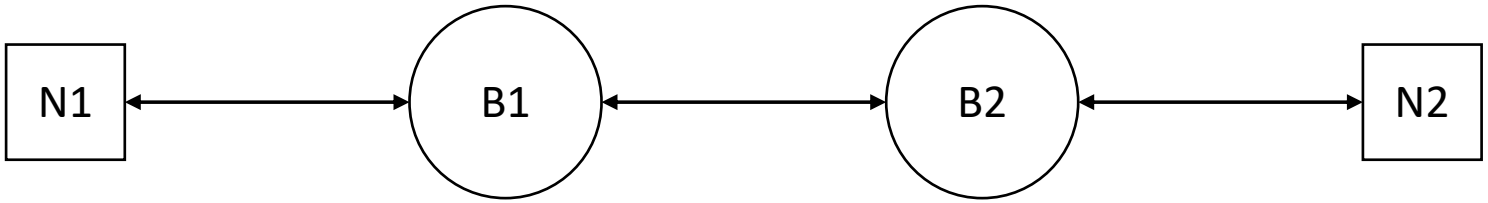

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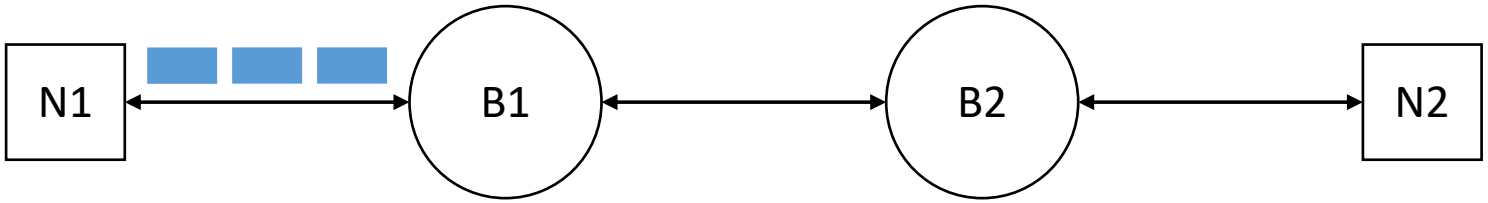

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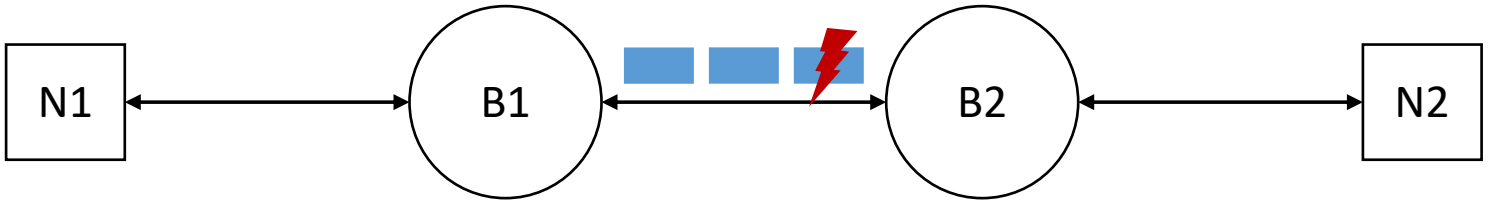

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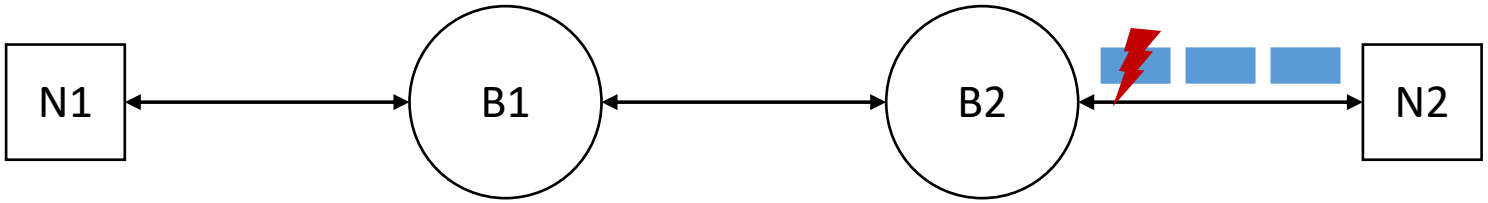

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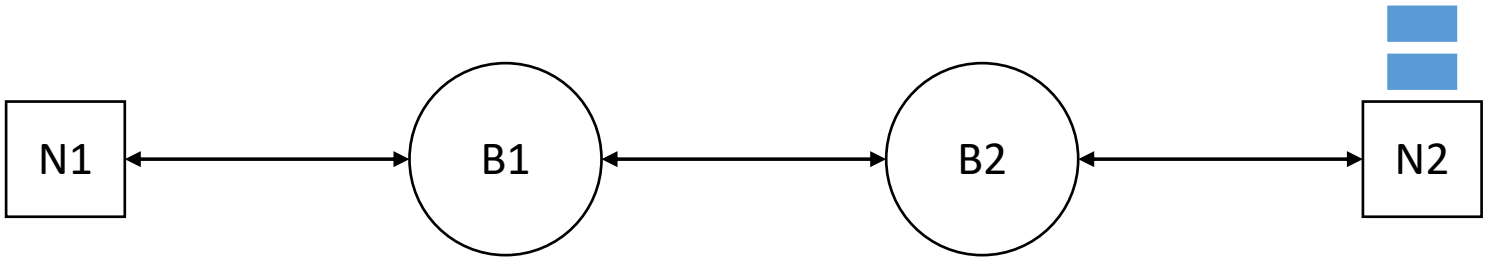

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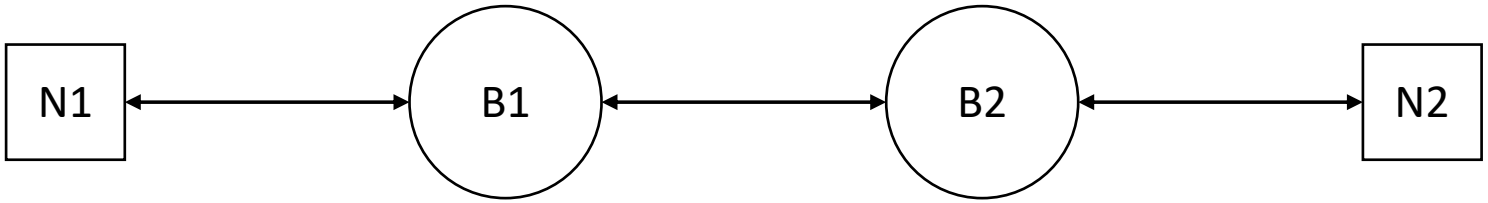

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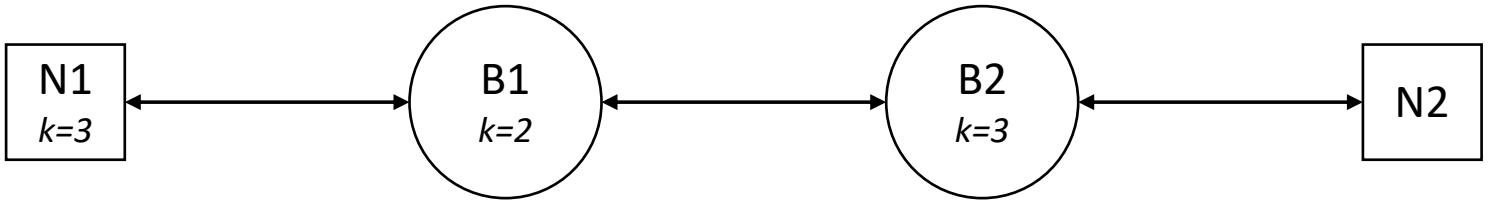

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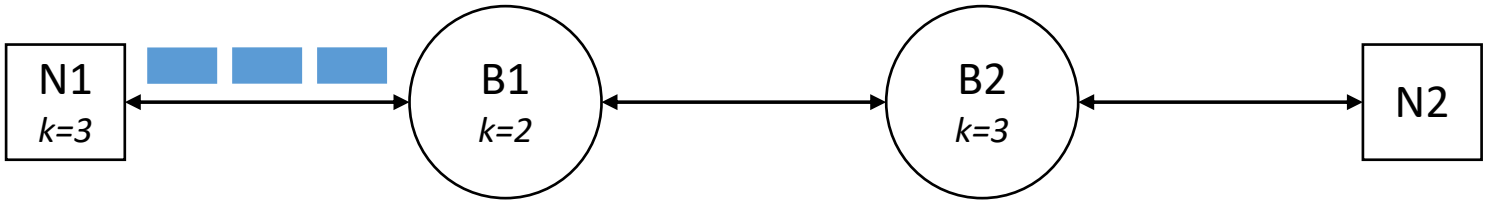

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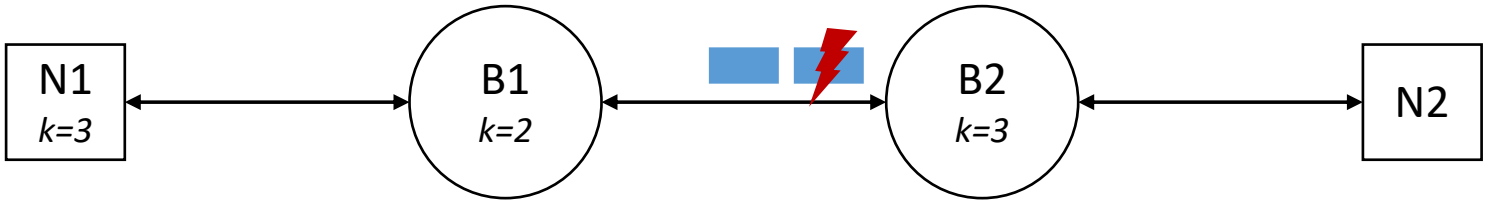

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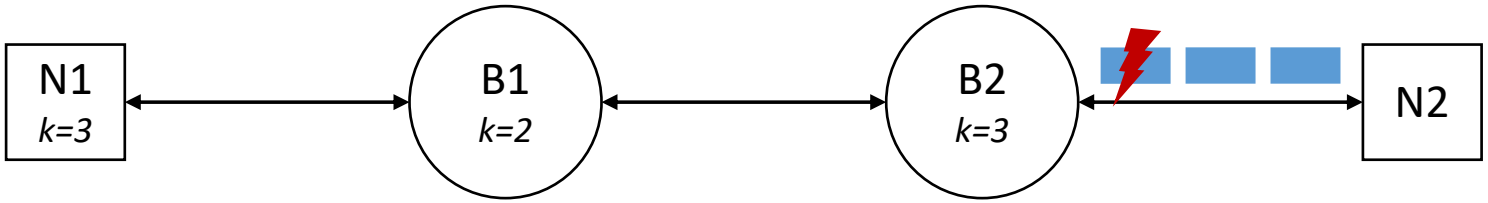

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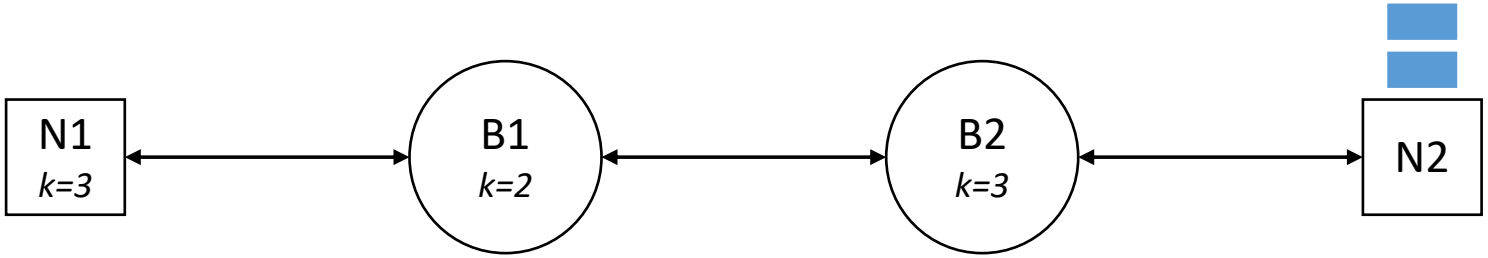

Current work

- Which approach should we choose?
  - Reliability analysis: what is the level of reliability we can achieve with each approach?
  - Simulation: faster and simpler way to do a proof of concept, validate the designs and inject faults.
  - Implementation in TSN-like switches: obtain a real prototype of the selected approach.
  - Performance impact: what are the consequences of replicating frames in the performance of the system.

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- Overview of key aspects
- Can we do in TSN what we did in FTT?
- How to increase reliability of TSN itself?

Future work: key aspects

TSN is more than nodes and bridges

Future work: key aspects

TSN aims at providing standard Ethernet with:

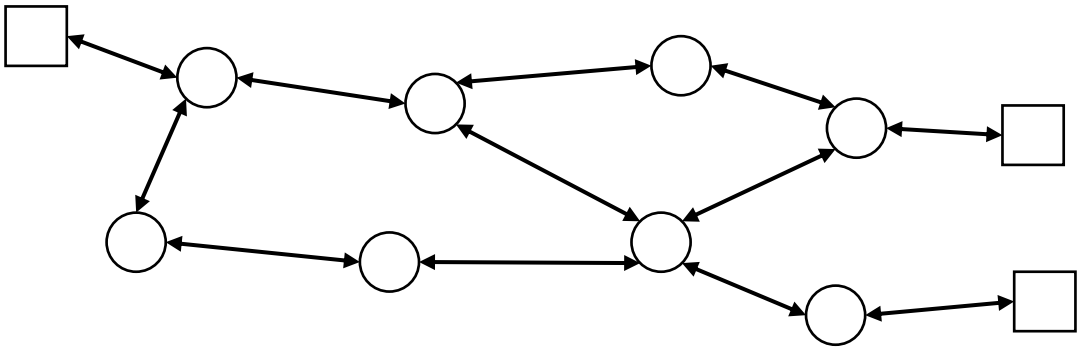
- Hard Real-Time
- Reliability
- Flexibility
- Configurability

Future work: key aspects

TSN aims at providing standard Ethernet with:

- Hard Real-Time
- Reliability
- Flexibility
- Configurability (or at least enable configuration)

Future work: key aspects



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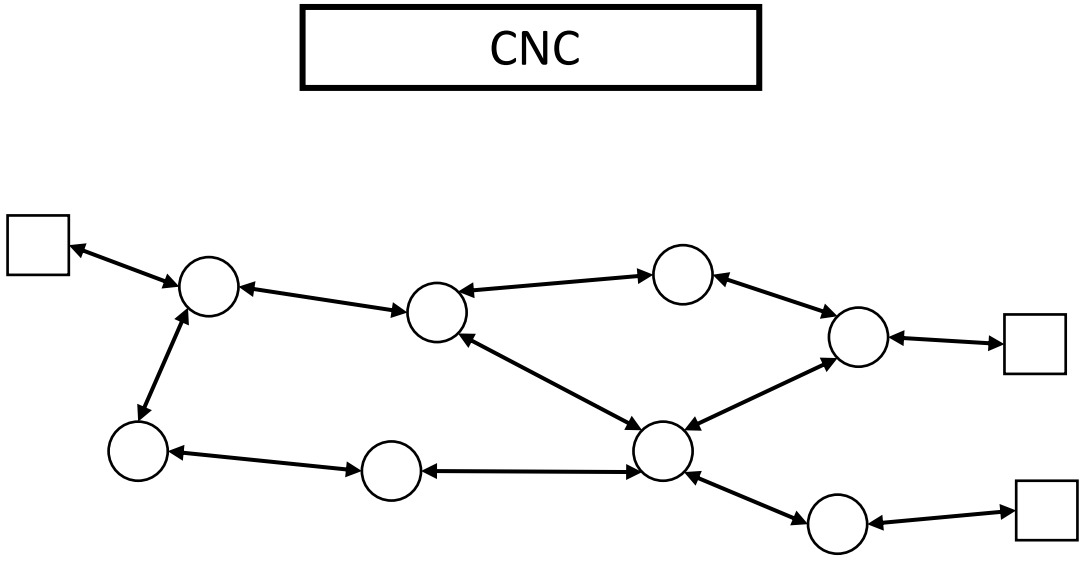

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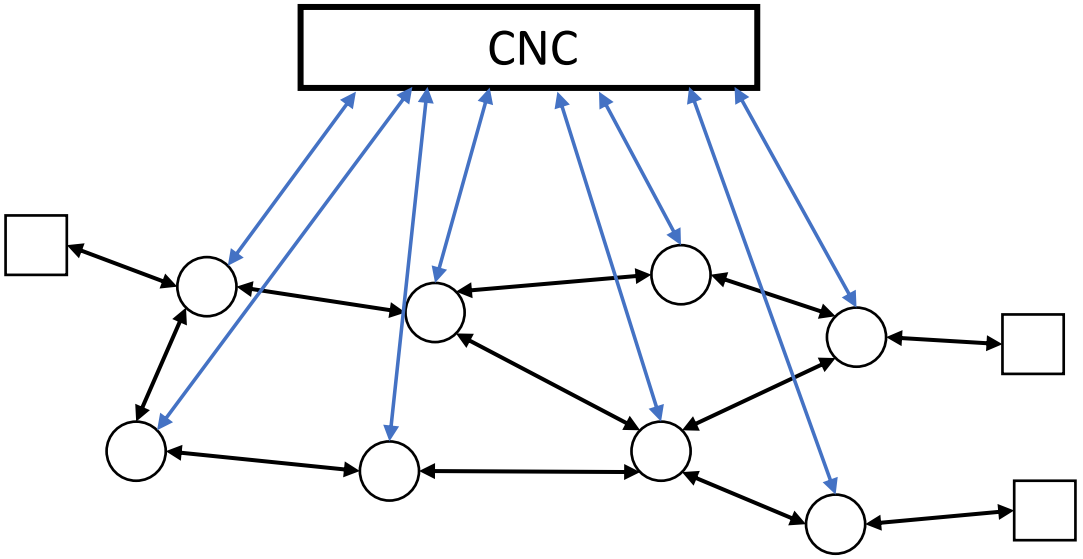

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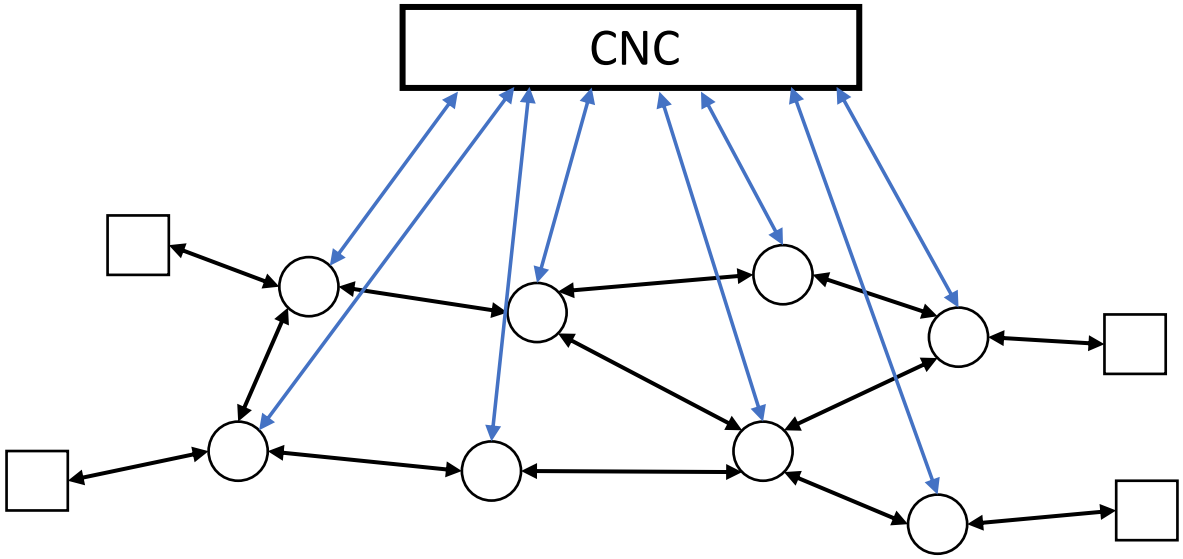

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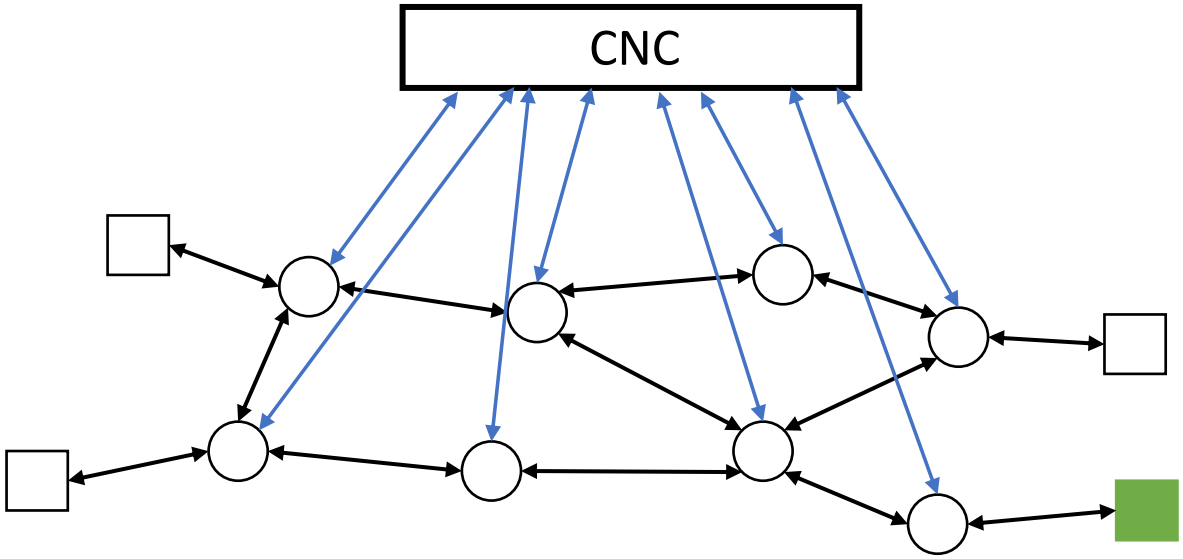

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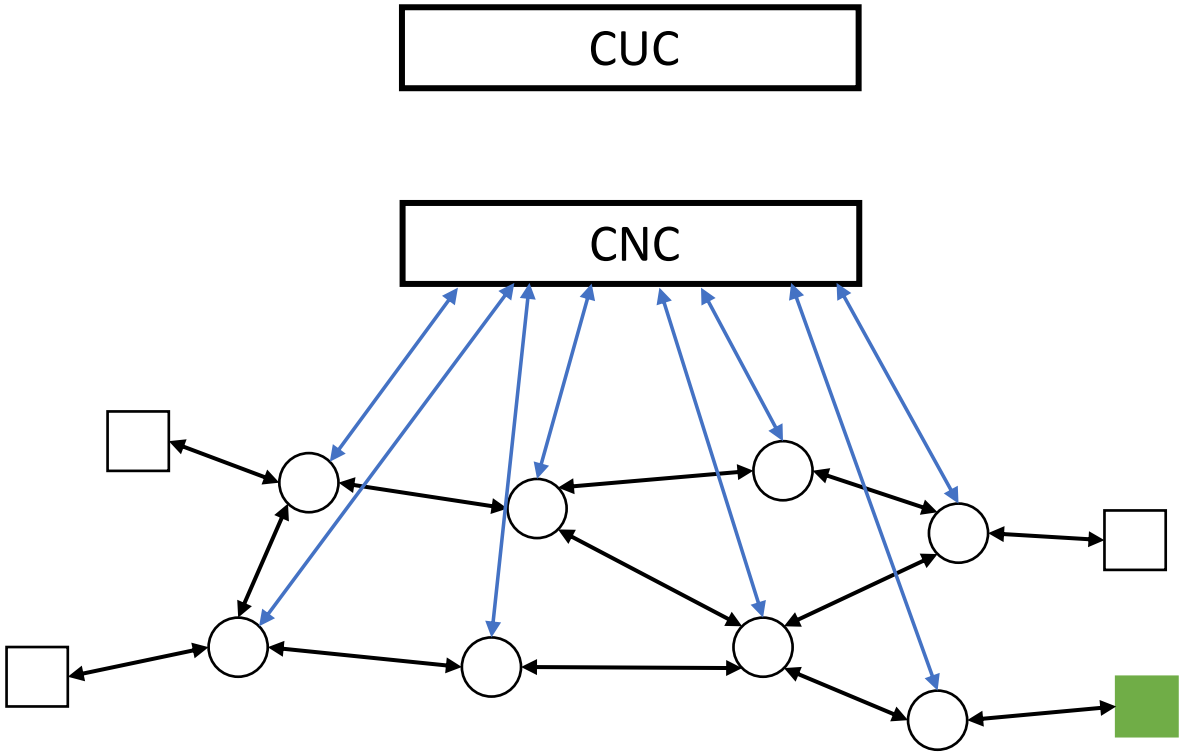

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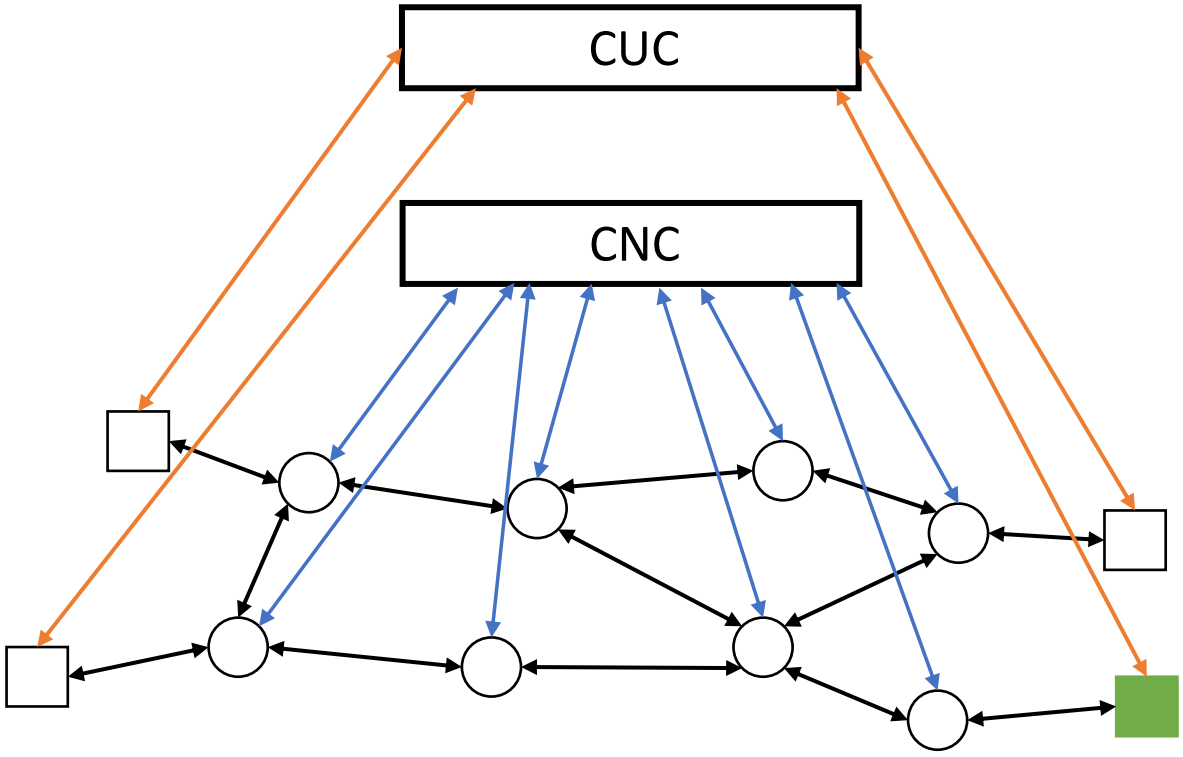

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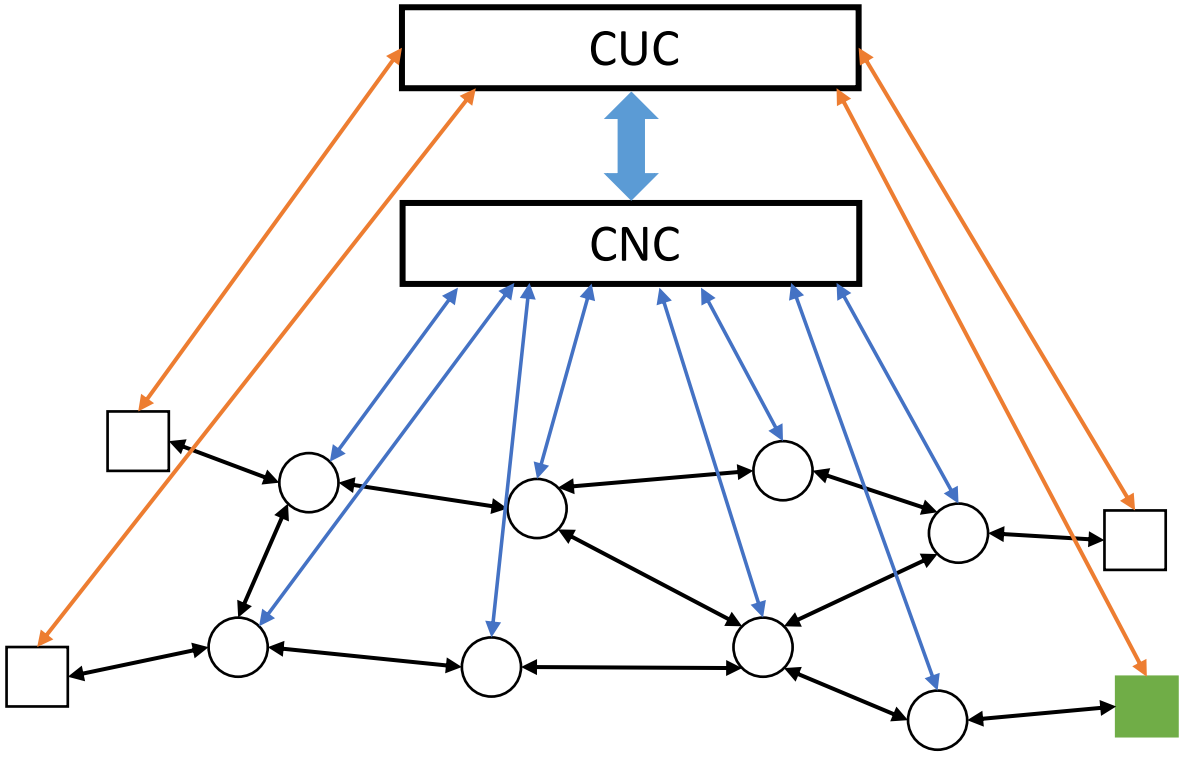

Future work

What can we do?

Future work

- Try to do what we've done in FTT, now in TSN
  - Can we provide the same network services?
  - Can we use our node replication schemes?
  - Dynamic fault-tolerance

Future work

- Try to do what we've done in FTT, now in TSN
  - Can we provide the same network services?
  - Can we use our node replication schemes?
  - Dynamic fault-tolerance
- Increase reliability of TSN itself
  - Vulnerabilities identified so far

Future work

- **Try to do what we've done in FTT, now in TSN**
  - Can we provide the same network services?
  - Can we use our node replication schemes?
  - Dynamic fault-tolerance
- Increase reliability of TSN itself
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Future work

- Can we provide the same network services?
  - In HaRTES we have a centralized admission control.
  - We could use the same approach, placing this service in the CNC.
  - HaRTES does not check the nodes' resources, we trust nodes do it.
  - AVB does check the node's resources and reserve them during AC.
  - Which approach should we use?

Future work

- Can we provide the same network services?
  - In HaRTES reconfiguration is affected by load of the network and length of EC.
  - We can get significantly short reconfiguration times.
  - Can we achieve the same speed? Can we improve it with respect to HaRTES?
  - What are the consequences if we can’t?

Future work

- Can we use our node replication schemes?
  - FTT has the Trigger Message (synchronize, trigger communication)
  - Triggering of tasks done by the Trigger Message.

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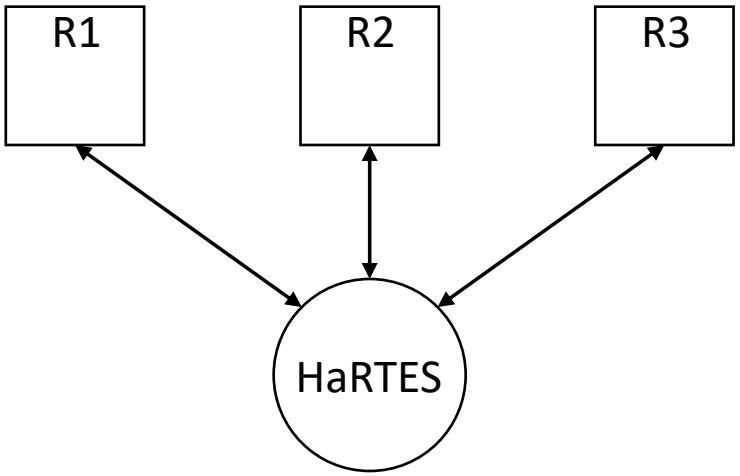

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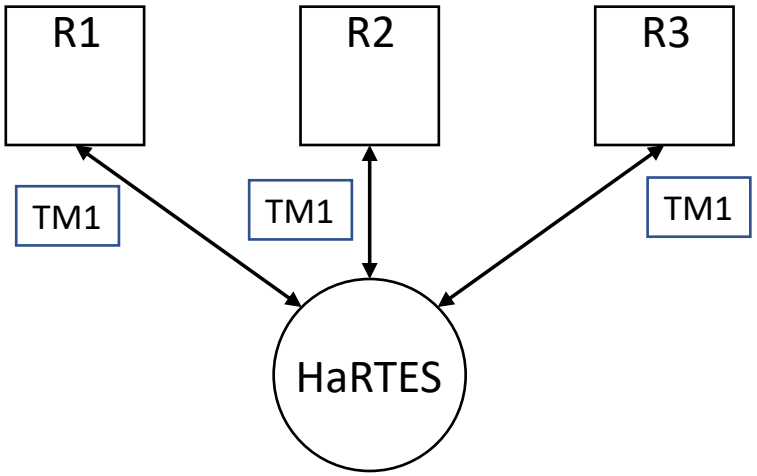

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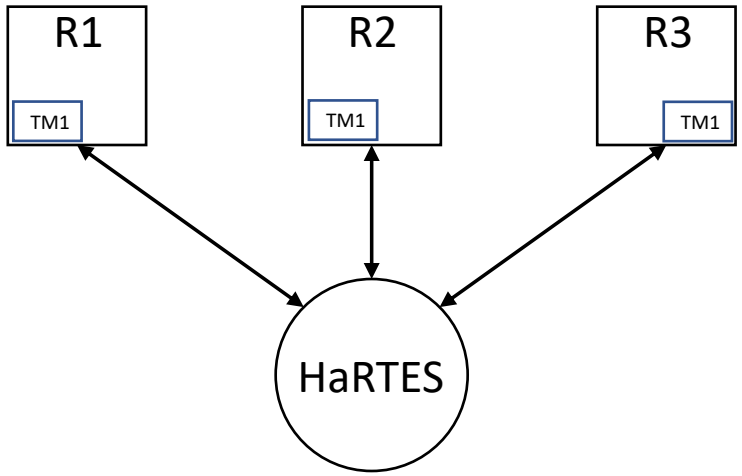

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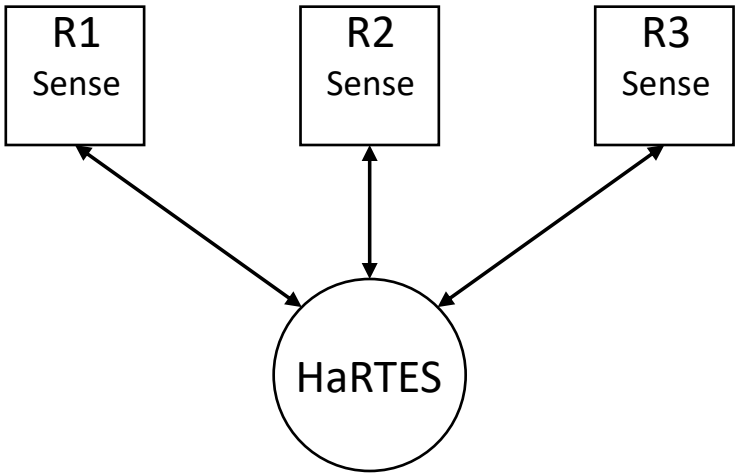

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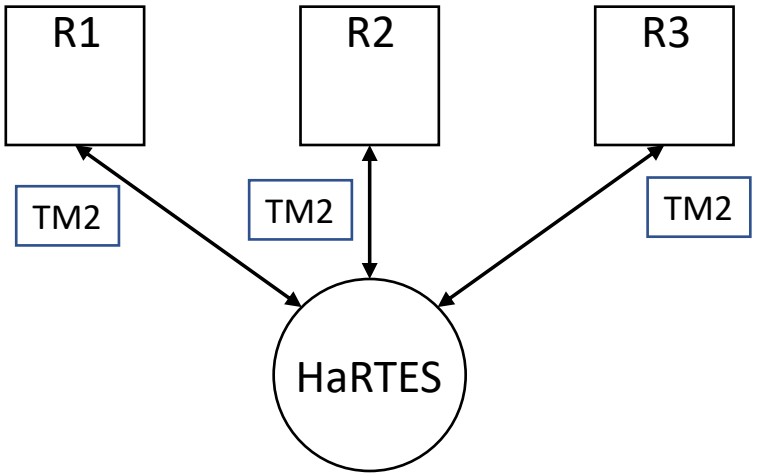

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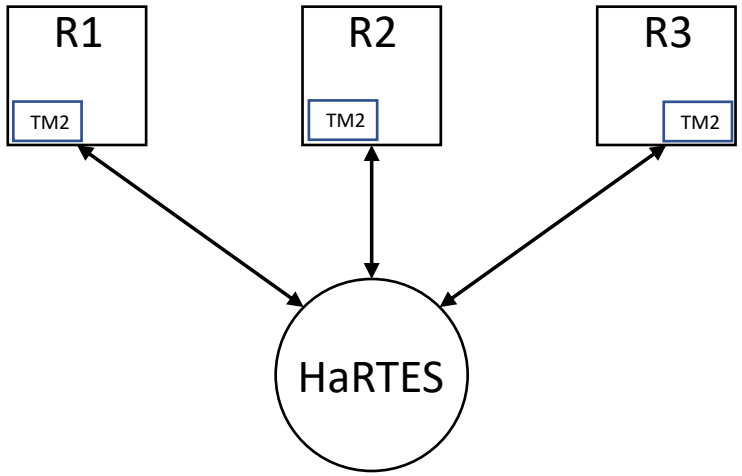

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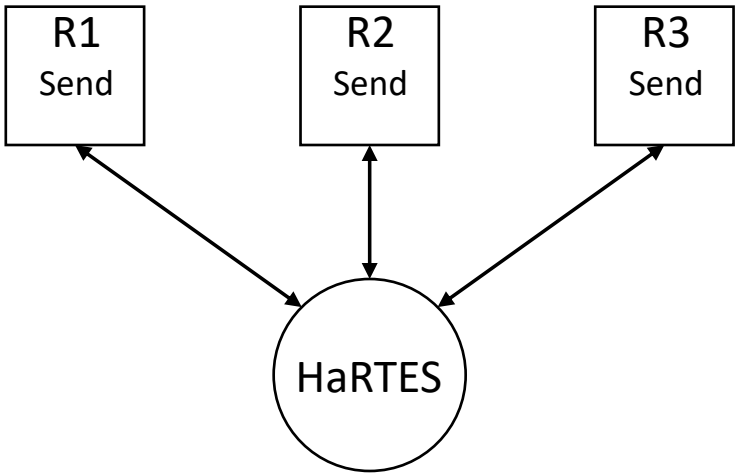

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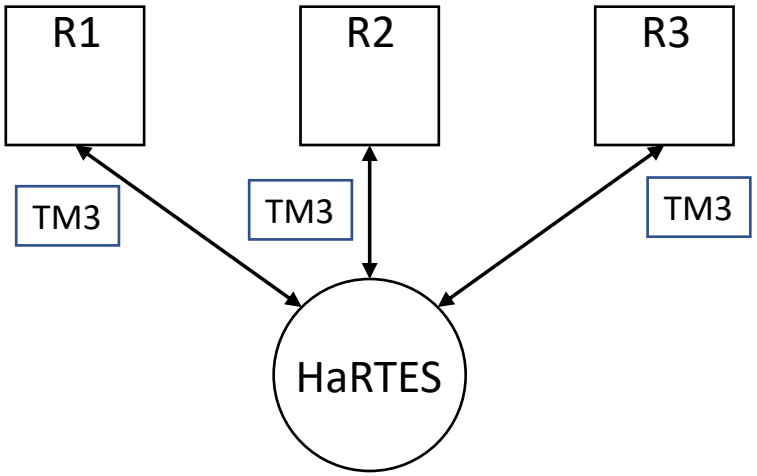

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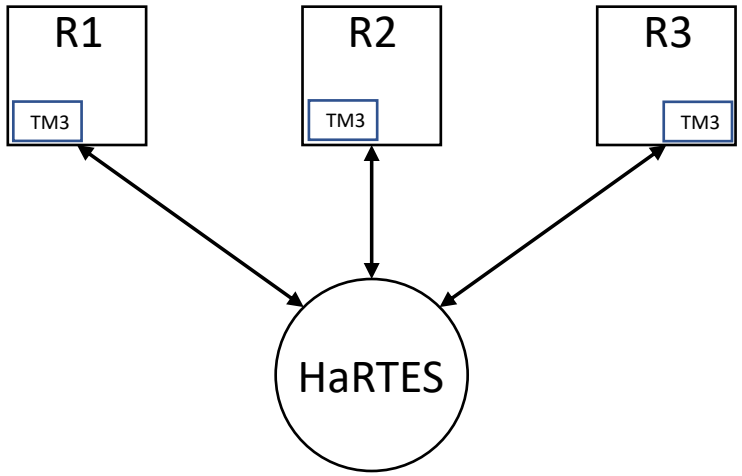

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- Can we use our node replication schemes?
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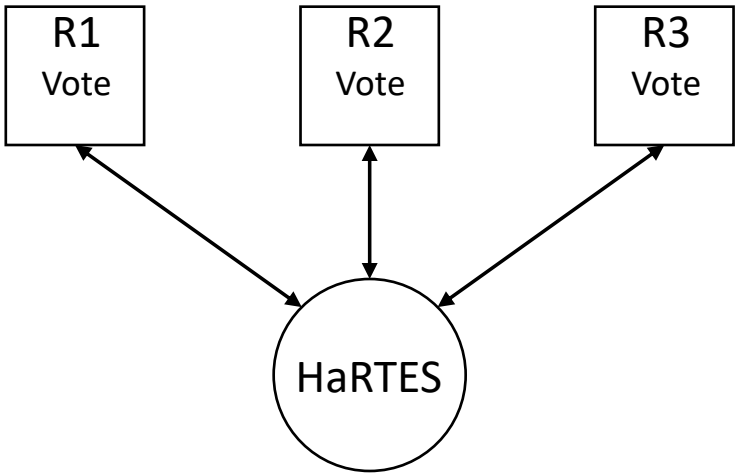

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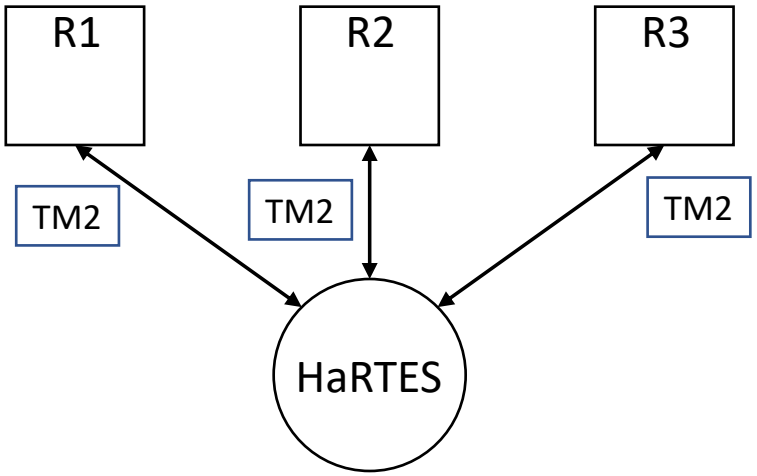

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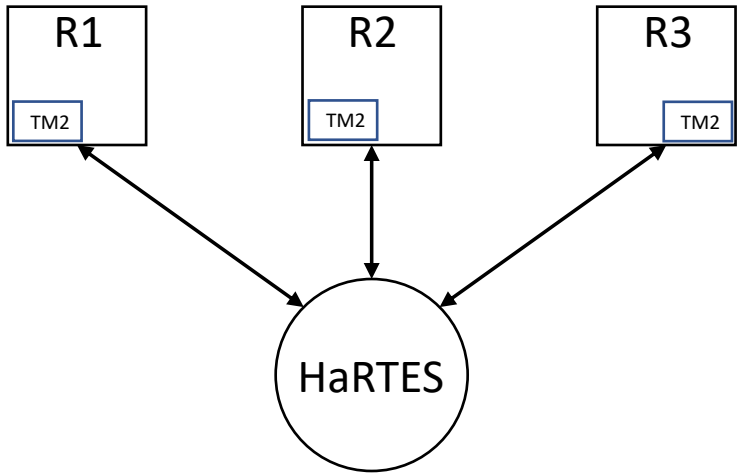

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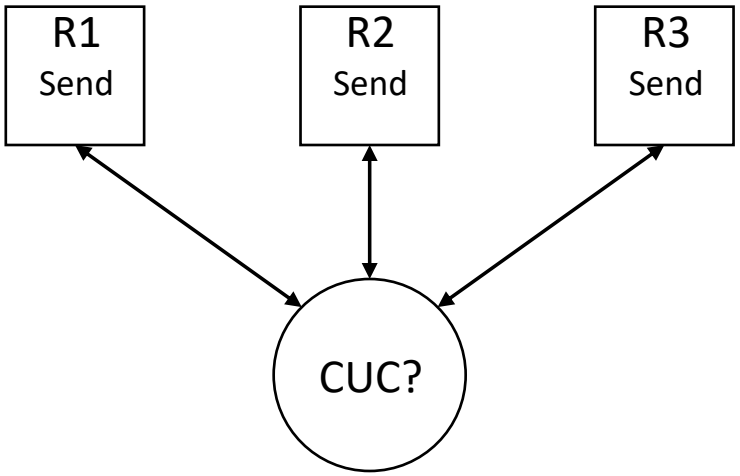

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- Dynamic fault-tolerance
  - Can we achieve dynamic fault-tolerance in the nodes?
  - Do we need to adapt Alberto's work? Can we use it as it is?
  - What about the network?
  - Manuel has been focusing on this part

Future work

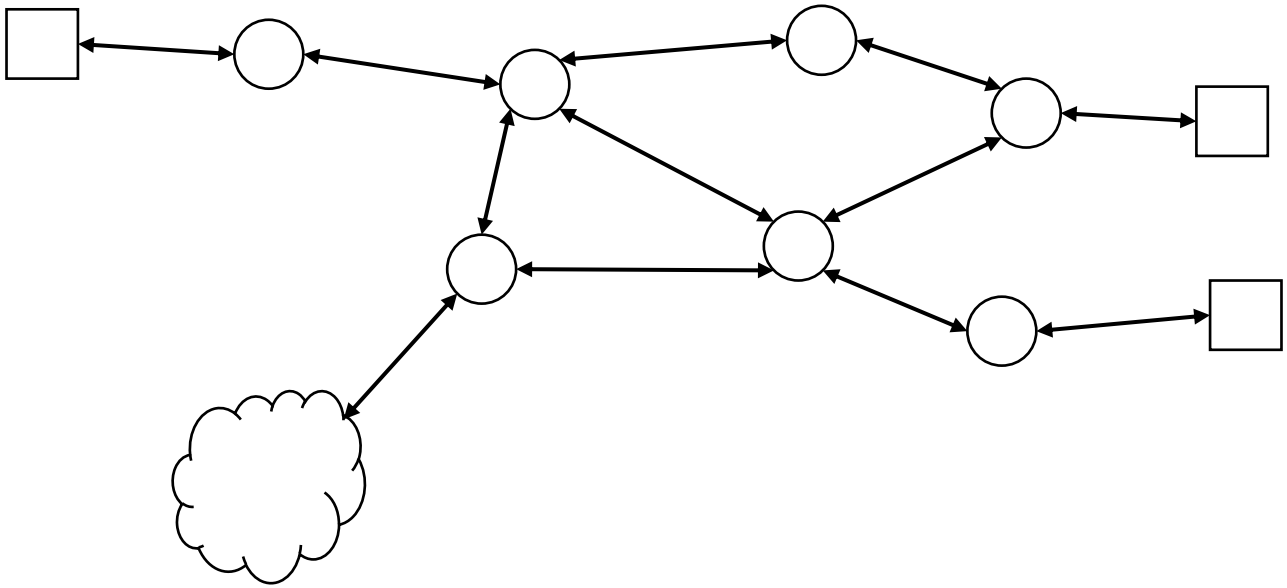
- Dynamic fault-tolerance
  - We propose the configuration to be done in the CNC
  - As part of our design, we want to gather information of the network
  - We use the replication to check the status of the links
    - Switches count the number of replicas received
    - Send information to the CNC
    - If many replicas are lost, then we maybe need increase of replicas
    - If all replicas are received, then maybe we can reduce replicas

Future work

- Dynamic fault-tolerance
  - Next work, focusing in mixed spatial and time redundancy
  - In networks that don’t require high reliability
  - Use time redundancy when spatial redundancy is not available

Future work

- Dynamic fault-tolerance



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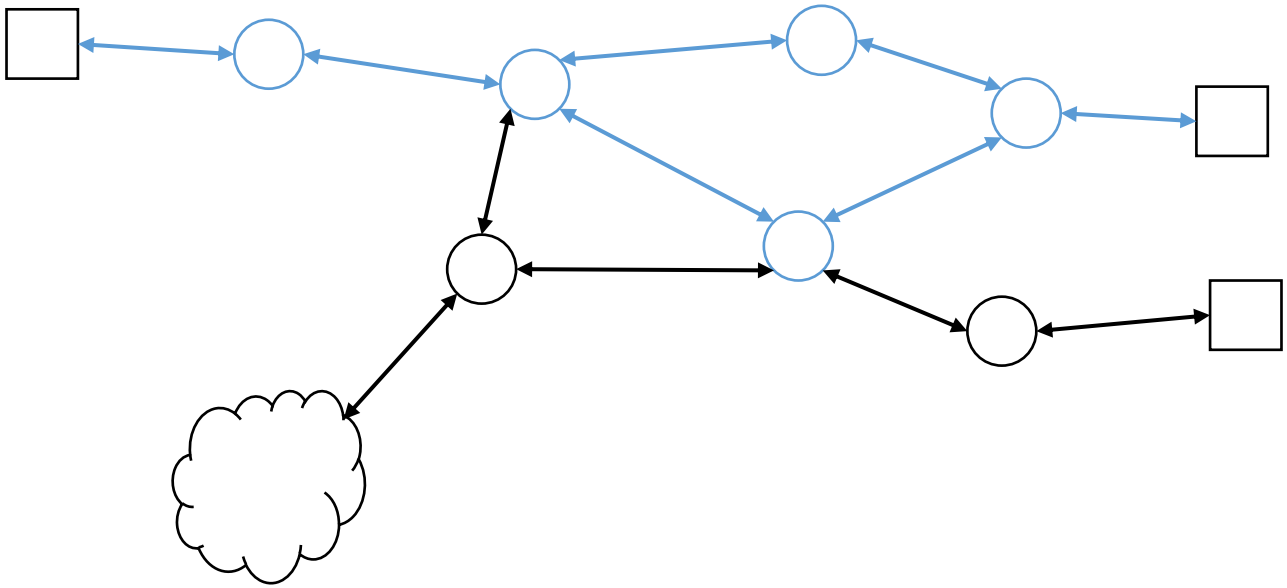

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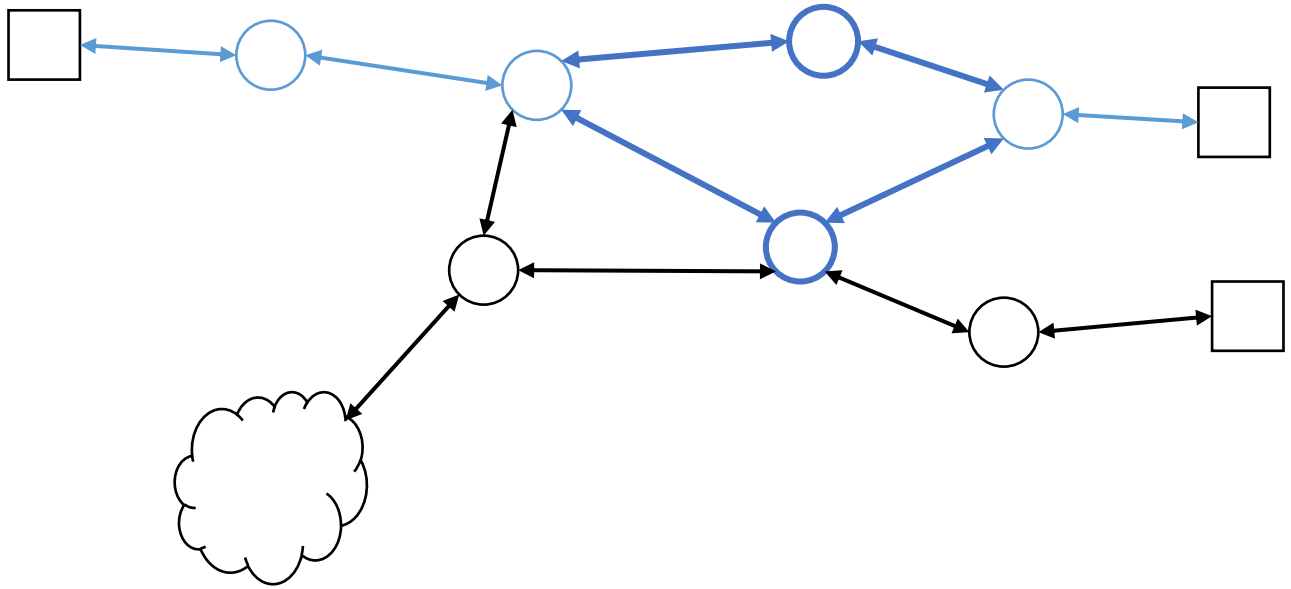

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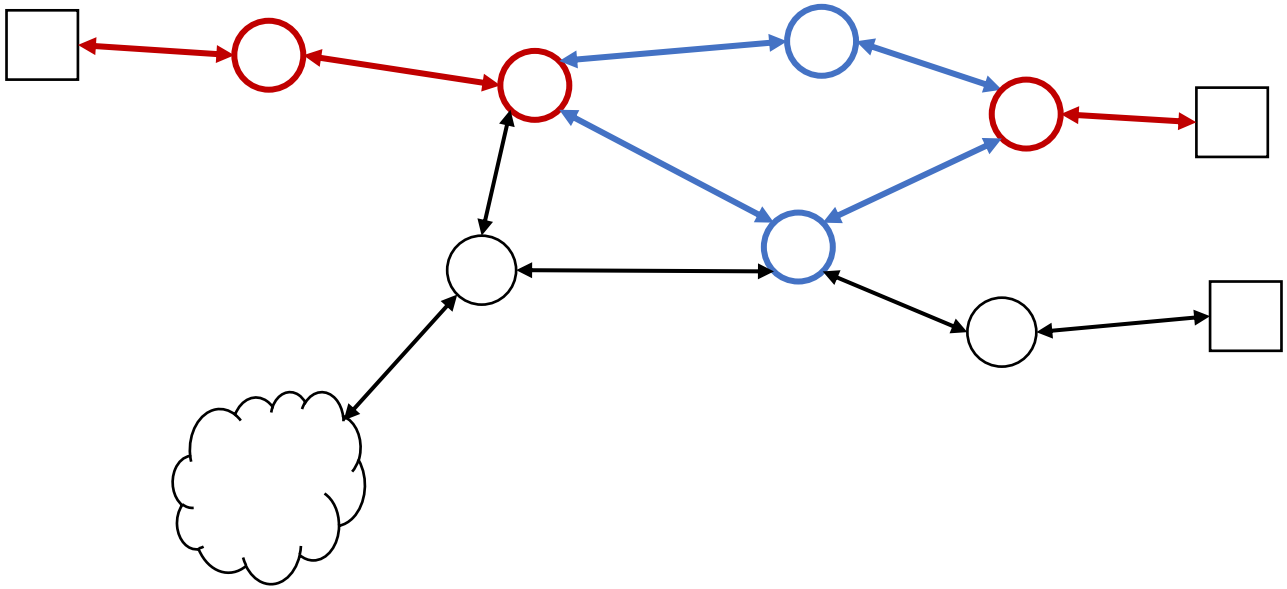

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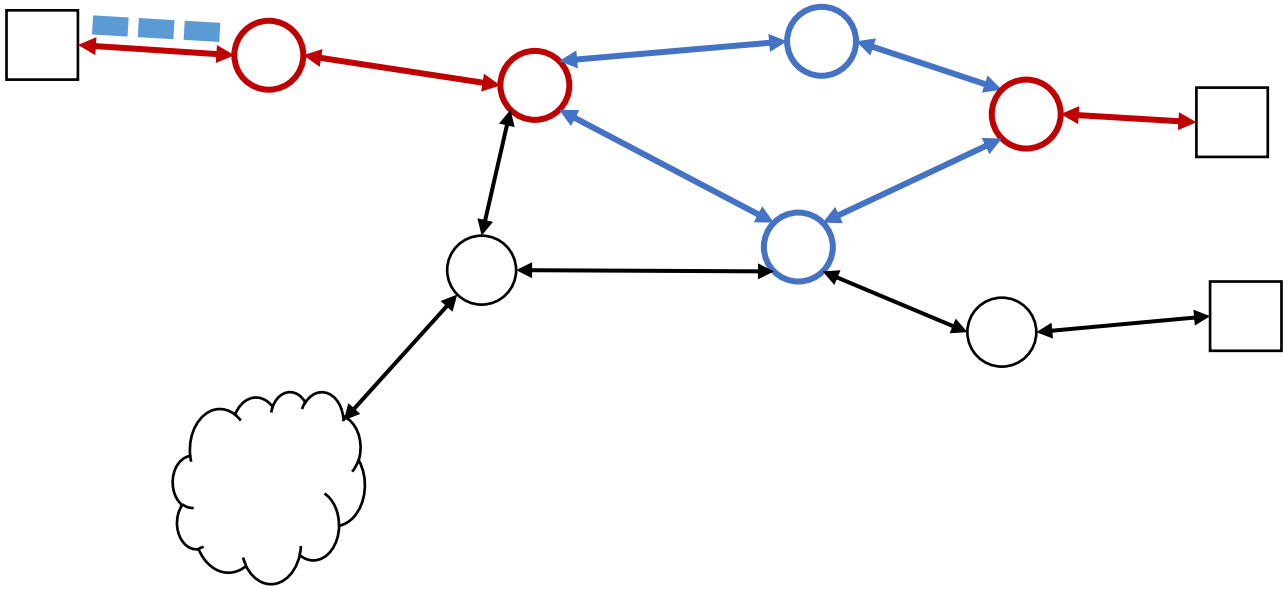

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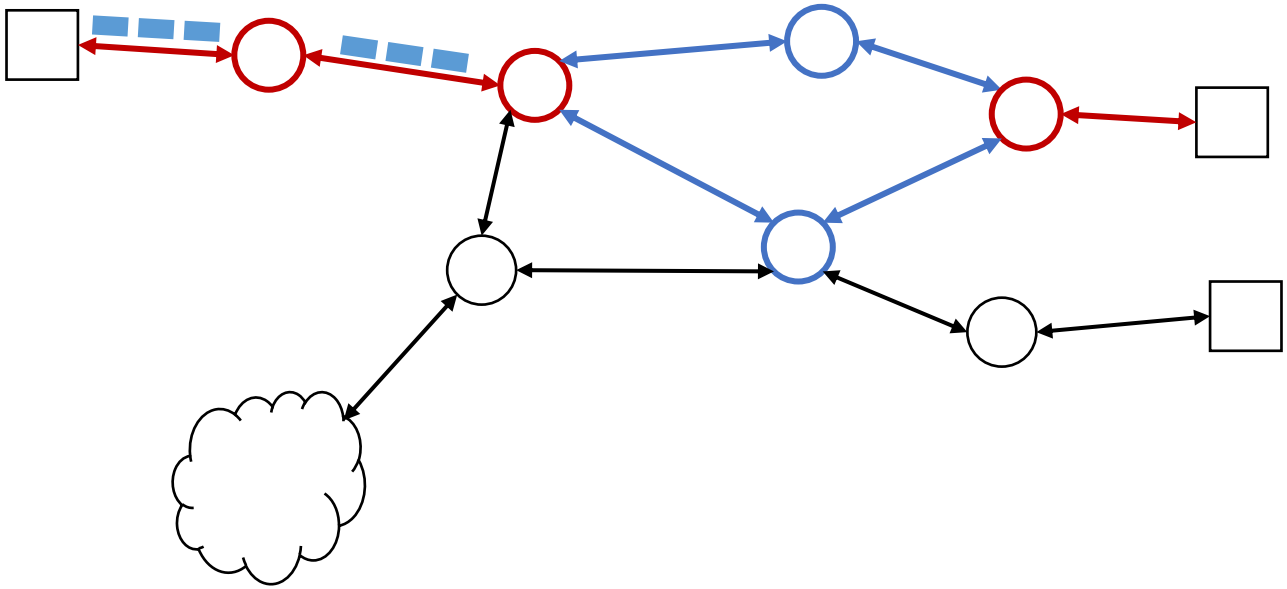

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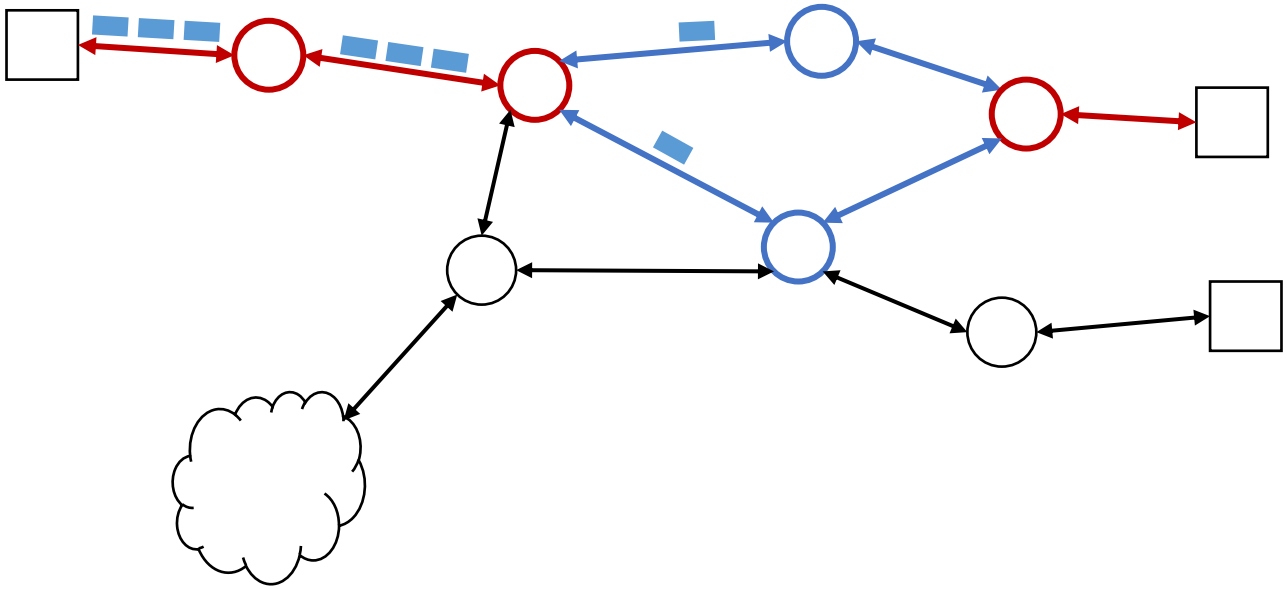

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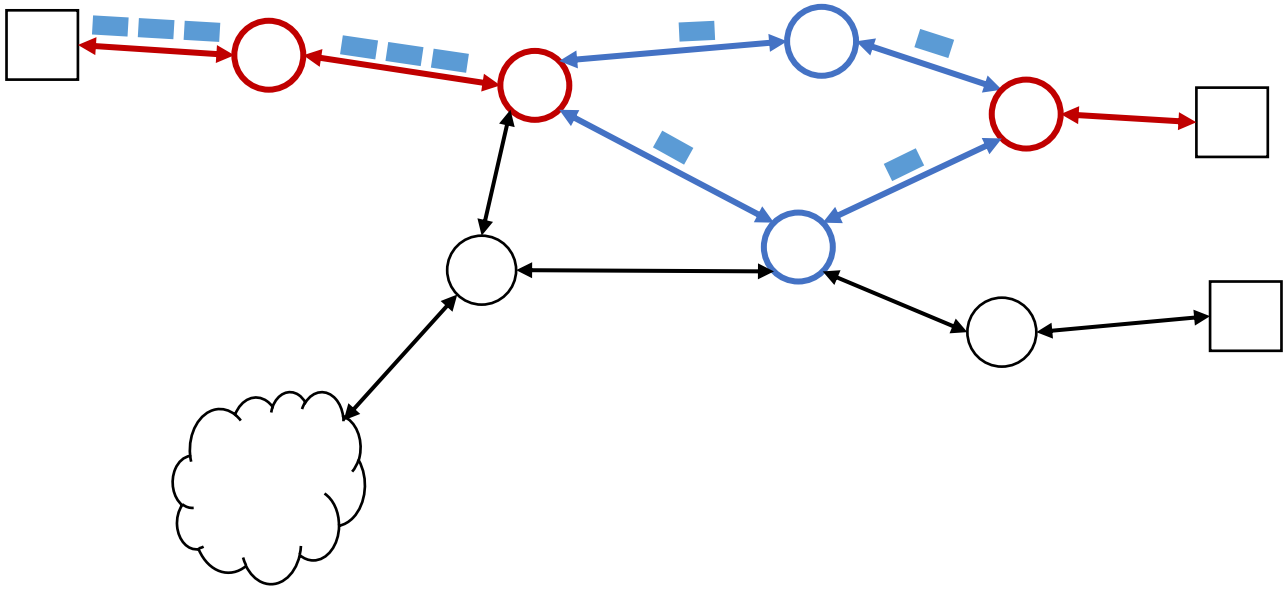

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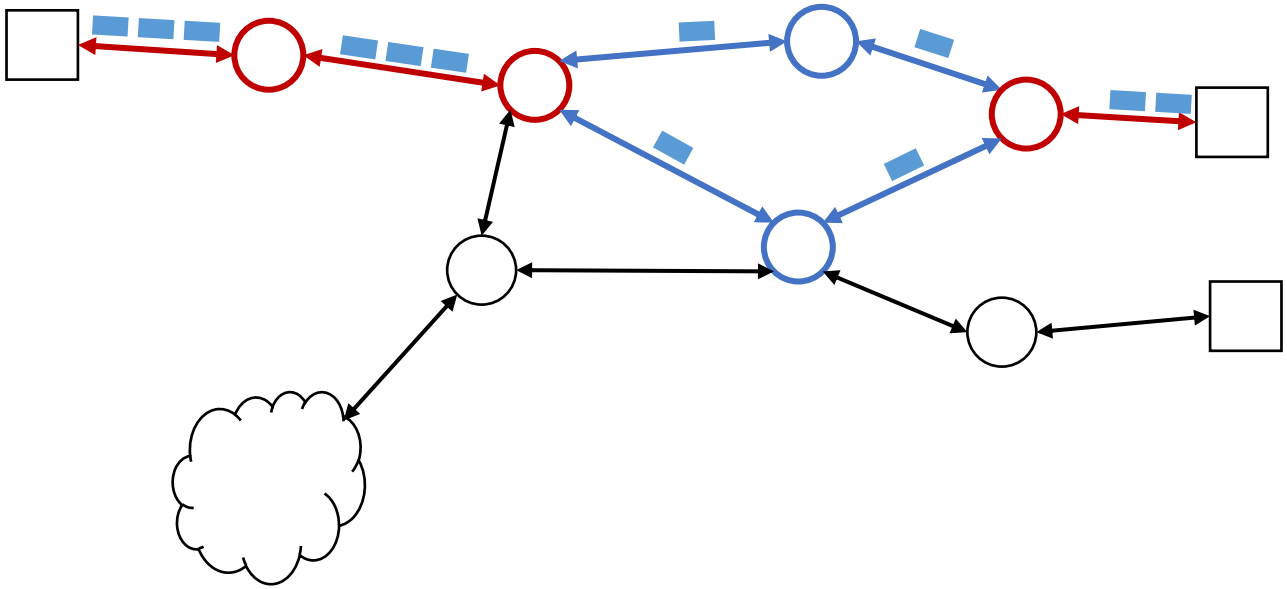

Future work

- Dynamic fault-tolerance
  - Next work, focusing in mixed spatial and time redundancy
  - In networks that don’t require high reliability
  - Use time redundancy when spatial redundancy is not available
  - So, how do we achieve this? Starting to explore…

Future work

- Try to do what we've done in FTT, now in TSN
  - Can we provide the same network services?
  - Can we use our node replication schemes?
  - Dynamic fault-tolerance
- **Increase reliability of TSN itself**
  - Vulnerabilities identified so far

Future work

- Path control and reservation for multiple paths
  - Path Computation Entities (PCE) define and paths
  - There may be multiple PCEs
  - PCEs can define more than one path
  - BUT each path is just managed by one PCE.

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  - Path Computation Entities (PCE) define and paths
  - There may be multiple PCEs
  - PCEs can define more than one path
  - BUT each path is just managed by one PCE. SPoF

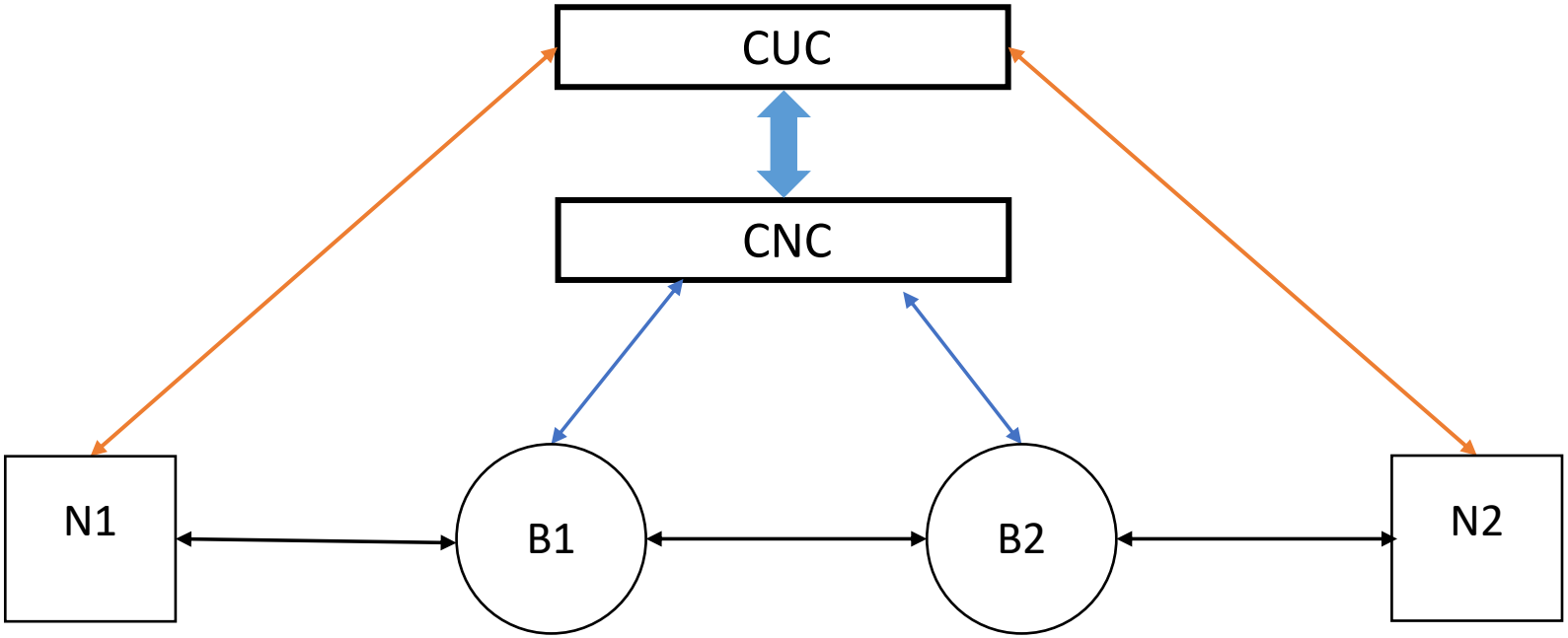
Future work

- Frame replication and elimination for reliability
  - FRER allows for frames to arrive out of order
  - How this is handled is out of the scope of TSN
  - How can this affect our work?
  - Can we take this into account when configuring to discard replicated paths?

Future work

- Stream reservation protocol
  - SRP proposes the existence of CNCs and CUCs
  - The specification is out of the scope
  - So there are many configuration options…

Future work



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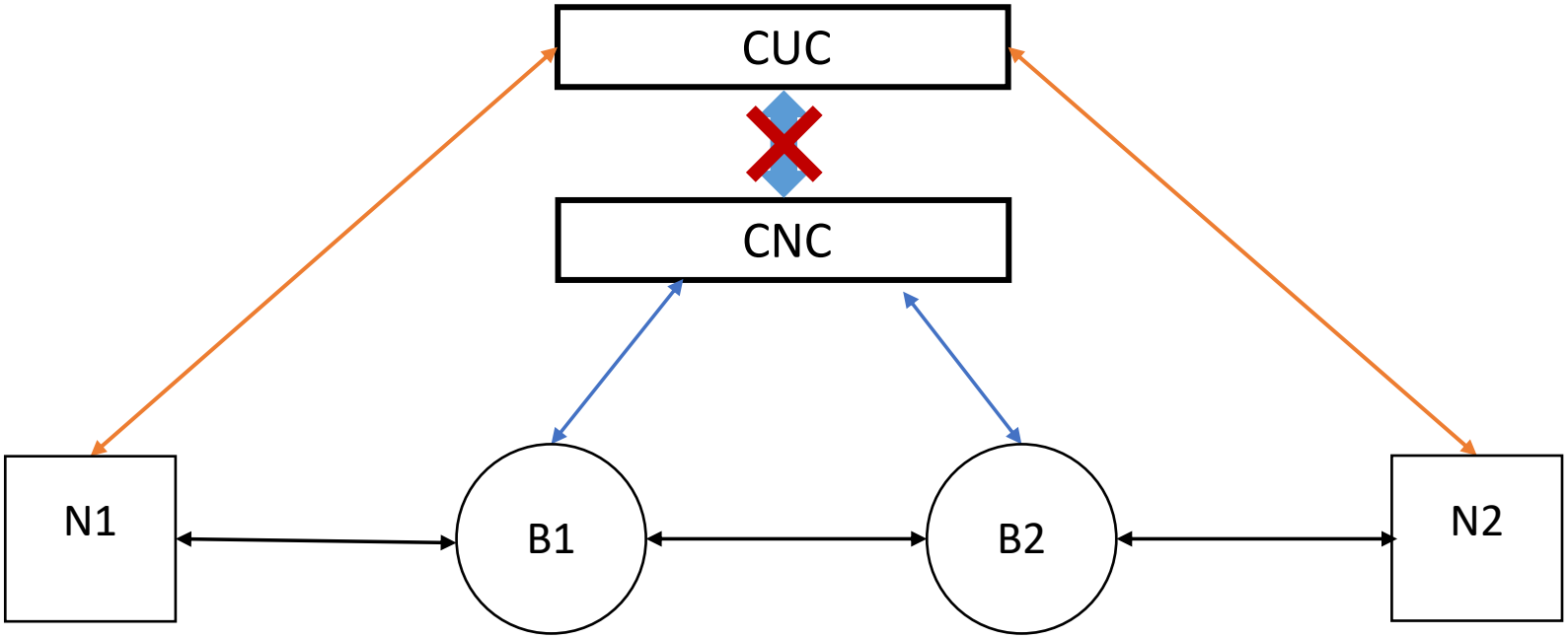

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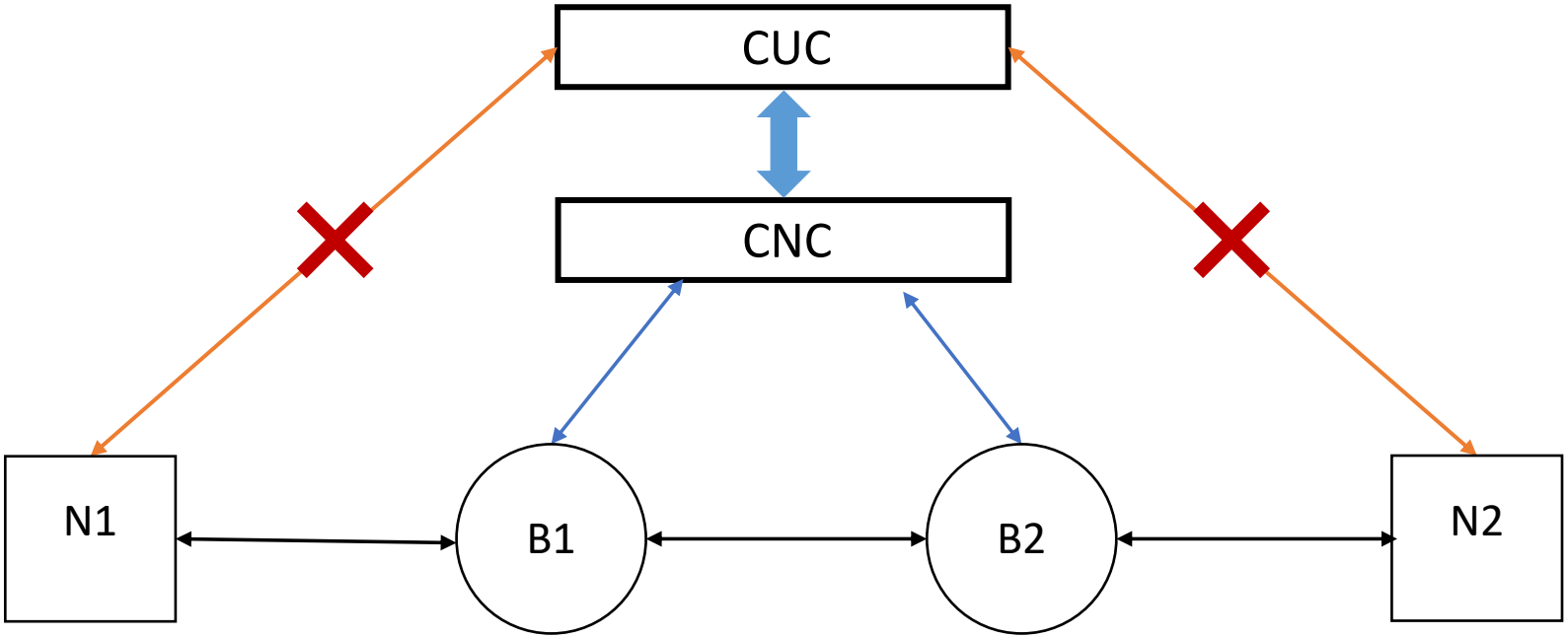

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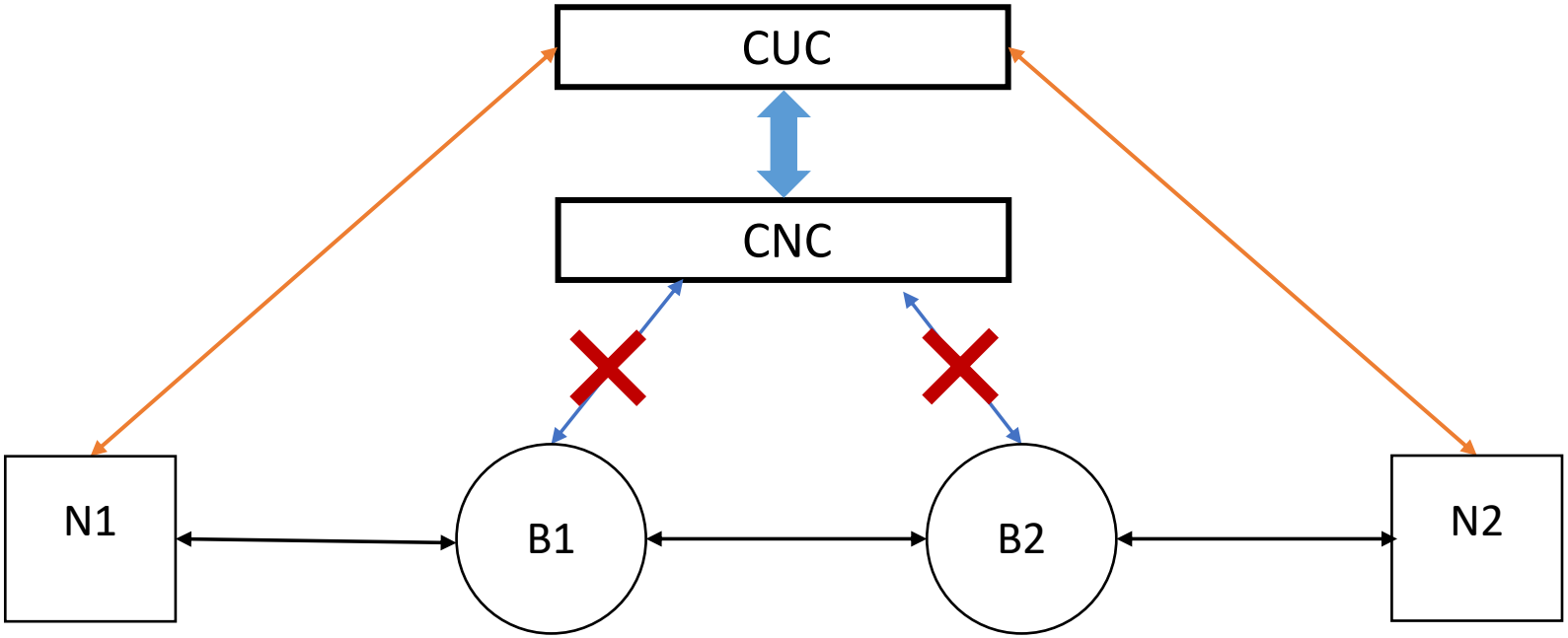

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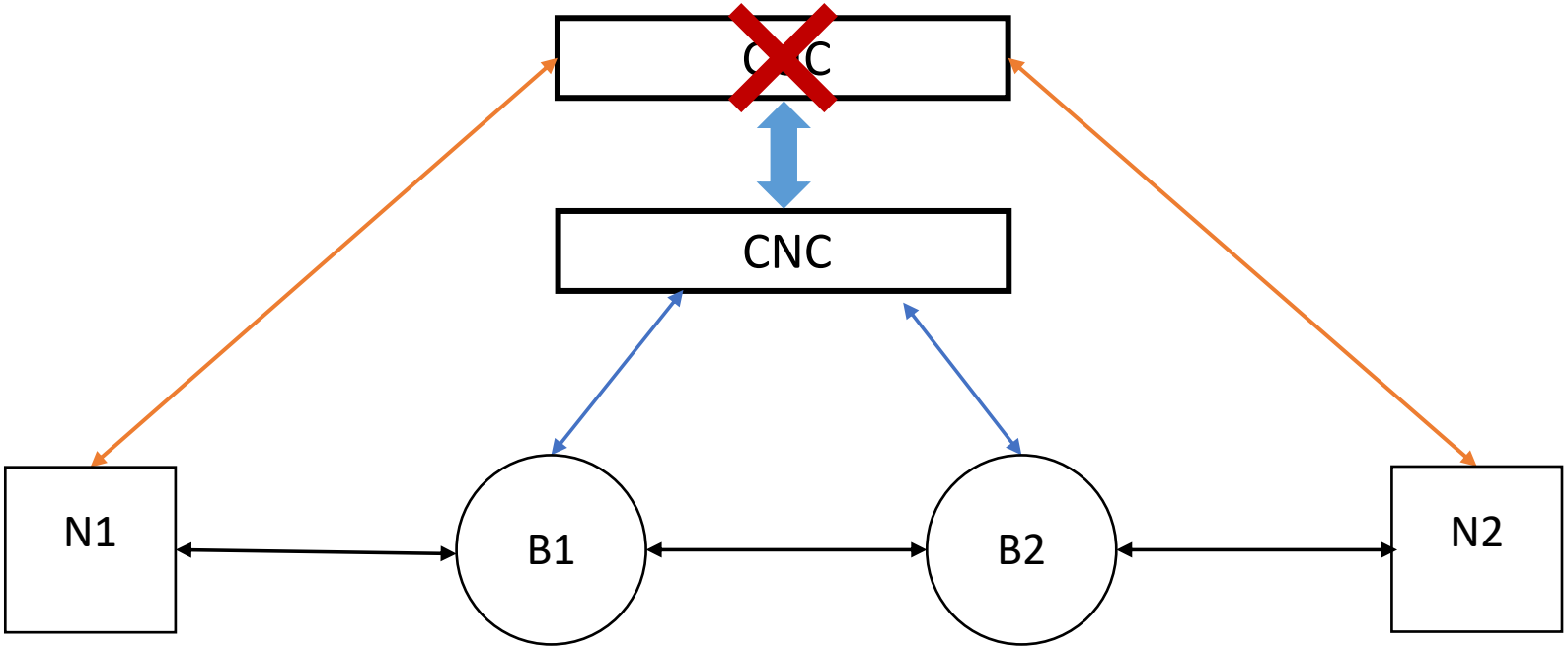

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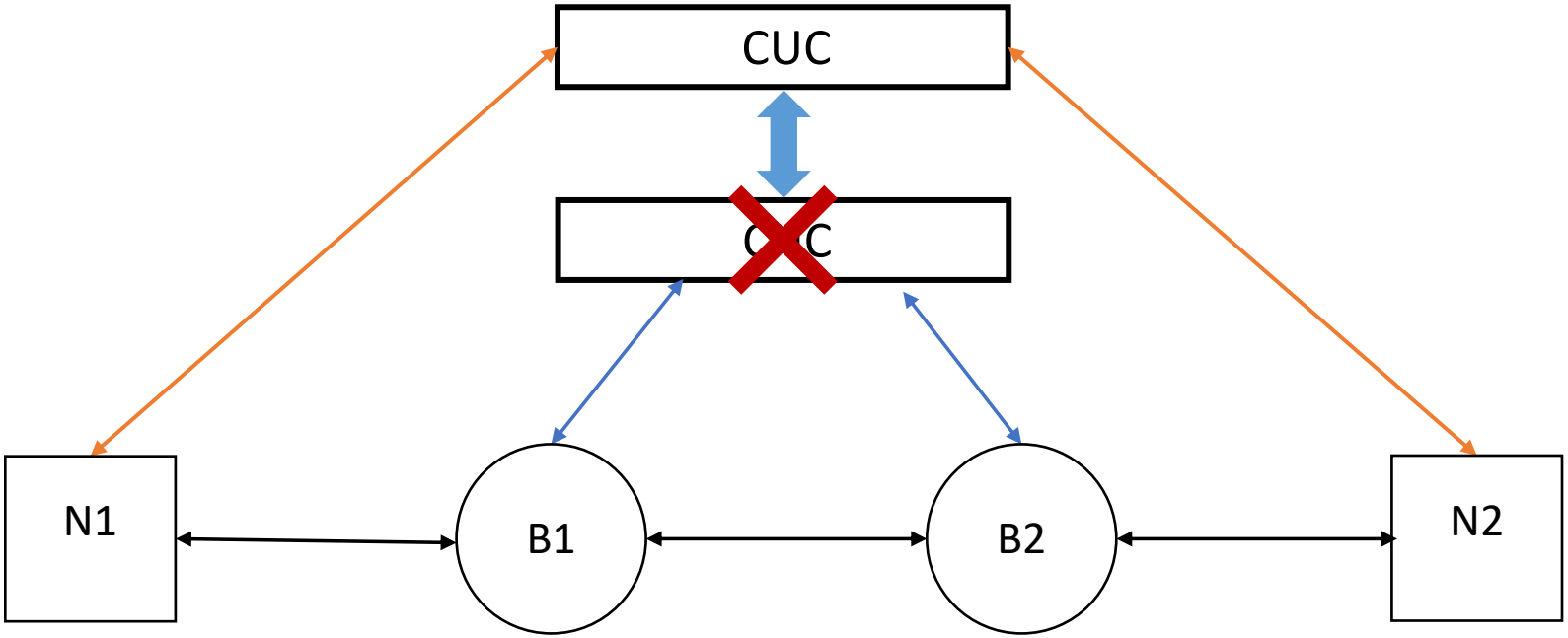

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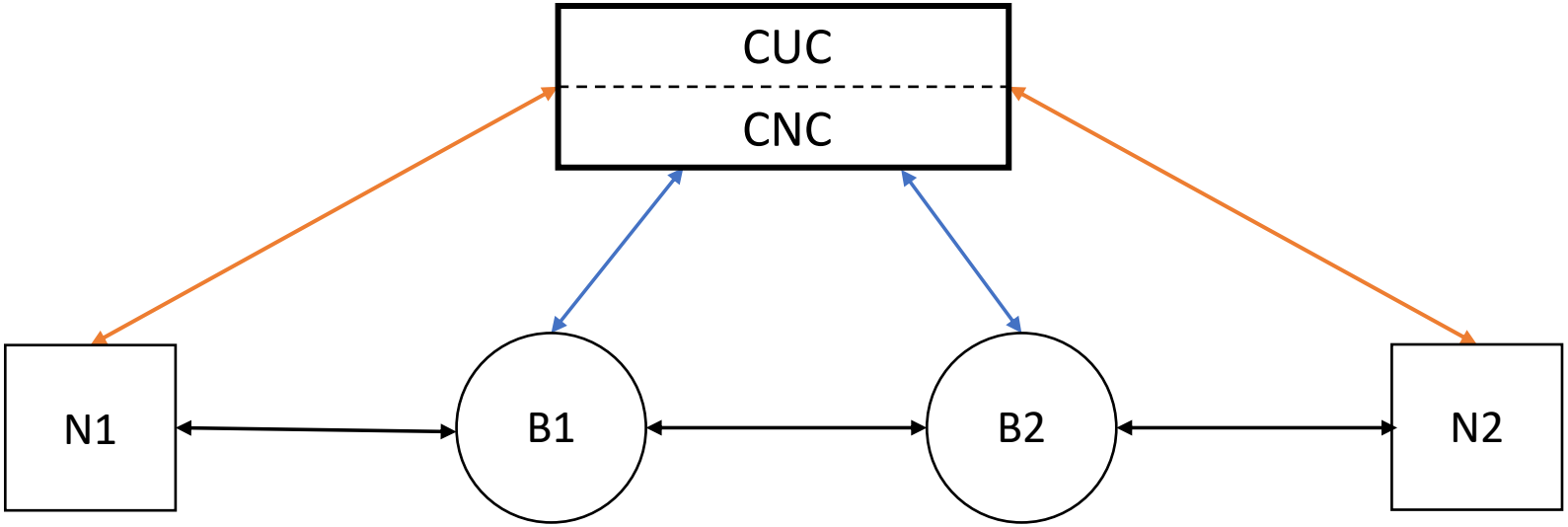

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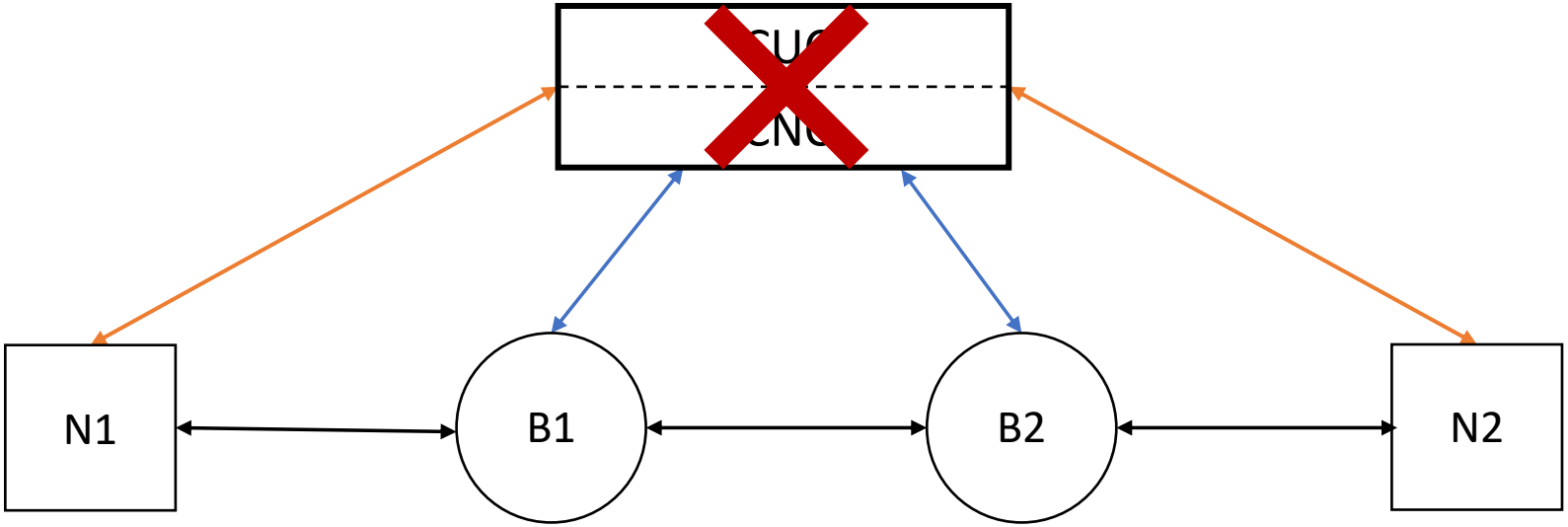

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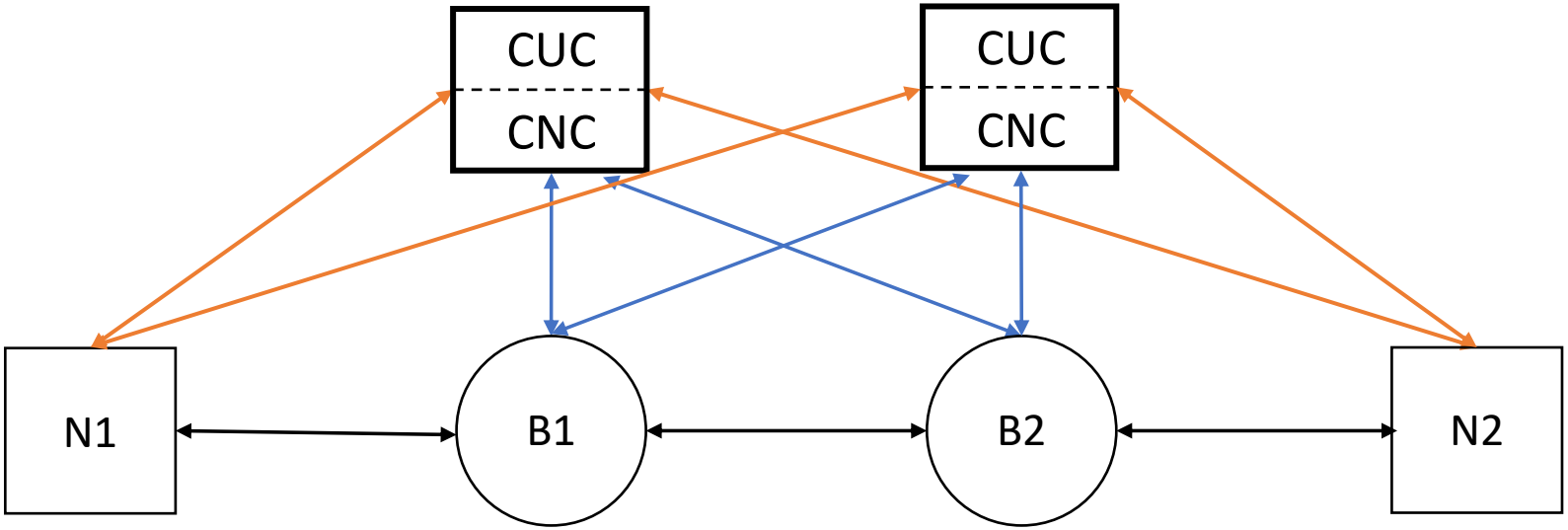

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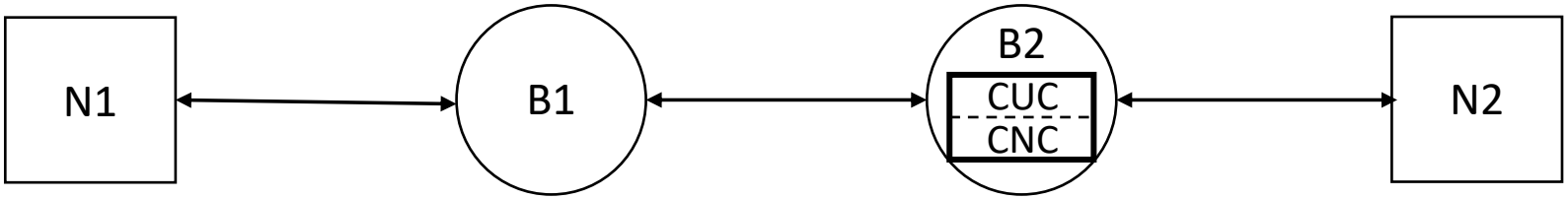

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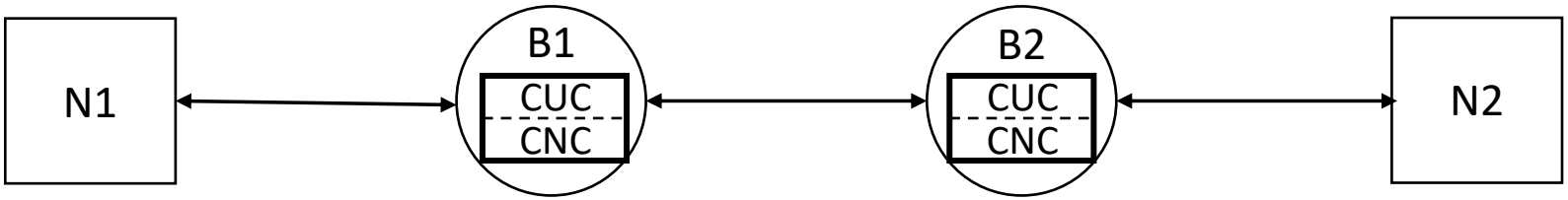

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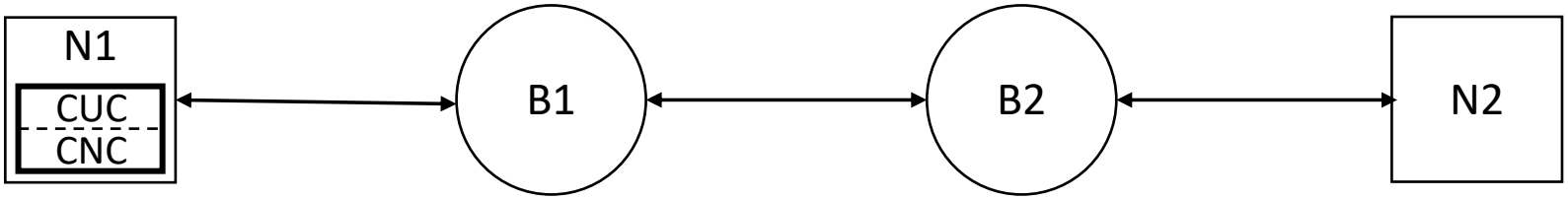

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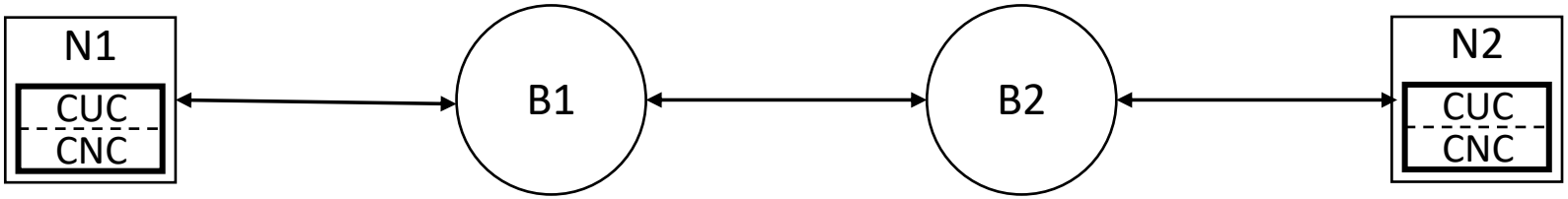

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  - SRP proposes the existence of CNCs and CUCs
  - The specification is out of the scope
  - So there are many configuration options…
  - All of these would require a dependability evaluation

Reliability in Time Sensitive Networking:

Overview, current efforts and future work

Inés Álvarez Vadillo

Universitat de les Illes Balears