Planter: Seeding Trees Within Switches

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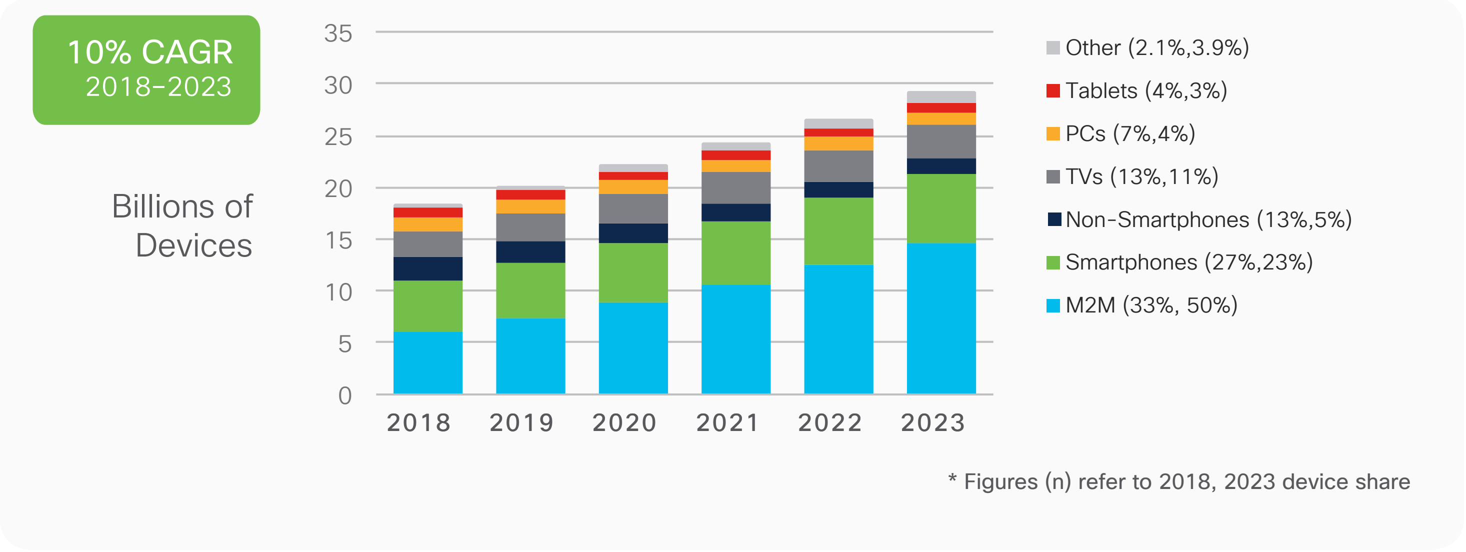
coseners2021 - 1st July 2021

Why on-switch classification?

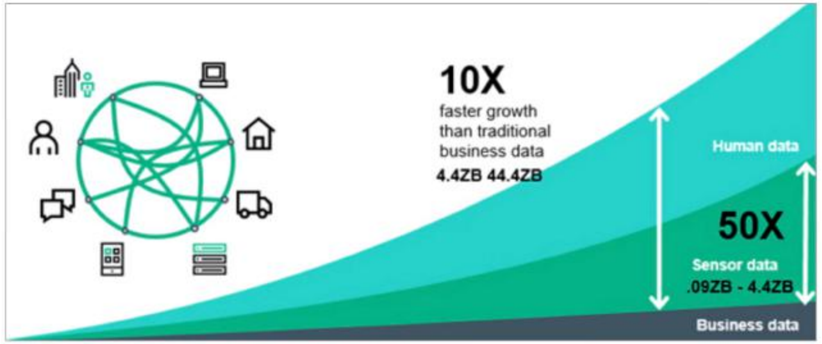
Growth of network connections

Figure 2. Global device and connection growth



Source: Cisco Annual Internet Report, 2018–2023

Exponential growth of data



Source: The Intelligent Use of Big Data on an Industrial Scale

Why on-switch classification?

Anomaly detection use case

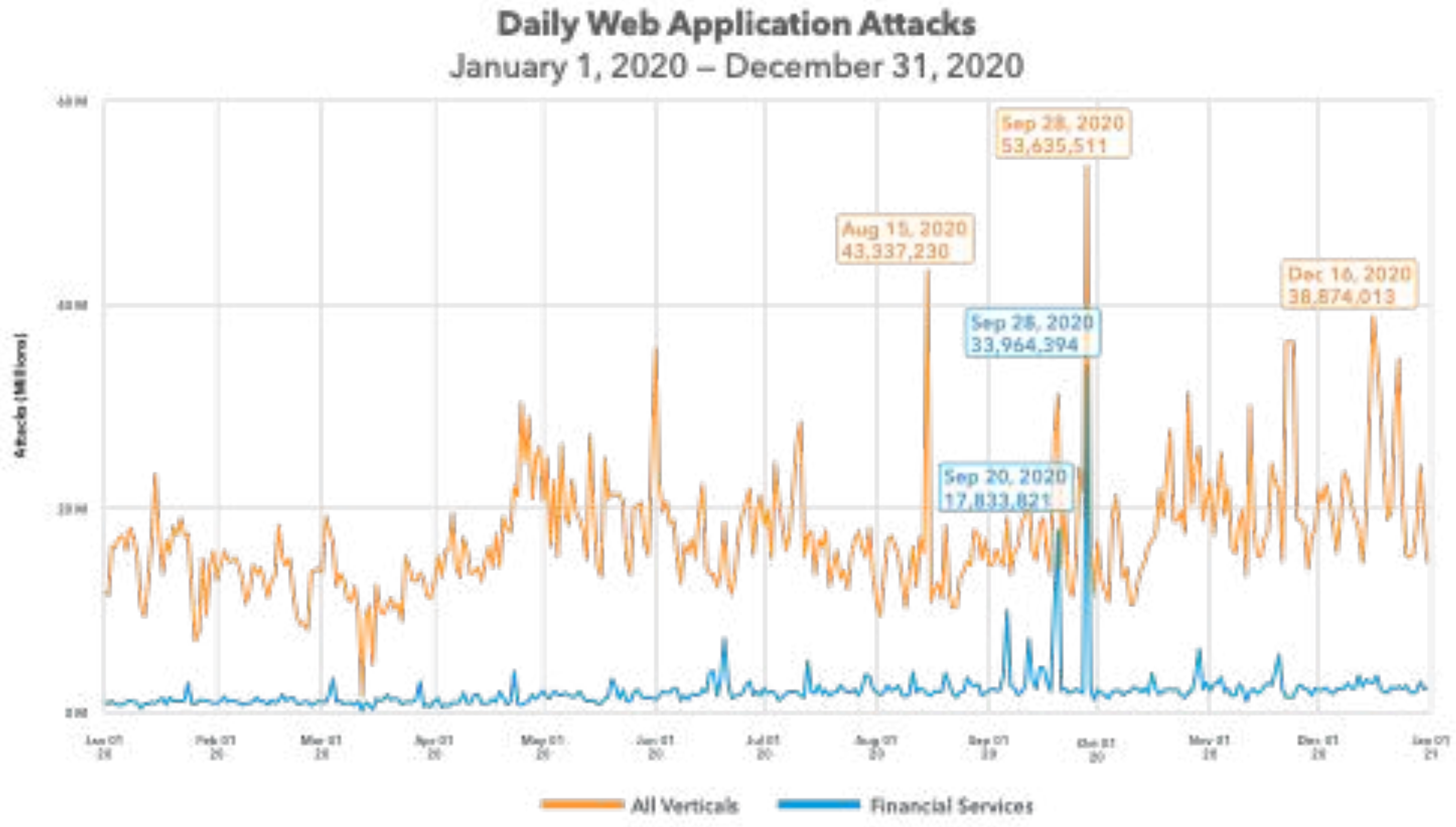
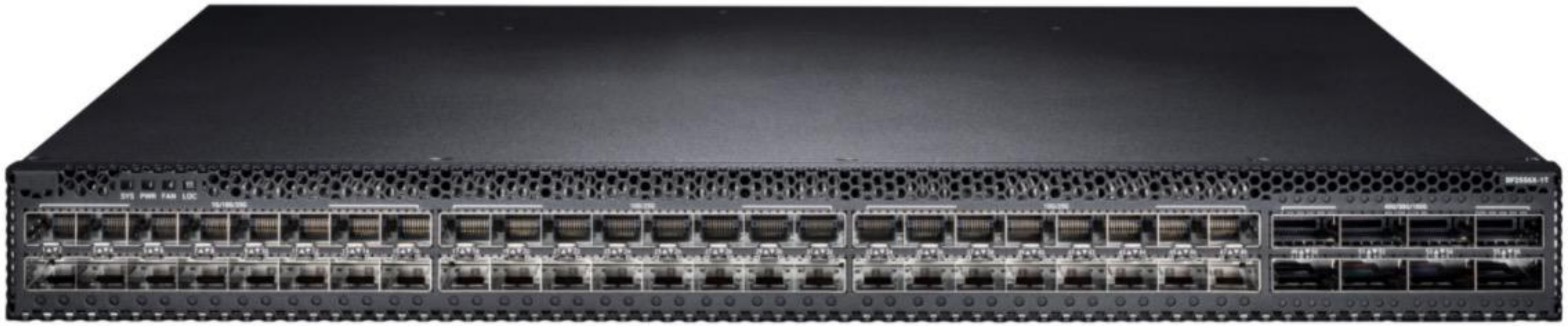


Fig. 2: Web attacks reached five notable peaks in 2020, all in Q3 and Q4

Source: 2021 State of the Internet / Security: Phishing for FinancePhishing for Finance

Why on-switch classification?

1. Better energy effiency
2. Processing speed



Intel® TofinoTM 6.4 Tbps 64x100Gb switch.

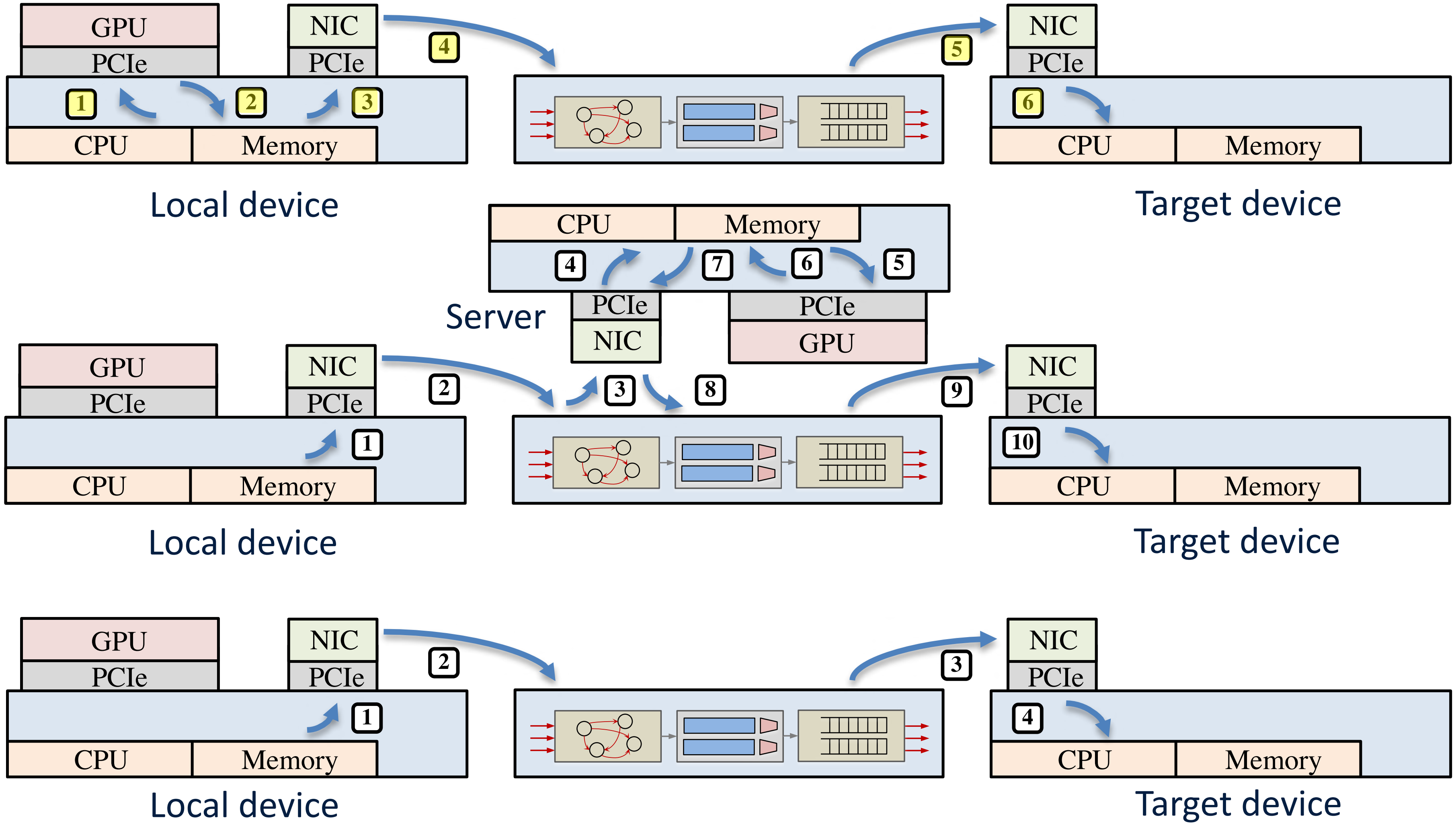
Why on-switch classification?

Better Position

On local GPU:

On Server GPU:

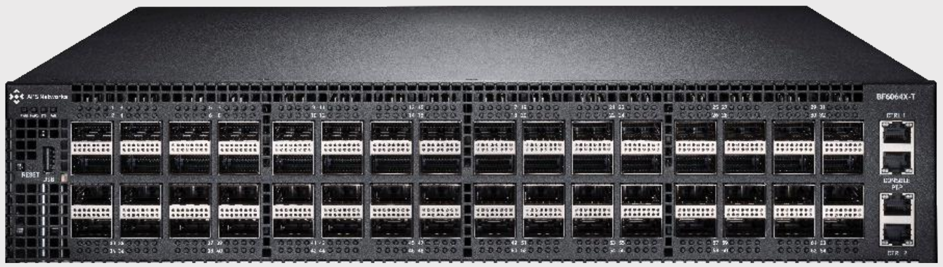
On Switch:



On-switch classification challenges

1. Limited mathematical operations
2. Limited memory
3. Limited data types
4. Limited stages

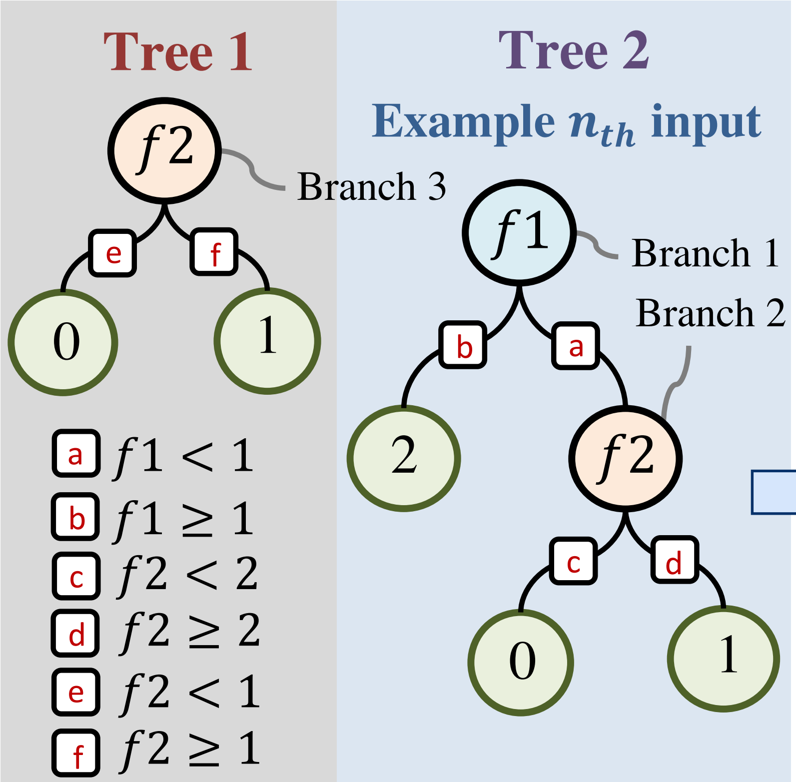
The **APS Networks BF6064X-T** is a dedicated platform for intelligent network programming, SDN and NFV development. Capture the full benefits of the powerful Intel® Tofino™ 6.4 Tbps 64x100Gb switch.



OCP ACCEPTED

Source from: Advanced Programmable Switch www.aps-networks.com

Our goal



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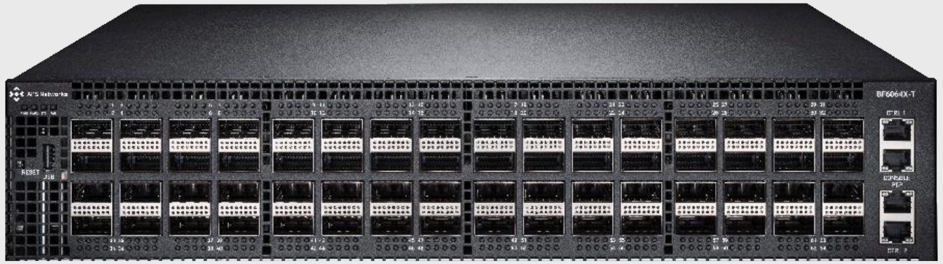
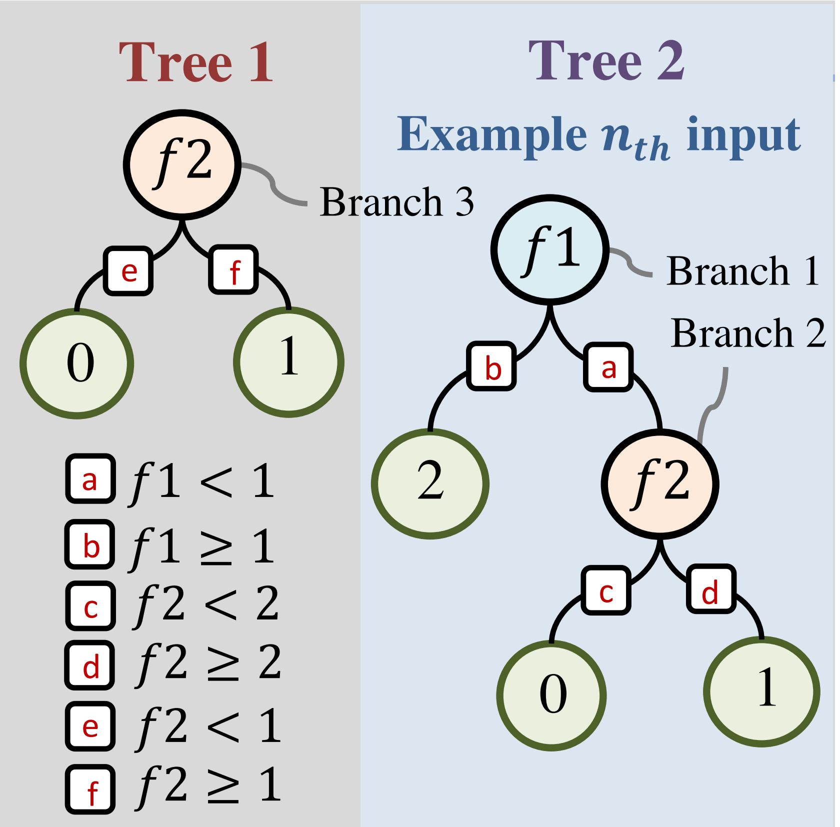


What is & Why ensemble models?



From machine learning perspective

1. Robust.
2. Straight forward and explainable.
3. Adapt to different learning tasks.
4. Widely used.

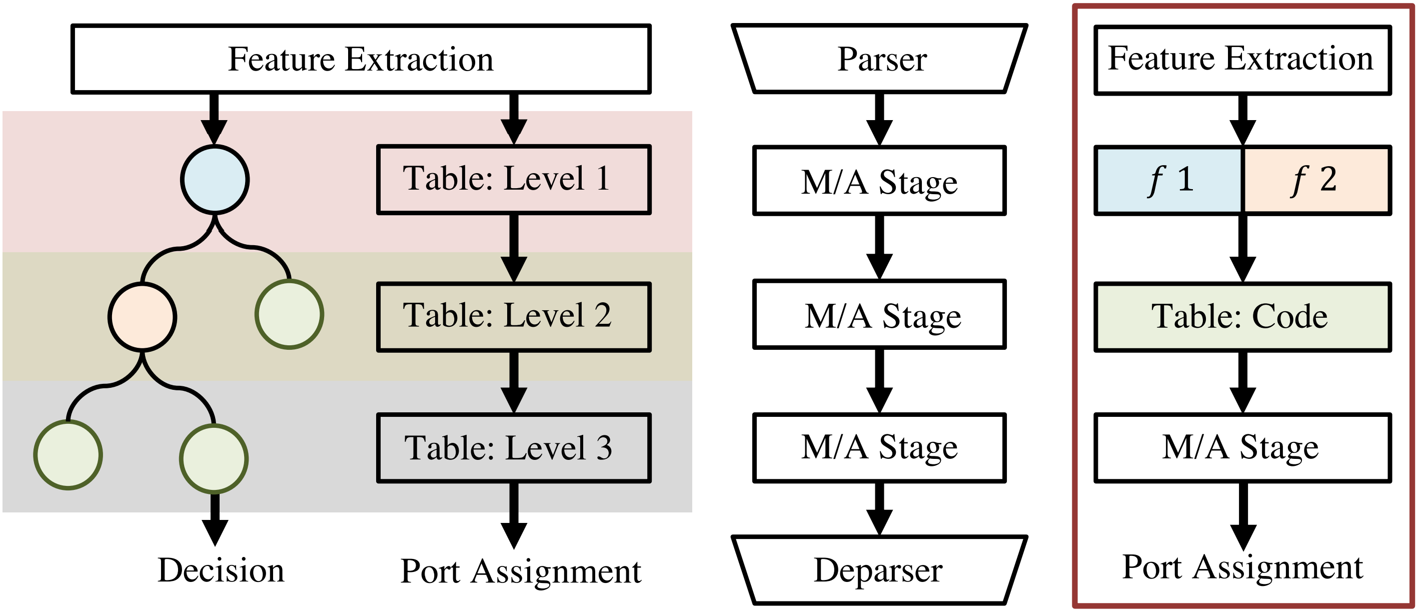
From implementation perspective

1. Simple structure and operation

Two mapping approaches

SwitchTree & pForest use a match-action stage for each level in the tree.

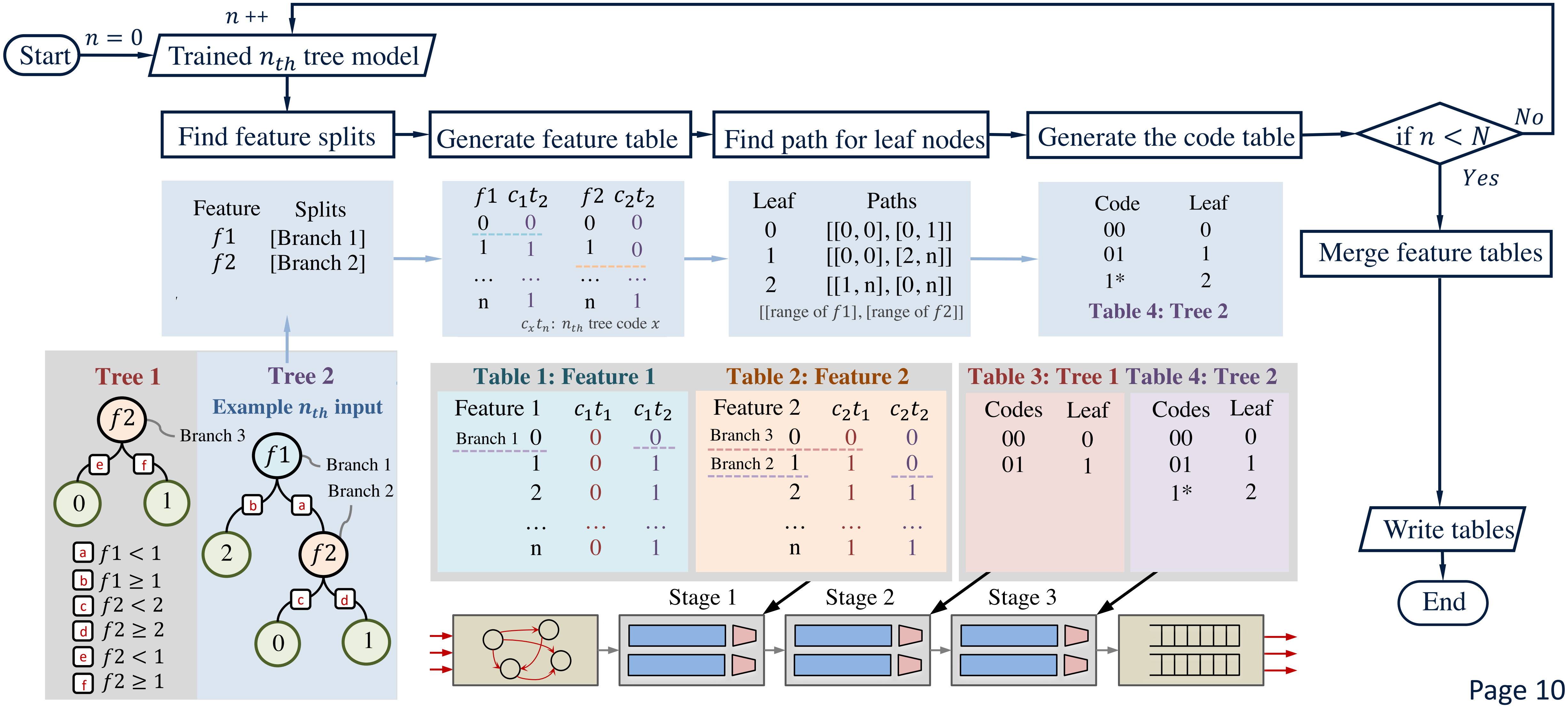
IIsy & Planter encode the model using a table per feature, coding the decision into tree leaves.



(a) **SwitchTree & pForest** (b) **IIsy & Planter**

Planter: the number of stages is independent of model's depth.

Planter algorithm



Some ensemble models

XGBoost

$label = \arg\max_{x} (p_x)$

$p_1 = prob_1 + \cdots + prob_{j\text{-}1}$

$p_2 = prob_j + \cdots + prob_k$

Table $m+1$ to Table $m+k$: Code to Probability

Code	Tree 1
$codes_1$	$prob_1$
…	…
$codes_n$	$prob_1$

…

Code	Tree k
$codes_1$	$prob_k$
…	…
$codes_n$	$prob_k$

Tree i codes = $code_{i1}$ ++ $code_{i2}$ … ++ $code_{im}$

Random Forest

$label = \arg\max_{x} (label_x)$

$label_1 = vote_1 + \cdots + vote_{j\text{-}1}$

…

$label_k = vote_j + \cdots + vote_k$

Table $m+1$ to Table $m+k$: Code to Probability

Code	Tree 1
$codes_1$	$vote_1$
…	…
$codes_n$	$vote_1$

…

Code	Tree k
$codes_1$	$vote_k$
…	…
$codes_n$	$vote_k$

Tree i codes = $code_{i1}$ ++ $code_{i2}$ … ++ $code_{im}$

Isolation Forest

$if\ depth > threshold$

$label = anomaly$

$depth = depth_1 + \cdots + depth_k$

Table $m+1$ to Table $m+k$: Code to Depth

Code	Tree 1
$codes_1$	$depth_1$
…	…
$codes_n$	$depth_1$

…

Code	Tree k
$codes_1$	$depth_k$
…	…
$codes_n$	$depth_k$

Tree i codes = $code_{i1}$ ++ $code_{i2}$ … ++ $code_{im}$

Table 1: Feature 1 to code

Key	Tree 1	…	Tree k
k_1	$code_{11}$	…	$code_{k1}$
…	…	…	…
k_n	$code_{11}$	…	$code_{k1}$

…

Table m: Feature m to code

Key	Tree 1	…	Tree k
k_1	$code_{1m}$	…	$code_{km}$
…	…	…	…
k_n	$code_{1m}$	…	$code_{km}$

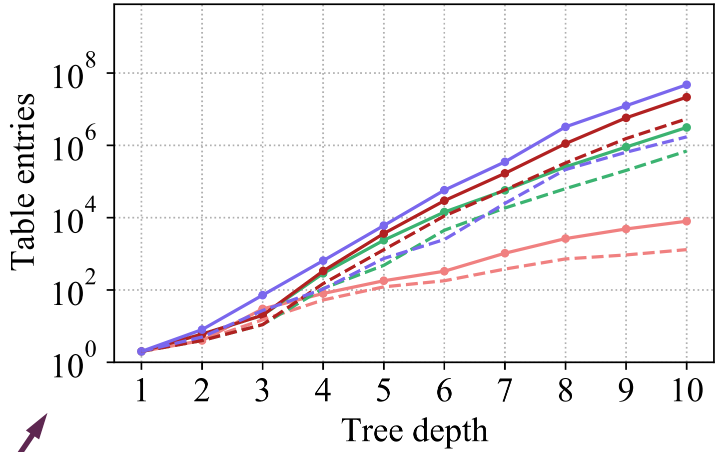
Preliminary evaluation on Tofino

Flowers classification (Iris dataset)

Model	Trees	Tables	Memory	Latency	Acc	Baseline
RF	3	7	1.4%	32.5%	97.8%	97.8%
XGB	3	8	1.3%	41.1%	97.8%	97.8%

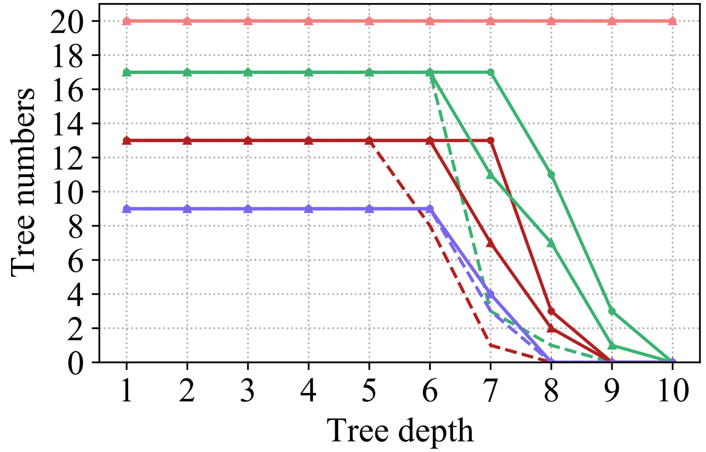
Anomaly detection (UNSW dataset)

Model	Trees	Tables	Memory	Latency	Acc	Baseline
RF	6	11	6.8%	64.0%	97.3%	98.5%
XGB	6	11	6.7%	64.3%	96.7%	98.7%



Depth - Table entries

Resource consumption of anomaly detection use case



Depth - Tree numbers

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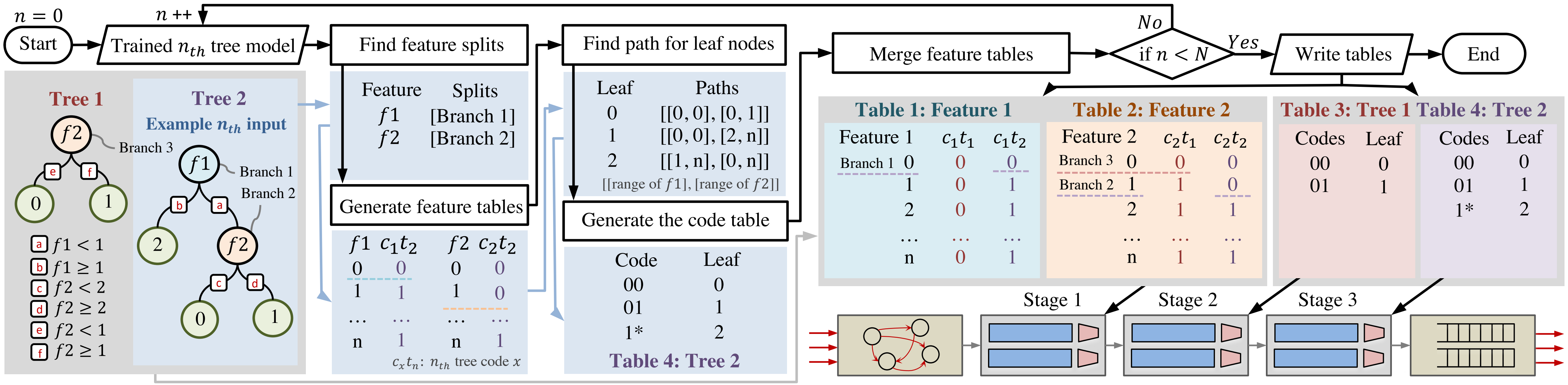

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