# Reliability Estimation of Adaptive Distributed Embedded Systems Using GATs

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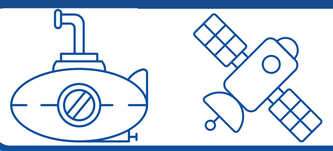
## A system with these qualities can be defined as an ADES:

**Distributed**
Made up of multiple components that communicate and share information.

**Embedded**
Integrated into a larger system to perform specific functions.

**Adaptive**
Able to adjust and reorganize itself by managing its components.

## Use Cases for ADES



Unpredictable Environments

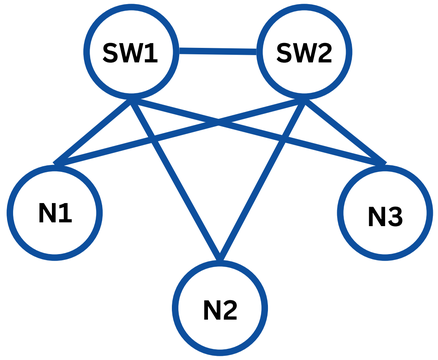
## How are ADES represented in our project?

As fully connected graphs

**Switches (SW)**
Coordinate node communication.

**Nodes (N)**
Execute designated functions and communicate output to switches.

**Links**
Physical connections between components.




## Problems with ADES

**Any component may fail unexpectedly.** While the system's adaptive nature **allows reconfigurations** to address this, it introduces a new problem: **each reconfiguration requires a reliability re-estimation.**

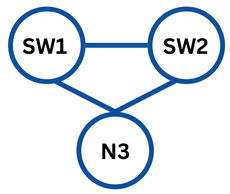
The time required for this makes them **impractical for critical scenarios**, as a new configuration cannot be applied **without ensuring it meets the system's reliability requirements.**

## Project Motivation

Explore machine learning solutions to estimate the reliability of ADES faster than traditional methods.

## Dataset

The dataset comprises an initial fully connected graph (3SW/5N) and **all possible degraded configurations.** Every data entry has an adjacency matrix, timestamp, and reliability value. There are **86,760 entries** in the range of 0 to 8500 hours.



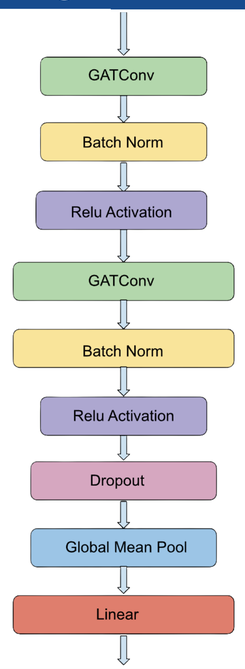

*Degraded Graph at 1000 hours*

## Vertex Features


**Centrality Measures**
**K-core number**
**Degree**
**Mean Failure rate of neighboring vertices**
**Count per vertex type**

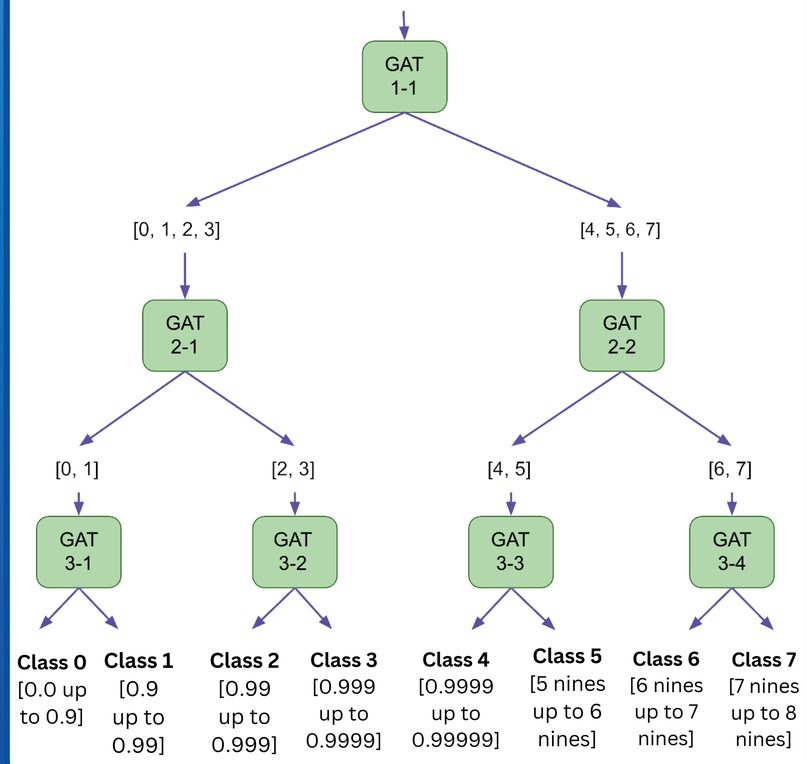
The following values were added to each vertex of the graph. They were selected based on their high correlation to the target variable out of 20 features.

## Single GAT Model

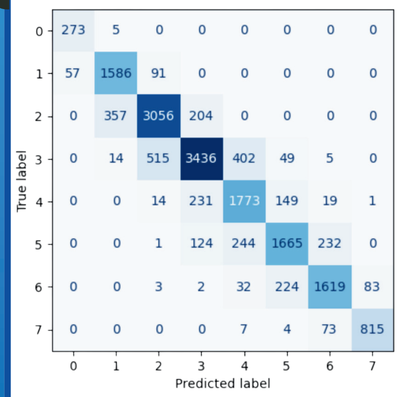



## Model Architecture

Each sample was assigned a class based on the number of 9's in its reliability value. Seven binary classification Graph Attention Networks (GAT) were arranged in a binary tree composition. The ensemble allows the model to narrow down the reliability class, with each level of the tree handling a more refined classification task.

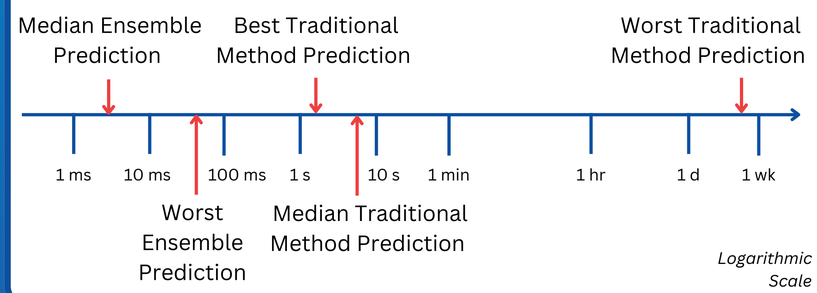



## Model Evaluation




The matrix on the left shows the model got **82%** of samples correct, with only **1.8%** more than one class off.

The plot below compares the inference times of the ensemble and traditional methods. Our model is **several orders of magnitude faster**.




*Logarithmic Scale*

## Conclusion

The inference time of our model was, on average, **three orders of magnitude quicker** than conventional methods. The reliability estimation based on a graph and a timestamp achieved an **accuracy of 82%.** This supports the notion that Graph Attention Networks **(GATs) can be effectively utilized in this area of research.**