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The Center for Education and Research in Information Assurance and Security

2024 – NS – V1F-KLD – Leo: Online ML-based Anomaly Detection at Multi-Terabit Line Rate – jafri3@purdue.edu – Syed Usman Jafri

Leo: Online ML-based Anomaly Detection at Multi-Terabit Line Rate

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Motivation

Context: ML-based anomaly detection

- Intrusion detection and prevention
- Application and IoT device classification

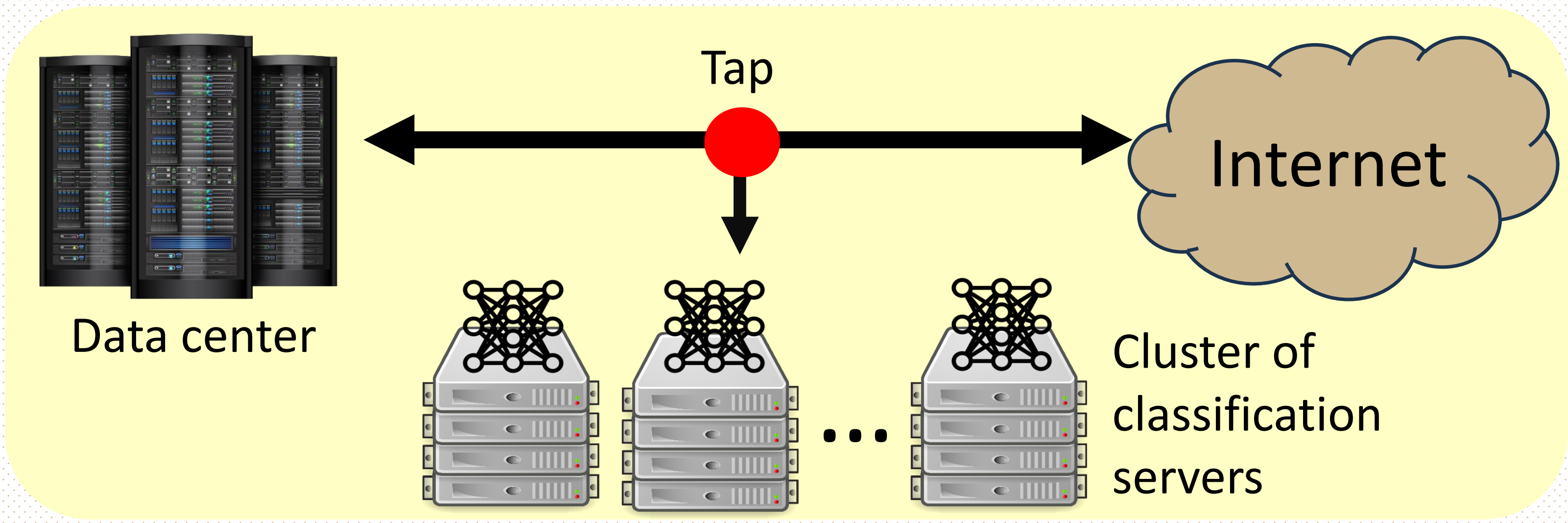
Why machine learning?

- Captures behavioral and statistical patterns
- Learn complex patterns w/o payload inspection
  → Useful for encrypted traffic

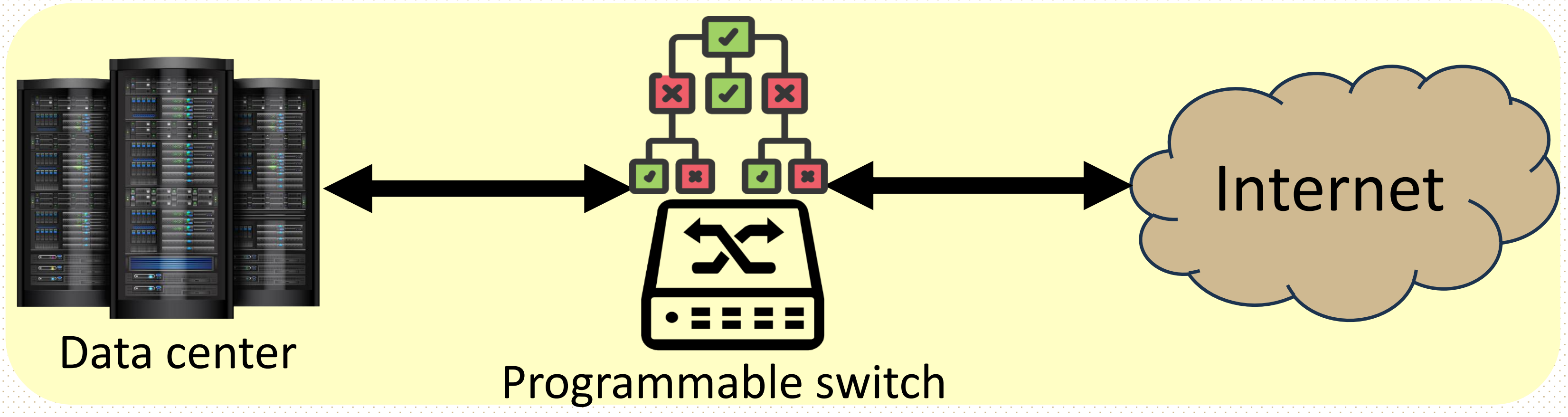
Why in-network anomaly detection?

- Today's networks: Tbps / 100s of Gbps
- Servers can only handle few Gbps
- Programmable switches offer new opportunities
  → Multi-terabit execution of user programs

Traditionally:



Our goal:



Challenges with programmable switches

- Not run-time programmable
  - Program changes → Reboot (downtime)
- No support for mul./div. and floating points
- Limited computation and memory resources

Why decision trees?

- Good match for programmable switches
- No multiplication/division required
- Easily interpretable and high accuracy

Limitations of prior work:

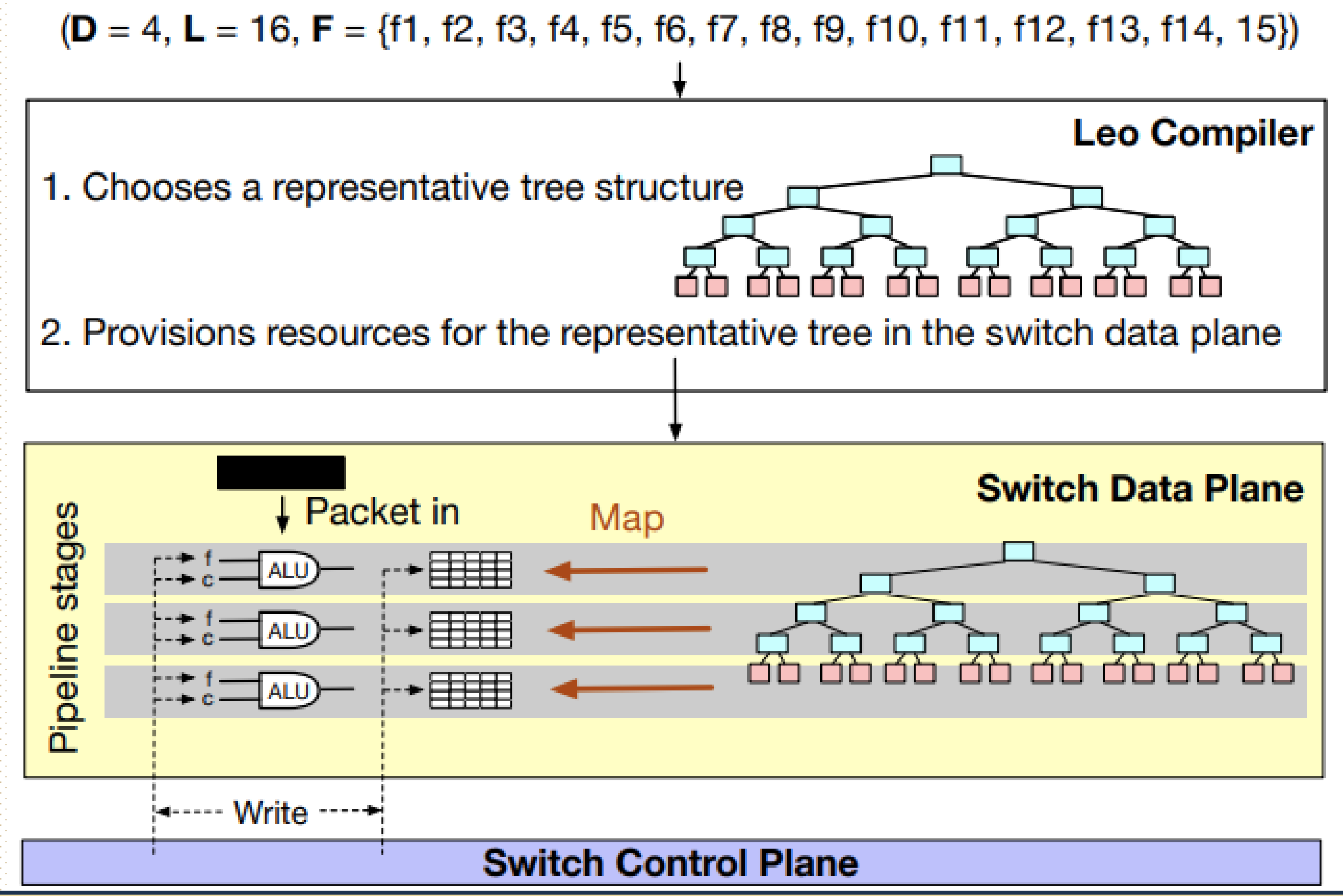
	Runtime Prog.	Not limited by tree dependency	Implementable in ASIC switch	Low ALU usage	Low memory usage
Infocom			✓		✓
pForest	✓			✓	✓
SwitchTree	✓			✓	✓
IIsy	✓	✓	✓	✓	
Leo	✓	✓	✓	✓	✓

Limitations of prior work

- Not run-time programmable
- Limited tree depth
- Expensive memory requirement

Our solution: Leo

- **Support a class of decision trees:**
  - ✓ Run-time programmable
  - ✓ Resource efficient
  - ✓ Large models supported
  - ✓ Multi tera-bit line rate


(D = 4, L = 16, F = {f1, f2, f3, f4, f5, f6, f7, f8, f9, f10, f11, f12, f13, f14, 15})
Leo Compiler
1. Chooses a representative tree structure
2. Provisions resources for the representative tree in the switch data plane
Switch Data Plane
Packet in
Map
Pipeline stages
f
c
ALU
Write
Switch Control Plane

Design

Enabling run-time programmability

- ***Multiplexed ALU:*** different (feature, constraint) pairs populated to the same ALU

Resource efficient mapping

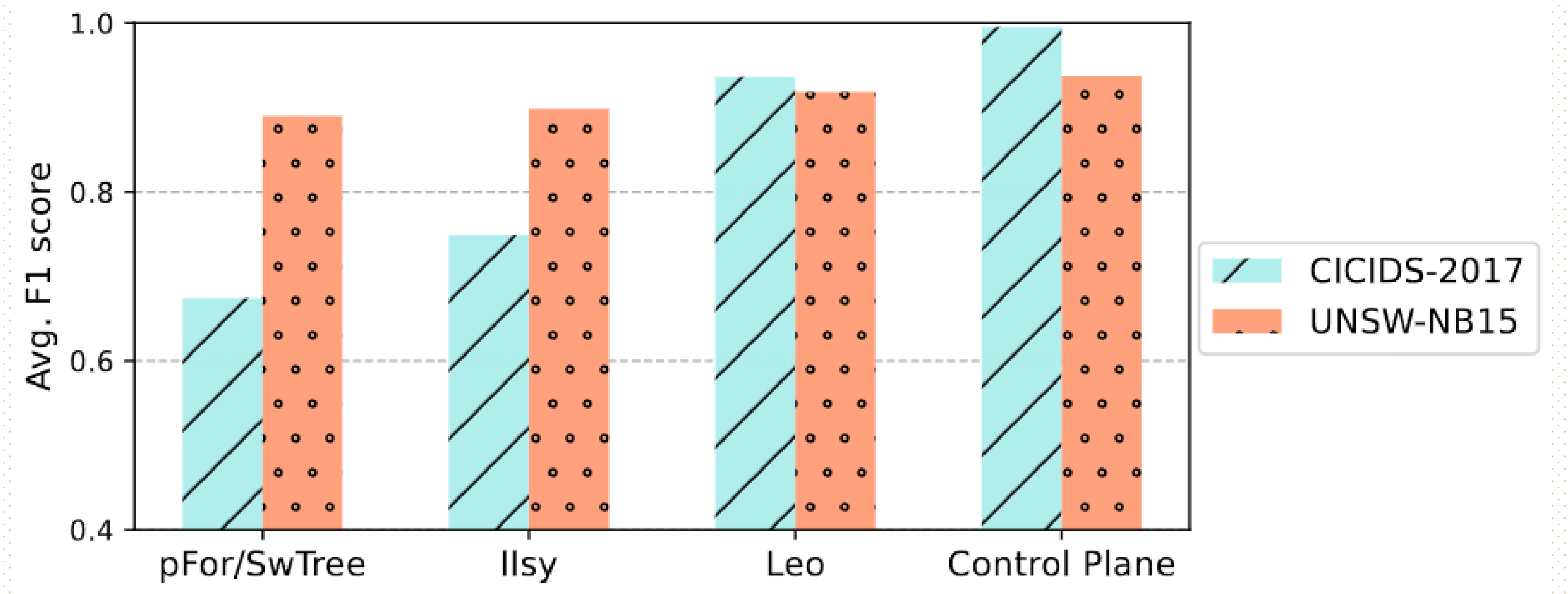
- **Insight:** a packet accesses one node per tree level
  → Only a single ALU per tree level required

Scaling to larger, deeper trees

- We develop ***Sub-tree multiplexing***
- Flattens portions of the tree (sub-trees) to execute in parallel

Evaluation

- We evaluate Leo in a hardware testbed
- Using SRAM, Leo can support classes of trees 2x deeper than the state of the art achieving F1 scores of 0.94 on a IDS dataset



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