XIV JORNADA DE JÓVENES INVESTIGADORES/AS DEL I3A

# TSN Incremental Routing and Scheduling through parallel MILP computation

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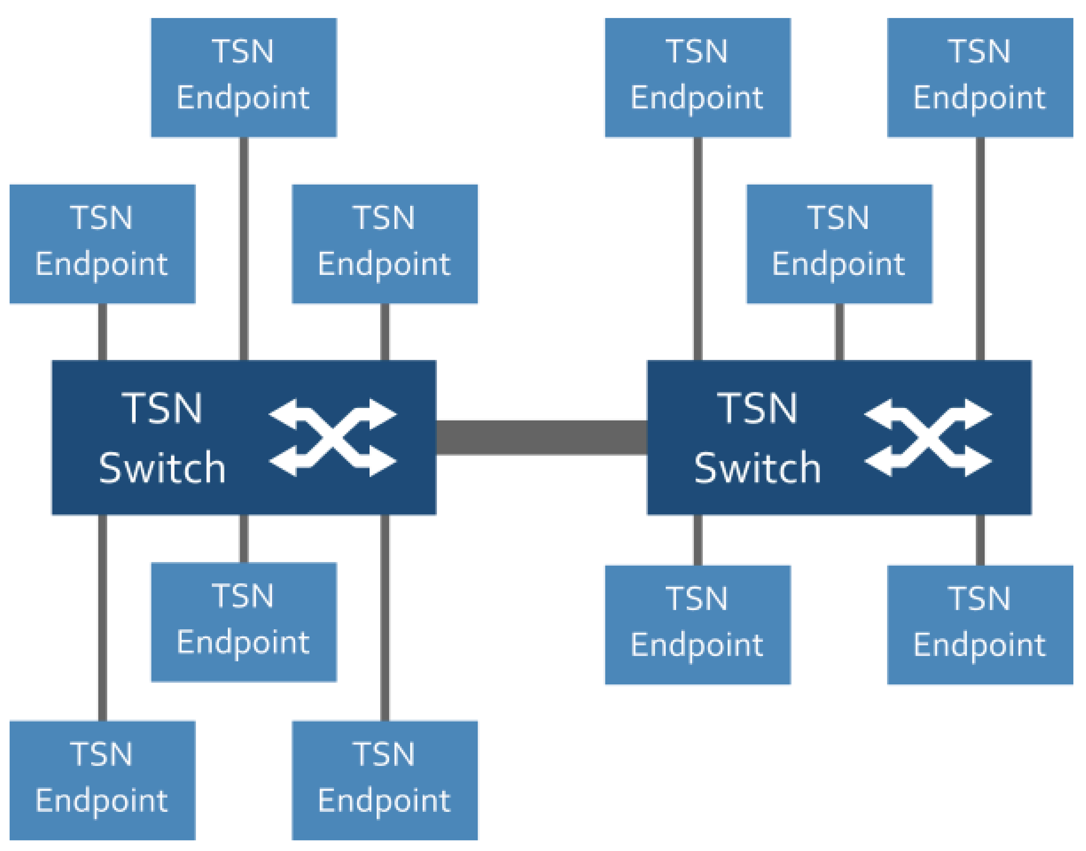
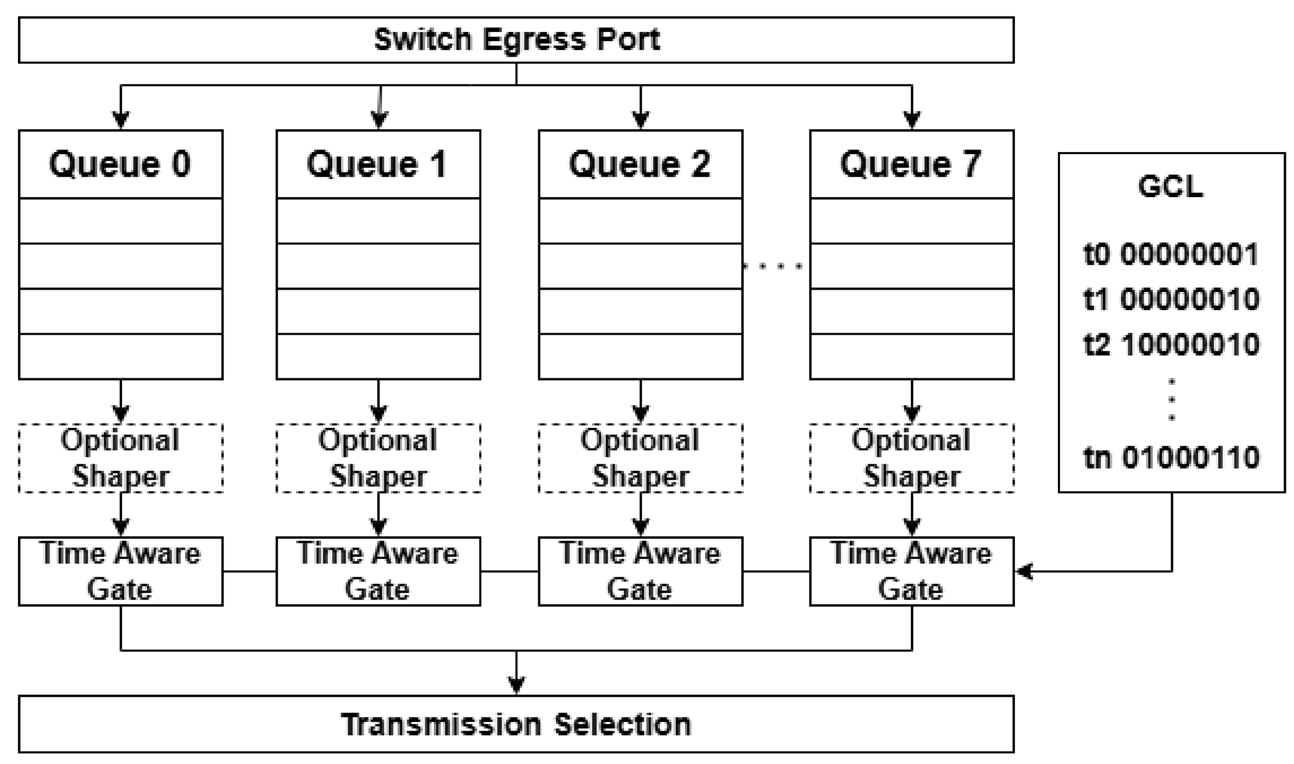
## Time Sensitive Networking

TSN is a set of IEEE standards that enables deterministic communication over Ethernet




## IEEE 802.1 QBV - Time Aware Shaper

The IEEE 802.1Qbv standard delineates a time-triggered communication paradigm, incorporating a time-aware shaper (TAS) that governs the selection of frames at egress queues of network bridges in accordance with a predetermined schedule.

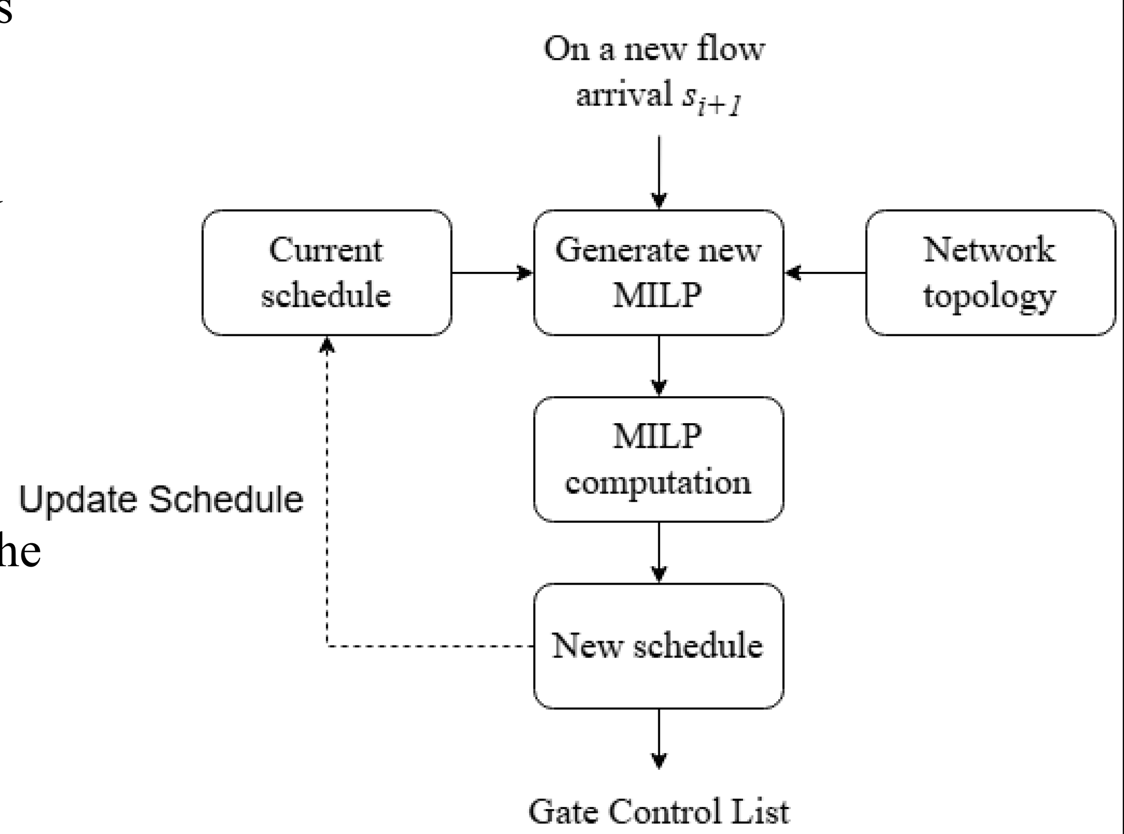



Scheduling a stream in the TSN network means optimizing the timing of its frames for the best path, and setting Gate Control List (GCL) accordingly

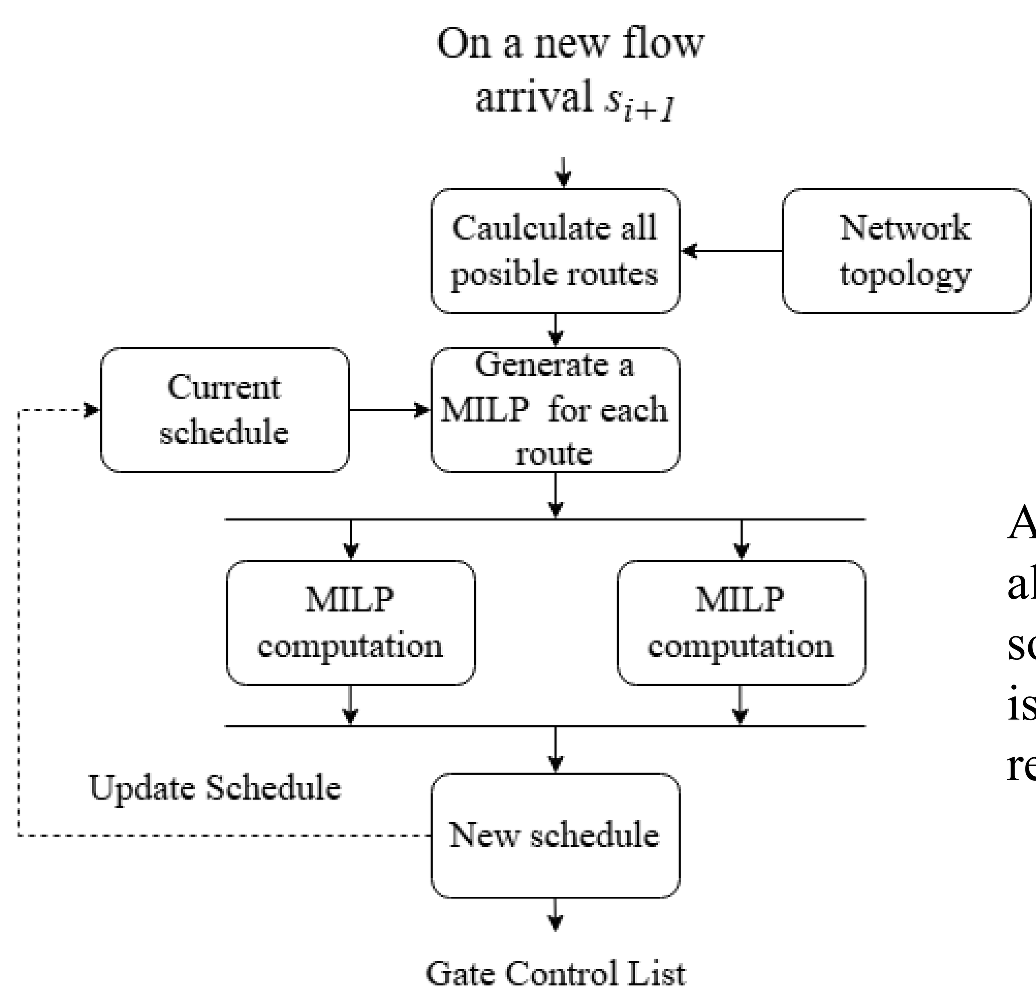
**GCL SCHEDULE IS A NP COMPLETE PROBLEM WITH HIGH COMPUTATIONAL DEMANDS!!!**

## Monolithic MILP Solution

A MILP model based on [1] is constructed to schedule all frames of a single stream across all possible routes, and then selects the best schedule among the candidate paths. Once a stream has been scheduled, a new model is generated for the subsequent streams, taking into account the remaining network resources.

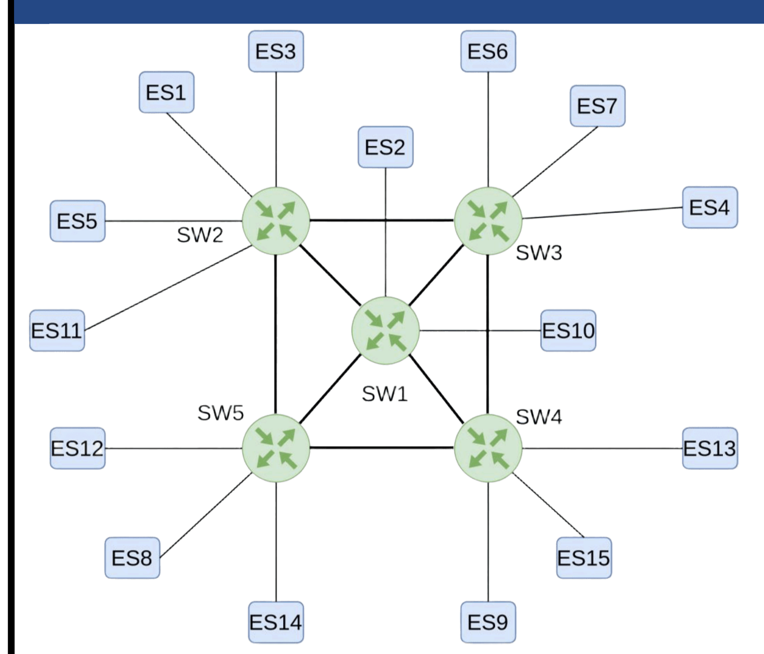



## Parallel MILP Solution




A MILP model is generated from all the candiadate paths and solved in parallel. The final path is selected based on the computed results.

## TSN Avionics Use Case




Avionics TSN use case provided by Thales [2].

- 241 Streams
- From 1 to 32 frames per stream

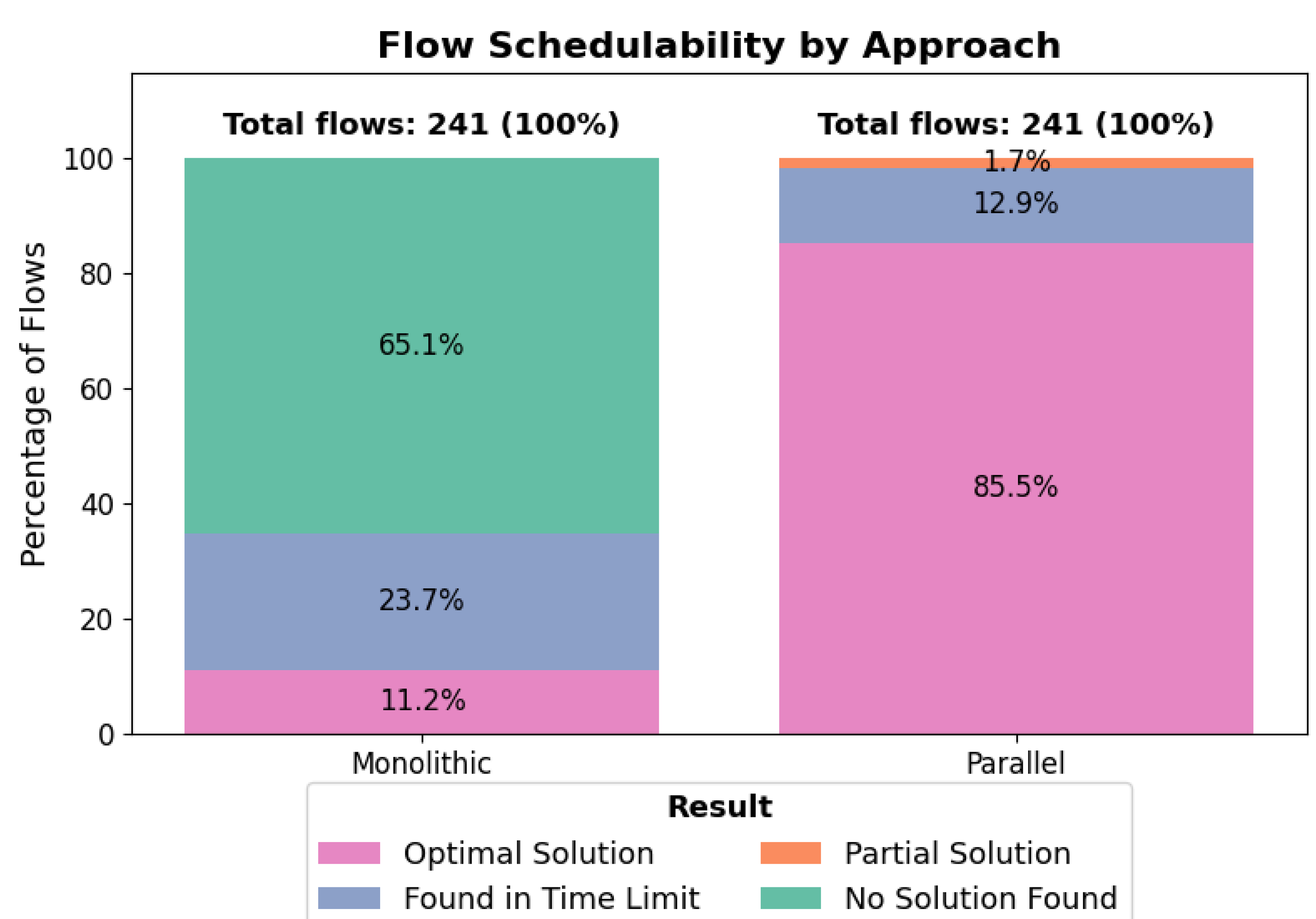
## Evaluation Methodology

- The experiments are conducted on an Intel® Xeon® Gold 5120 CPU running at 2.20 GHz, with 56 cores (Skylake architecture)

- MILP models are solved using the CBC solver [3], version 2.10.12.

- A one-hour timeout is set for solving the MILP model in the first approach. In the second approach, this time is evenly divided among the individual tasks.

## Evaluation Results




Monolithic model falls short in complex cases.

Parallel model reaches the optimal schedule in 85.5% of the cases.

[1] A.G. Torres-Macías et al. Optimal and Fast IEEE 802.1Qbv Incremental Scheduling. Under Review, 2025.
[2] Marc Boyer and Rafik Henia. Industrial challenge: Embedded reconfiguration of TSN. working paper or preprint, July 2024.
[3] COIN-OR. CBC: COIN-OR Branch and Cut (Version 2.10.12) [software]. August 2024. DOI: 10.5281/zenodo.13347261

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