Nov-28-2018 第 31 屆 TWNIC OPM 暨第二屆 TWNOG 會議 :

Machine Learning and AI for Networking

Machine Learning, Popular Model, iCAM, Historical and Predictive Analytics, Visualizations

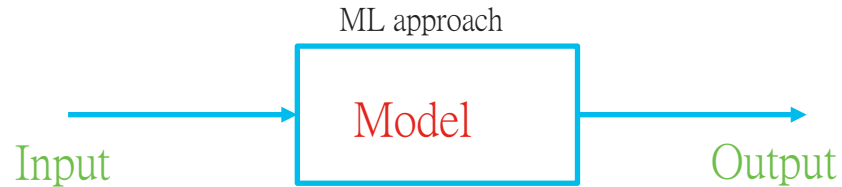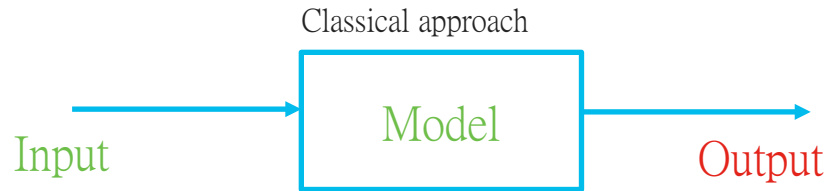錢小山

首席技術顧問

思科大中華區數據中心架構事業部

二〇一八年十一月

Machine Learning

Nov. 2018

Machine Learning Vs Classical approach

Given

Wanted

Classical approach

Input → Model → Output

ML approach

Input → Model → Output

Supervised Learning

X is the known input
Y is the known output

Y = F(X)

Goal: Find the Function F

So that new outputs can be predicted using new inputs

      Terminology :
      X : training data
      Y : output
      F : Model
      Finding F: Training the data

Features

Label

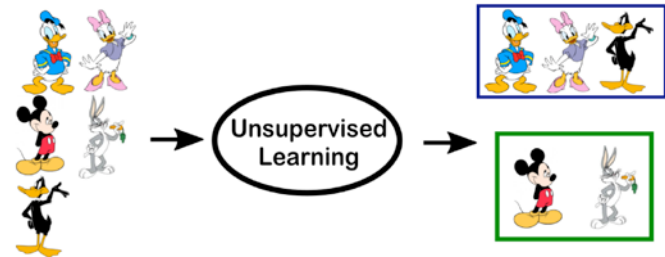| Bedrooms	Sq. feet	Neighborhood	Sale price
3	2000	Normaltown	$250,000
2	800	Hipsterton	$300,000
2	850	Normaltown	$150,000
1	550	Normaltown	$78,000
4	2000	Skid Row	$150,000

training data

Test data

Unsupervised Learning
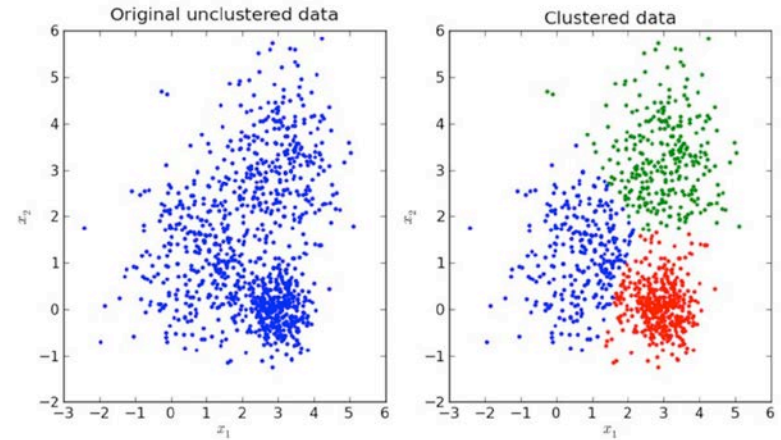
Only X inputs are known
Outputs Y,F are unknown

Y = F(X)

Goal:
- Group and interpret data based on input data X
- Find hidden structure
- Partition the data set

Popular Machine Learning Libraries

Popular Model

Nov. 2018

Linear Regression

Constant

Coefficient

$$y = b_0 + b_1 x_1$$

Dependent Variable

Independent Variable

Linear Regression Example

Experience Vs Salary
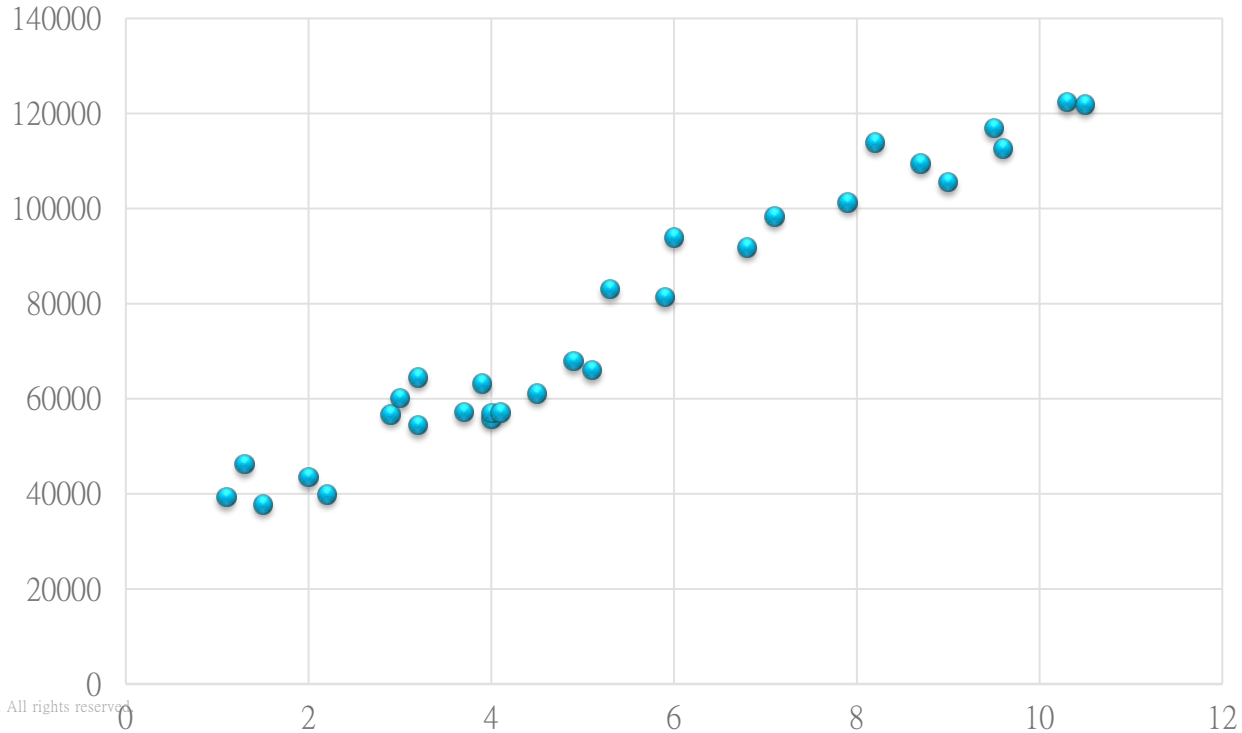
Polynomial Regression

Linear Regression $\qquad\qquad\qquad\qquad y = b_0 + b_1x_1$

Multi-Linear Regression $\qquad\qquad\quad y = b_0 + b_1x_1 + b_2x_2 + \ldots + b_nx_n$

Polynomial Regression $\quad y = b_0 + b_1x_1 + b_2x_1^2 + \ldots + b_nx_1^n$

Polynomial Regression Example
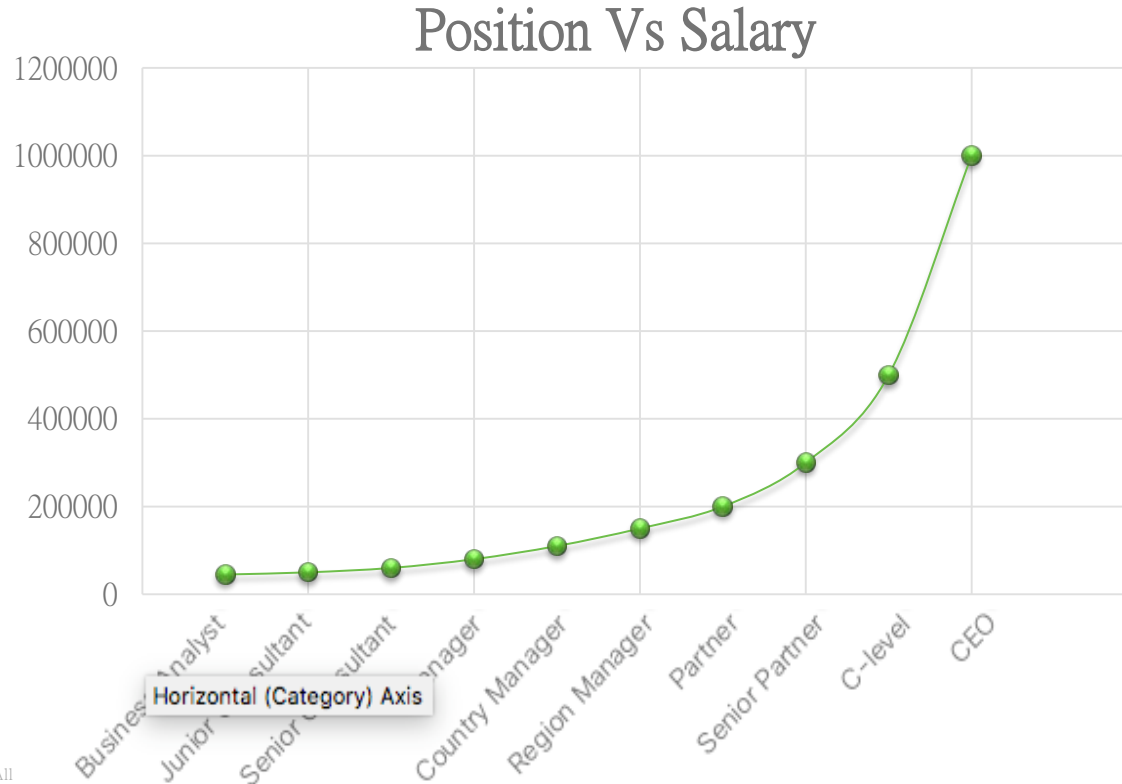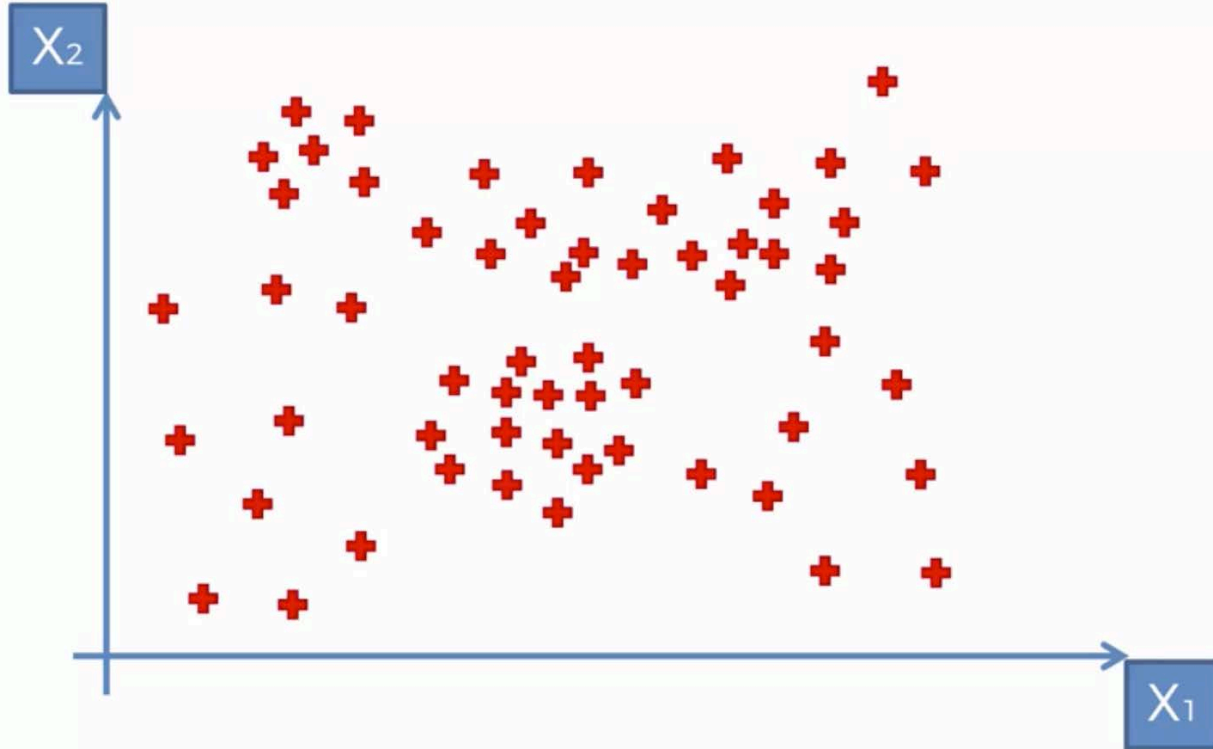
Position Vs Salary

Decision Tree Intuition

Decision Tree Intuition
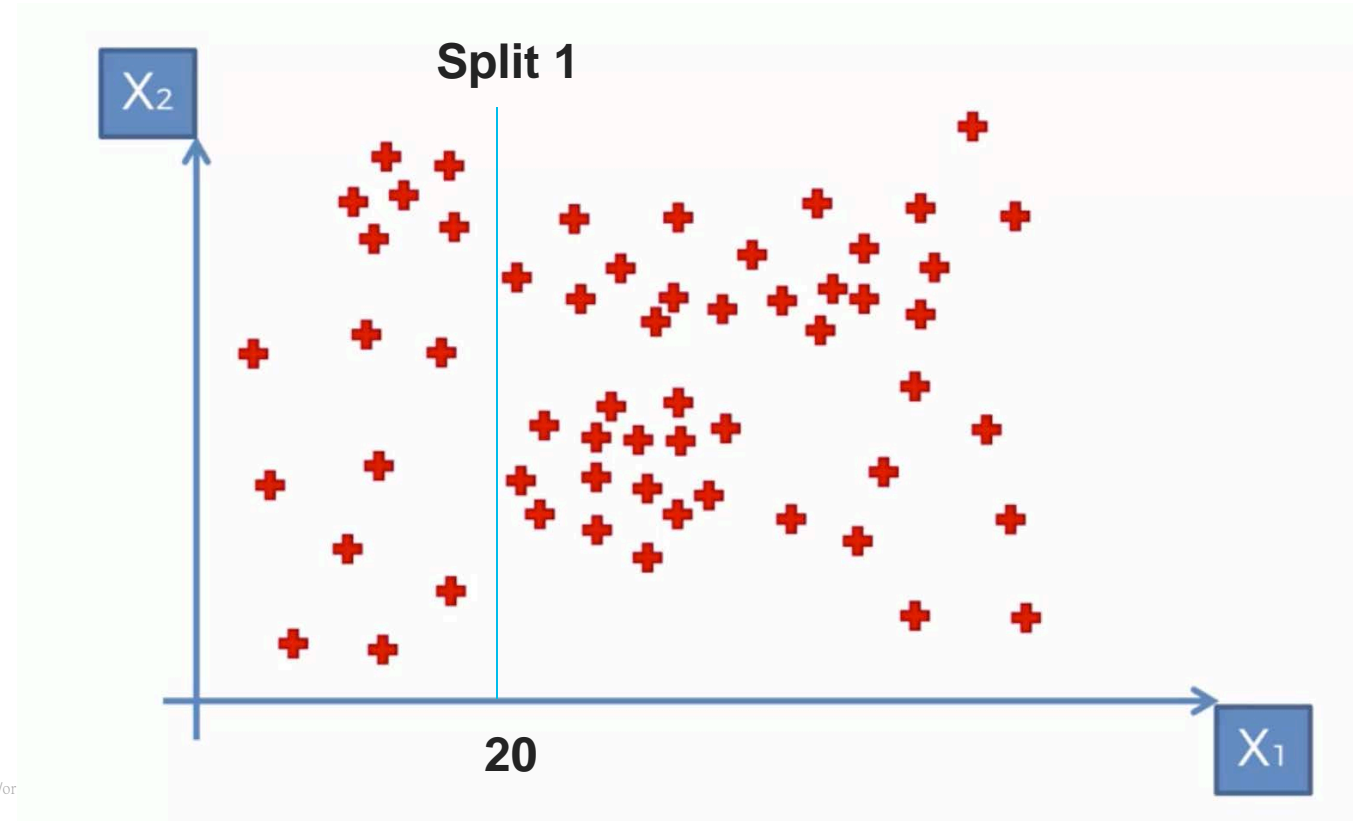
Decision Tree Intuition
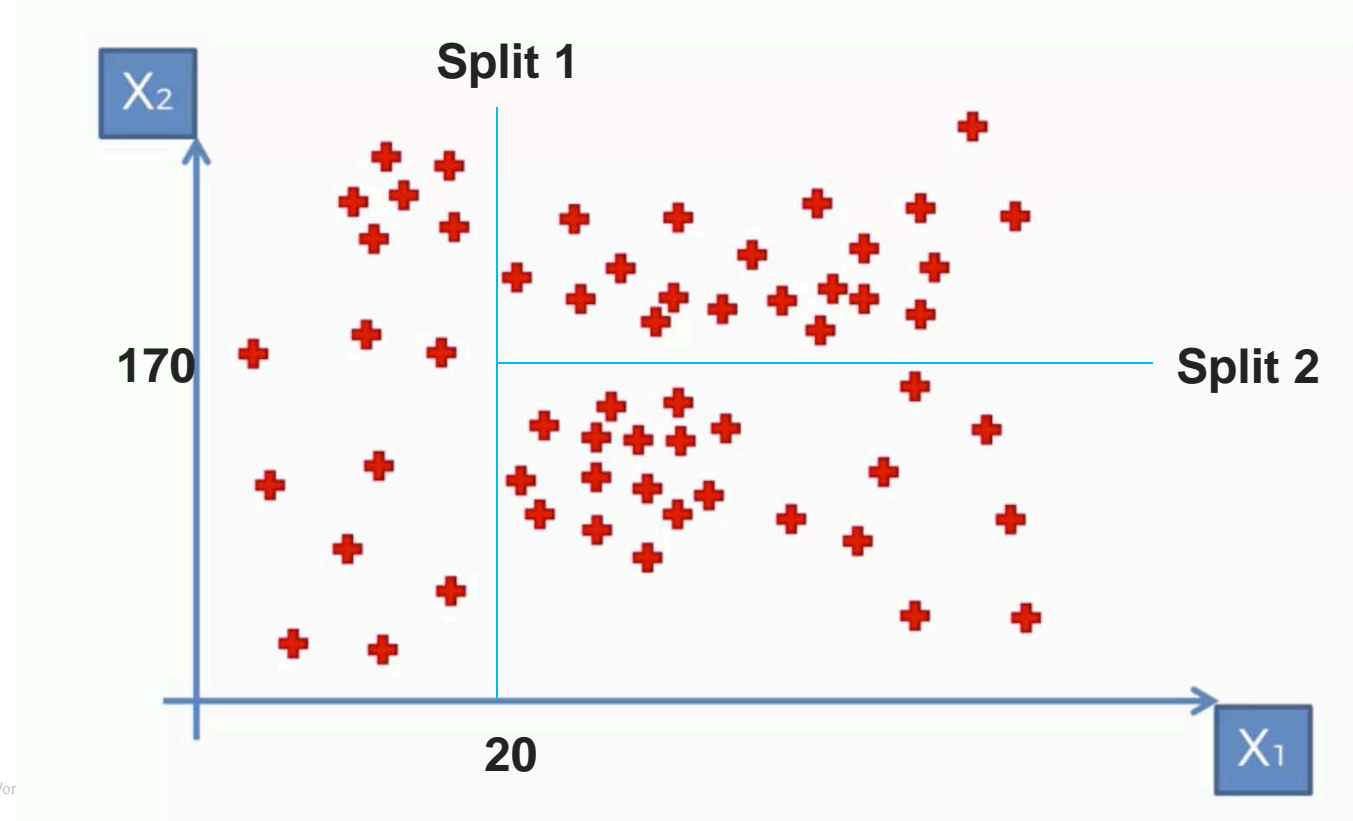
Decision Tree Intuition
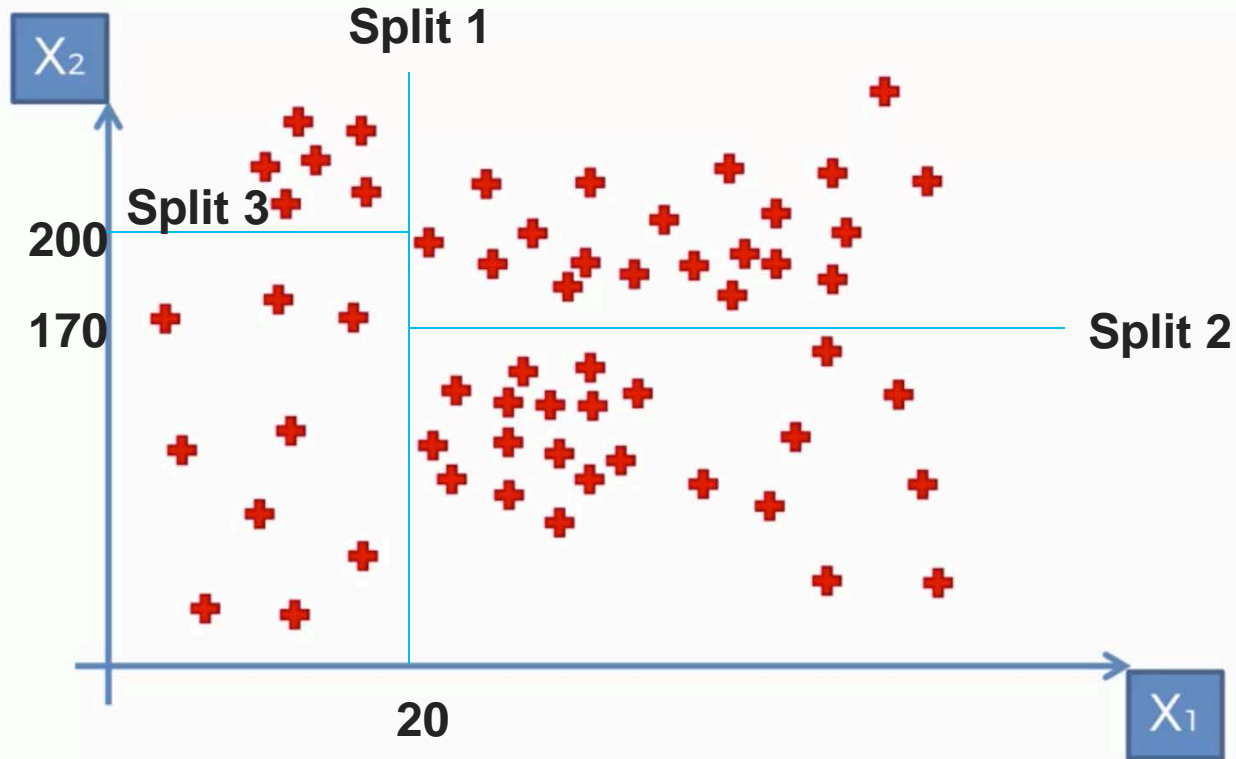
Decision Tree Intuition
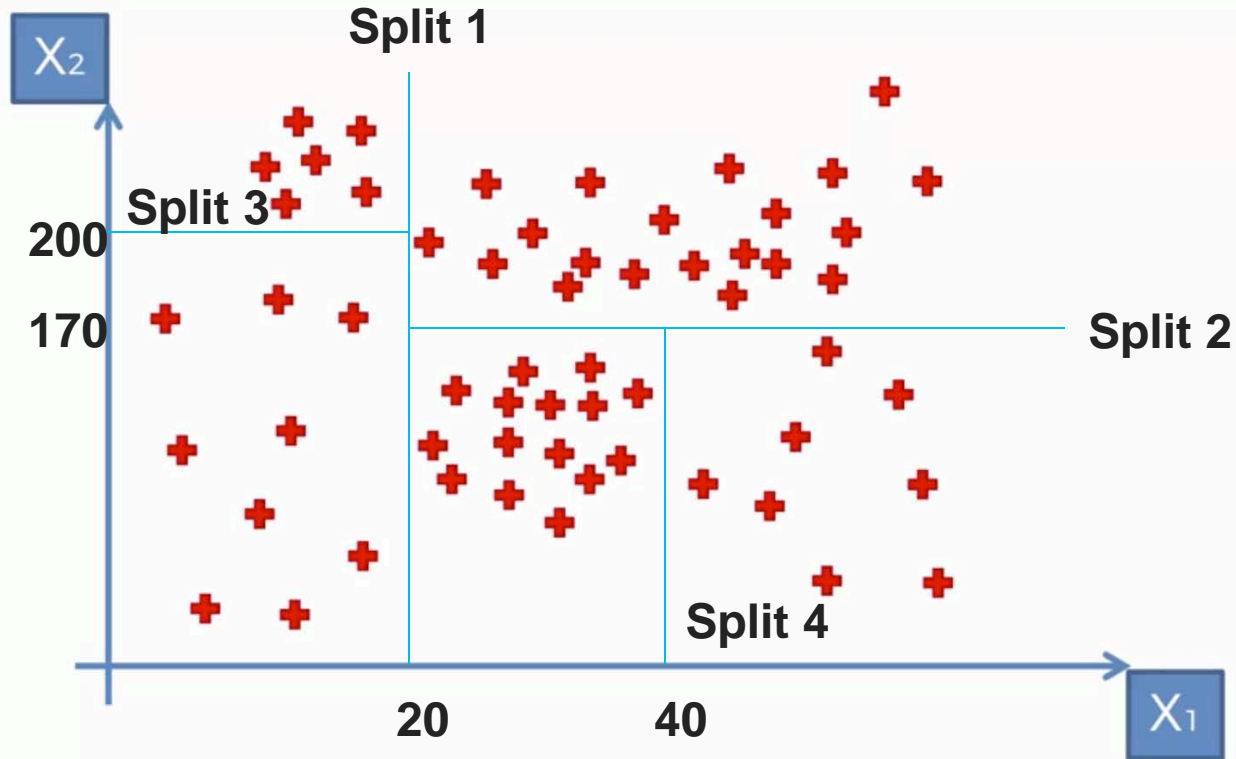
Sample Code: Linear Regression

```python
#Importing the libraries
import numpy as np
import matplotlib.pyplot as plt
import pandas as pd

# Importing the dataset
dataset = pd.read_csv('Position_Salaries.csv')
X = dataset.iloc[:, 1:2].values
y = dataset.iloc[:, 2].values

# Fitting Linear Regression to the dataset
from sklearn.linear_model import LinearRegression
regressor = LinearRegression()
regressor.fit(X, y)

# Visualising the Linear Regression results
plt.scatter(X, y, color = 'red')
plt.plot(X, regressor.predict(X), color = 'blue')
plt.title('Truth or Bluff (Linear Regression)')
plt.xlabel('Position level')
plt.ylabel('Salary')
plt.show()

# Predicting a new result with Linear Regression
regressor.predict(6.5)
```

Sample Code: Decision Tree Regression

```python
# Decision Tree Regression

# Importing the libraries
import numpy as np
import matplotlib.pyplot as plt
import pandas as pd

# Importing the dataset
dataset = pd.read_csv('Position_Salaries.csv')
X = dataset.iloc[:, 1:2].values
y = dataset.iloc[:, 2].values

# Fitting Decision Tree Regression to the dataset
from sklearn.tree import DecisionTreeRegressor
regressor = DecisionTreeRegressor(random_state = 0
regressor.fit(X, y)

# Predicting a new result
y_pred = regressor.predict(6.5)

# Visualising the Decision Tree Regression results (higher resolution)
X_grid = np.arange(min(X), max(X), 0.01)
X_grid = X_grid.reshape((len(X_grid), 1))
plt.scatter(X, y, color = 'red')
plt.plot(X_grid, regressor.predict(X_grid), color = 'blue')
plt.title('Truth or Bluff (Decision Tree Regression)')
plt.xlabel('Position level')
plt.ylabel('Salary')
plt.show()
```

iCAM

Nov. 2018

Problem Statement

- Currently customers do not know about

- Historical trends of traffic: per-subnet, per application

- Future predictions about traffic: per-subnet, per-application

- Top heavy hitters of traffic

- Historical trends of hardware/software tables on the switches

- Future predictions about hardware/software table utilizations

- When is a good time to schedule downtime?

- Which hardware entries can be retired to create space for new ones?

- Are there any anomalies (quick visualization)?

Solution: iCAM

- iCAM = Intelligent Comprehensive Analytics and Machine Learning
- Machine Learning natively on the switches.
- Already Shipped on Nexus 9000 and Nexus 7000 Series of switches
- Ship Date: Dec 2016
- Software License
- Several Patents pending

iCAM
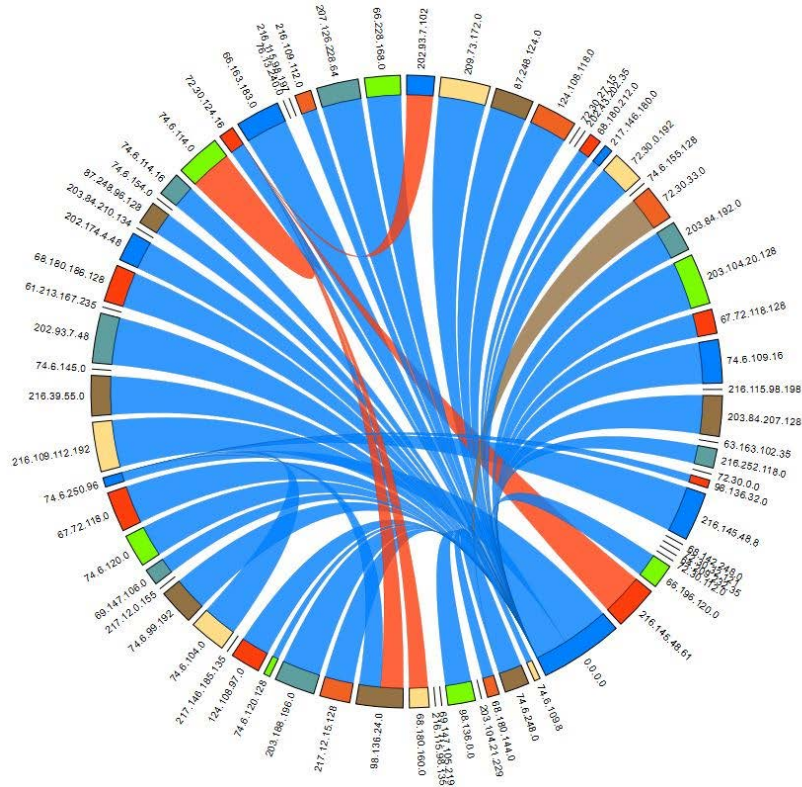
Contact : nxos-icam@cisco.com

2017 **BEST OF**
Interop ITX

iCAM Overview:
• **Machine Learning, natively on the switch/router**
• **Security access control analytics**
• **Internal hardware tables usage analytics**
• **Top/bottom heavy hitters**
• **Anomaly visualization**
• **Build apps on top of iCAM**
• **Historical Analytics**
• **Predictive Analysis**
• **Streaming telemetry**

Benefits:
Order of magnitude OPEX savings : Predictive analytics and historical analytics
Order of magnitude CAPEX savings : Natively on the switch/router: Wiring, Power, Rackspace and Cost savings
Scalability : Multi-Terabits/s
Security: Anomaly visualization

Interactive Graph/GUI
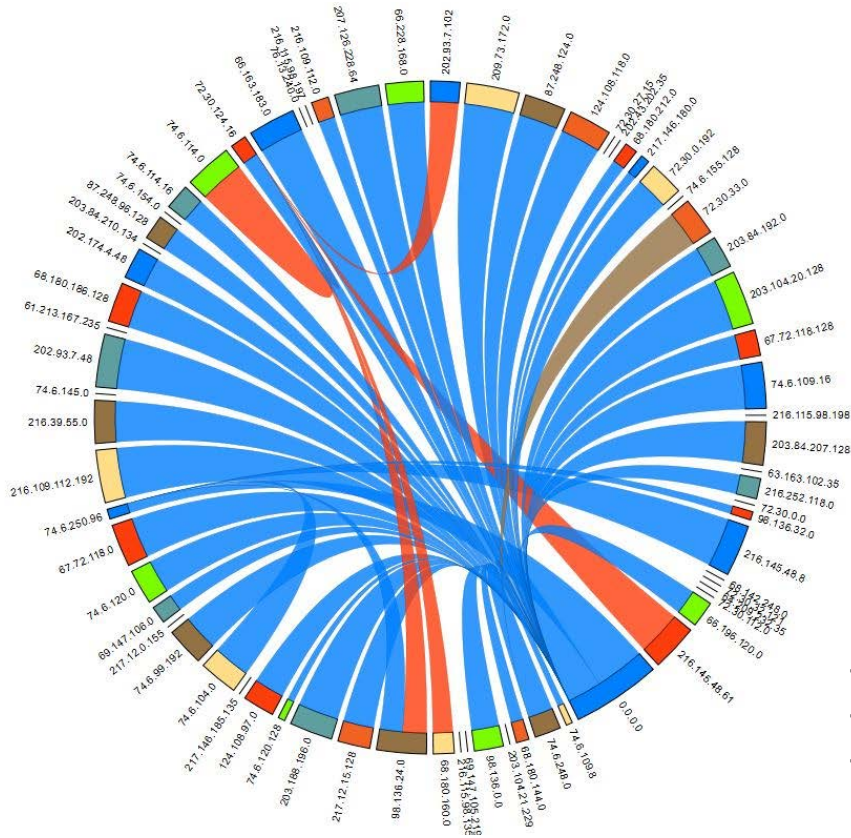
Thick end is the source IP/subnet.
Thin end is the dest IP/subnet.
Thickness represents the % traffic.

Interactive Graph/GUI
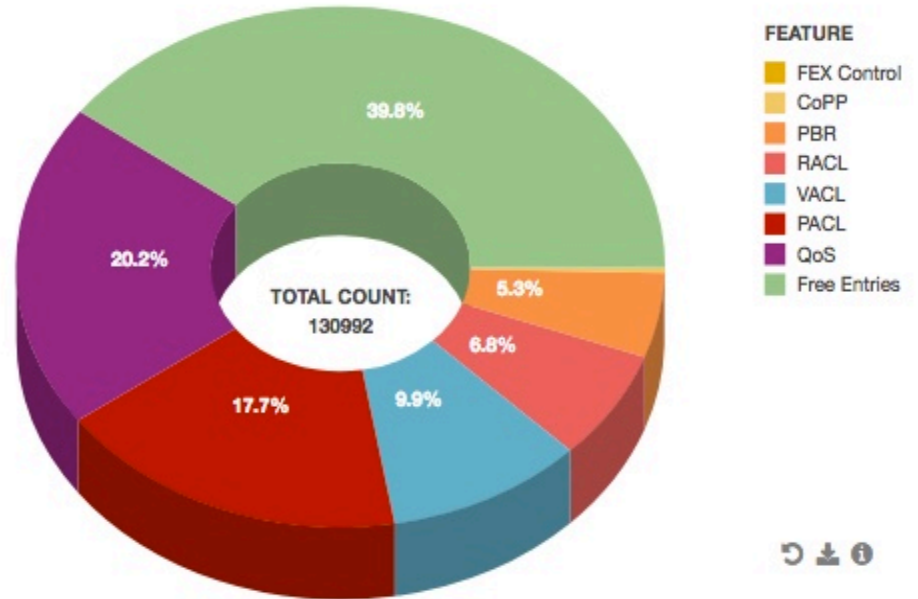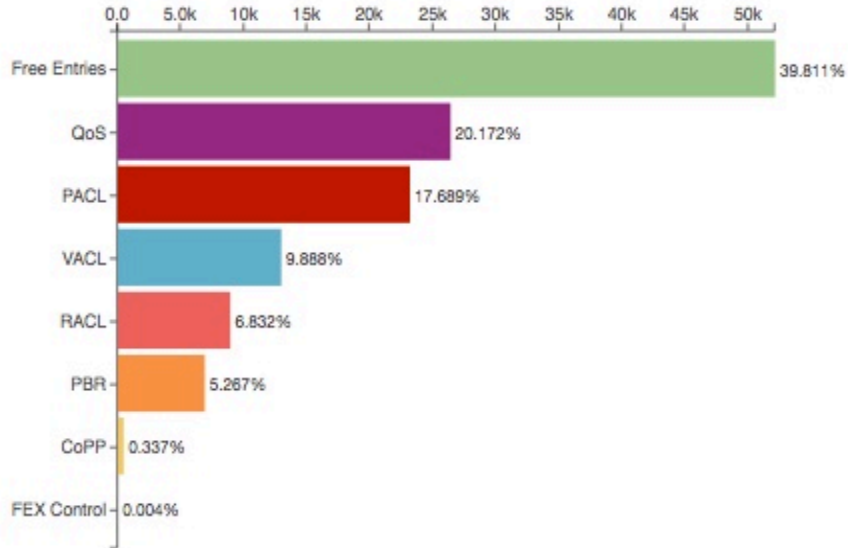
Historical and Predictive Analytics

Nov. 2018

Show ML Predictions

- show icam prediction entries {acl | multicast} module *module-number* inst *instance-number year month day HH:MM:SS* [top *x*]

- show icam prediction resource {acl_tcam | fib_cam | l2_table} module *module-number* inst *instance-number year month day HH:MM:SS*

iCAM Predictions

Time

Current Data

Feature Name	Num of Entries Used	Num of Entries Free	Percentage Utilization
ACL	1202	798	60.1
QoS	576	1424	28.8
PBR	636	1364	31.8
FEX	865	1135	43.25
...	...	...	...
...	...	...	...

Future Data

Feature Name	Num of Entries Used	Num of Entries Free	Percentage Utilization
ACL	1798	202	89.9
QoS	1759	241	87.95
PBR	467	1533	23.35
FEX	1098	902	54.9
...	...	...	...
...	...	...	...

X Time Intervals

Time

Current TCAM Data

TCAM Entry	Traffic Stats
2.2.2.2 -> 3.3.3.3	4894
20.1.1.1 -> 23.4.3.2	4232
10.1.11.1 -> 11.1.1.1	621
...	...
...	...

Future TCAM Data

TCAM Entry	Traffic Stats
2.2.2.2 -> 3.3.3.3	9823
20.1.1.1 -> 23.4.3.2	10938
10.1.11.1 -> 11.1.1.1	3244
...	...
...	...

X Time Intervals

Example – Multicast Traffic Prediction

```
switch# show icam prediction entries multicast module 5 2018 July 10 10:00:00
=================================================================================================
Multicast Entries Prediction (Mod 5)
-------------------------------------------------------------------------------------------------
    VDC_ID      TABLE_ID      Source/Mask        Group/Mask         RPF           Stats      Prediction
-------------------------------------------------------------------------------------------------
         3        32768        0.0.0.0/0        224.0.0.0/24                        3198           3364
         2        32768        0.0.0.0/0        224.0.0.0/24                        7636           8421
         2            3      200.1.1.2/32     225.1.1.229/32     Ethernet5/1           1              1
         2            3      200.1.1.2/32     225.1.1.125/32     Ethernet5/1           1              1
         2            3      200.1.1.2/32     225.1.1.126/32     Ethernet5/1           1              1
         2            3      200.1.1.2/32     225.1.1.127/32     Ethernet5/1           1              1
         2            3      200.1.1.2/32     225.1.1.128/32     Ethernet5/1           1              1
         2            3      200.1.1.2/32     225.1.1.129/32     Ethernet5/1           1              1
         2            3      200.1.1.2/32     225.1.1.130/32     Ethernet5/1           1              1
         2            3      200.1.1.2/32     225.1.1.131/32     Ethernet5/1           1              1
         2            3      200.1.1.2/32     225.1.1.132/32     Ethernet5/1           1              1
         2            3      200.1.1.2/32     225.1.1.133/32     Ethernet5/1           1              1
         2            3      200.1.1.2/32     225.1.1.134/32     Ethernet5/1           1              1
         2            3      200.1.1.2/32     225.1.1.228/32     Ethernet5/1           1              1
         2            3      200.1.1.2/32     225.1.1.202/32     Ethernet5/1           1              1
         2            3      200.1.1.2/32      225.1.1.35/32     Ethernet5/1        2554           3192
         2            3      200.1.1.2/32      225.1.1.36/32     Ethernet5/1        2554           3192
         2            3      200.1.1.2/32     225.1.1.232/32     Ethernet5/1           1              1
         2            3      200.1.1.2/32     225.1.1.231/32     Ethernet5/1           1              1
         2            3      200.1.1.2/32     225.1.1.201/32     Ethernet5/1           1              1
         2            3      200.1.1.2/32      225.1.1.41/32     Ethernet5/1        2554           3192
         2            3      200.1.1.2/32      225.1.1.42/32     Ethernet5/1        2554           3192
         2            3      200.1.1.2/32      225.1.1.43/32     Ethernet5/1        2554           3192
         2            3      200.1.1.2/32      225.1.1.44/32     Ethernet5/1        2554           3192
```

Example – ACL Resource Prediction

```
switch# show icam prediction resource acl_tcam module 5 inst 1 2018 July 10 10:00:00

-----------------------------------------------------------------------------------
Feature Hardware Resource Prediction (Mod 5,Inst 1)
-----------------------------------------------------------------------------------
-----------------------------------------------------------------------------------
       Feature    Direction    TCAM#    BANK#    Feature_Entries    Free_Entries    Percent_Util
-----------------------------------------------------------------------------------
   FEX Control     ingress       1        0                  5          32743            0.00
          CoPP     ingress       1        1                442          32306            1.00


===================================================================================
ACL TCAM Resource Prediction (Mod 5,Inst 1)
-----------------------------------------------------------------------------------
                 Used    Free    Percent_Util
-----------------------------------------------------------------------------------
Tcam 1 Bank 1     462   32306          1.40
Tcam 1 Bank 0      25   32743          0.07
Tcam 0 Bank 1      20   32748          0.06
Tcam 0 Bank 0      20   32748          0.06
```

Example – FIB Resource Prediction

```
switch# show icam prediction resource fib_tcam module 5 inst 0 2018 July 10 10:00:00
```

```
===============================================================
FIB TCAM Resource Prediction (Mod 5, Inst 0)
---------------------------------------------------------------
            Type        logical      physical   Percent_Util
---------------------------------------------------------------
           FCMPLS             0             0           0.00
     IPV4 unicast           132           132           0.00
          DIAG_80             0             0           0.00
         EOM Peer             0             0           0.00
             MPLS             0             0           0.00
   IPV6 multicast             5            20           0.00
   IPV6 LinkLocal             1             2           0.00
             FCOE             0             0           0.00
         MPLS VPN             0             0           0.00
   IPV4 multicast         11273         11273           1.00
     IPV6 unicast             2             4           0.00
```

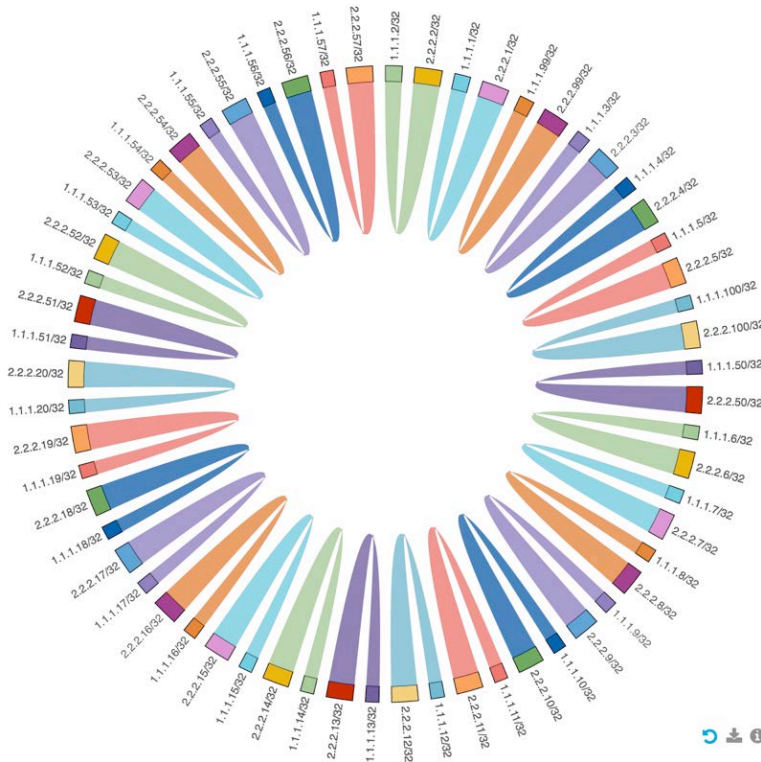# Visualizations of iCAM

Nov. 2018

Interactive Graph/GUI

Anomaly Visualization
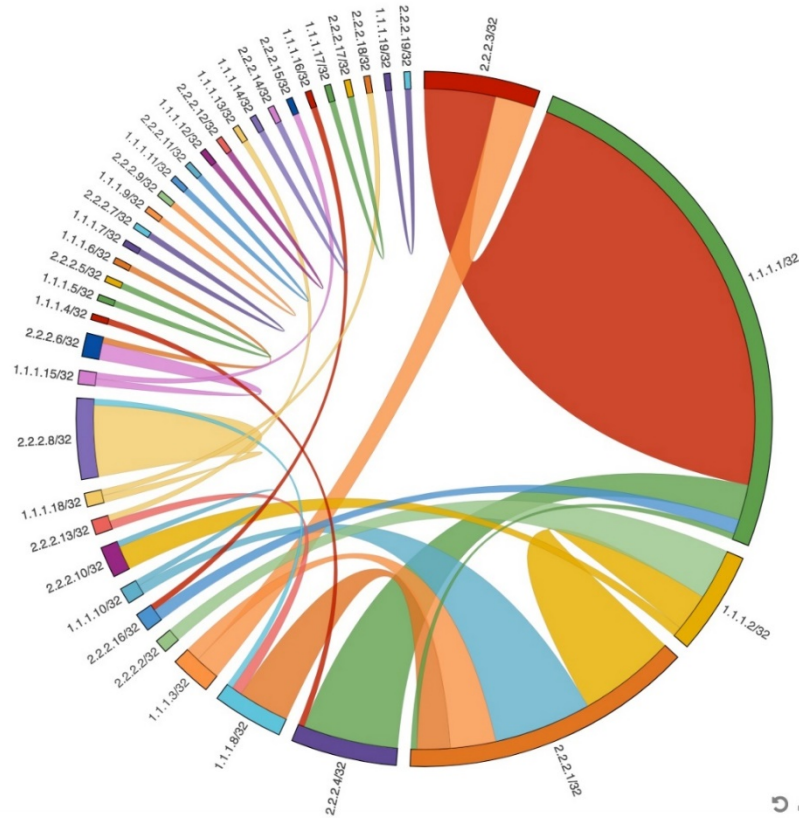
One specific TCAM entry has too much traffic

iCAM Supported Platforms/Software Release

	Nexus 7000/7700 Series	Nexus 9000 Series
Platform	Nexus 7000/7700 Series	Nexus 9000 Series
Version	NX-OS 8.0(1)	NX-OS 7.0(3)I7(1)
License	Enhanced Layer 2	Network Services

CLI - Configuration

- feature icam

- icam monitor interval *interval-hours* num_intervals *number-of-intervals*

- icam monitor resource {acl_tcam | fib_tcam | l2_table} module *module-number* inst *instance-number*

- icam monitor entries {acl | multicast} module *module-number* inst *instance-number*

Notes

- The monitor commands are optional

CLI – Show Analytics - 2

Sorting and Filtering the output.

- sort   Sorts the entries based on filter and sort-order.

- filter   Filters the entries based on the feature name. Any feature name as a   string such as "RACL", "QoS", etc., can be used to filter the output.

- exact   Exact keyword. Eg, "QoS CoPP"

- sort-order   Sorts the entries in either ascending or descending order.

- top   Displays the top x% iCAM entries for a feature. Values range from 1 to 100.

- history   Provide historical analytics.

Example:

show icam entries acl module 1 instance 0 sort filter RACL sort-order ascending top 10

iCAM Resources History - Example

Stats snapshots in last X intervals

```
n35(config)# sh icam resource fib_tcam module 5 inst 0 history 3

=================================================================================
 FIB TCAM Resource Utilization (Mod 5, Inst 0)
---------------------------------------------------------------------------------
        Type        logical      physical    Percent_Util     Timestamp (UTC)
---------------------------------------------------------------------------------
   IPV4 unicast        16           16           0.00       2017-09-12 06:06:53
                       16           16           0.00       2017-09-12 06:16:55
                       16           16           0.00       2017-09-12 06:26:37
                       16           16           0.00       2017-09-12 06:46:23
                       16           16           0.00       2017-09-12 06:56:59
       DIAG_80          0            0           0.00       2017-09-12 06:06:53
                        0            0           0.00       2017-09-12 06:16:55
                        0            0           0.00       2017-09-12 06:26:37
                        0            0           0.00       2017-09-12 06:46:23
                        0            0           0.00       2017-09-12 06:56:59
   IPV4 multicast       6            6           0.00       2017-09-12 06:06:53
                       45           45           0.10       2017-09-12 06:16:55
                       45           45           0.10       2017-09-12 06:26:37
                       62           62           0.17       2017-09-12 06:46:23
                       62           62           0.17       2017-09-12 06:56:59
          MPLS          0            0           0.00       2017-09-12 06:06:53
                        0            0           0.00       2017-09-12 06:16:55
                        0            0           0.00       2017-09-12 06:26:37
                        0            0           0.00       2017-09-12 06:46:23
                        0            0           0.00       2017-09-12 06:56:59
```

iCAM Entries History - Example

`switch# show icam entries acl module 5 inst 0 history 5`

```
================================================================================================================
TCAM Entries (Mod 5,Inst 0): Cumulative stats for last 5 intervals
----------------------------------------------------------------------------------------------------------------
   Feature  Pkt Type                                          Source IP/Mask Dest IP/Mask    Action    ifindex      Stats    Rate(pps)
----------------------------------------------------------------------------------------------------------------
       FEX  IPv4                                                 ip 0.0.0.0/0 0.0.0.0/0      Redirect   0x15090000        0            0
       FEX  IPv6   ip 0x0000000000000000000000000000000000/0 0x00000000000000000000000000      Redirect   0x15090000        0            0
       FEX  MAC      0000.0000.0000 0000.0000.0000 0000.0000.0000 0000.0000.0000      Redirect   0x15090000        0            0
       FEX  ARP   arp-rarp/all ip 0.0.0.0/0 0.0.0.0/0 0000.0000.0000 0000.0000.00      Redirect   0x15090000        0            0
      RACL  IPv4                                            ip 2.2.2.1/32 1.1.1.1/32      Permit     0x1a200000    23423          945
      RACL  IPv4                                            ip 2.2.2.2/32 1.1.1.2/32      Permit     0x1a200000 23946237       718353
      RACL  IPv4                                            ip 2.2.2.3/32 1.1.1.3/32      Permit     0x1a200000    83675          585
      RACL  IPv4                                            ip 2.2.2.4/32 1.1.1.4/32      Permit     0x1a200000        0            0
      RACL  IPv4                                            ip 2.2.2.5/32 1.1.1.5/32      Permit     0x1a200000  9693487        45986
      RACL  IPv4                                            ip 2.2.2.9/32 1.1.1.9/32      Permit     0x1a200000  9693487        45986
      RACL  IPv4                                              ip 0.0.0.0/0 0.0.0.0/0      Deny       0x1a200000        0            0
  QoS COPP  IPv4                                             tcp 0.0.0.0/0 0.0.0.0/0      QoS        0x0               0            0
  QoS COPP  IPv4                                           udp 0.0.0.0/0 224.0.0.0/24      QoS        0x0               0            0
```
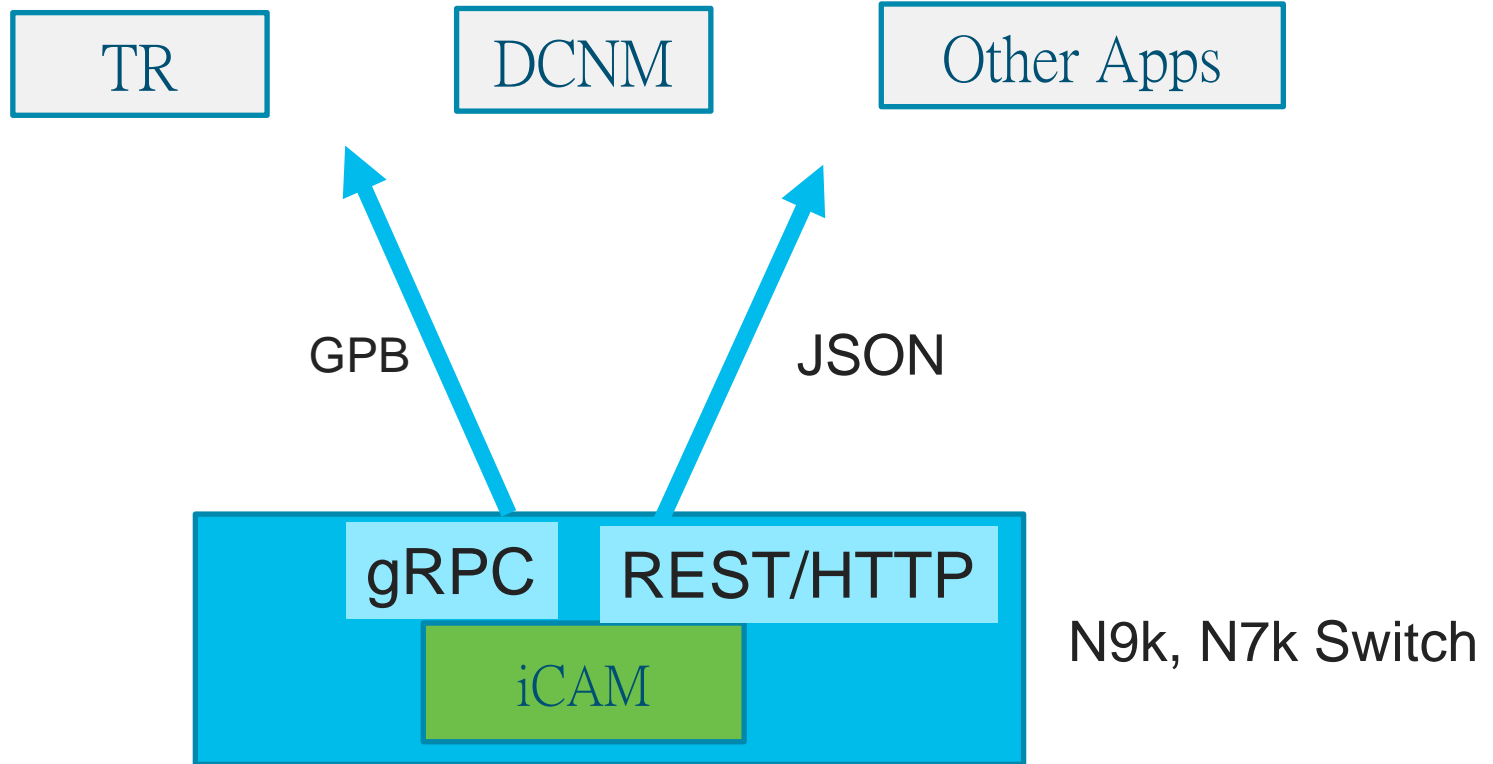
Cumulative Stats in the last X intervals

Average Rate in the last X intervals

Example – Layer 2 MAC Table

```
switch# sh icam resource l2_table module 1 inst 0

=================================================================
L2 Table Resource Utilization (Mod 1,Inst 0)
-----------------------------------------------------------------
 Total_entries   Used_entries   Percent_Util        Timestamp (UTC)
-----------------------------------------------------------------
         98304            341           0.34    2017-11-07 01:21:20
```

Streaming Telemetry with iCAM

Dashboard

Topology

Inventory

Monitor

Configure

Administration

System tools

	Name	Description
1	iCAM Traffic	Provides information about traffic exchange per switch based on CAM table configuration
2	iCAM Usage	Provides information about CAM table configuration per switch

Awards

- Best of Interop ITX 2017: [Finalist in Security Category](#)

- Best of Interop ITX 2017: [Finalist in DevOps Category](#)

- Light Reading Awards: Finalist in [Outstanding Communications Technology Vision](#)

- Best in Biz Awards: [Most innovative Product of the Year](#)

More media links

- Chuck Robbins, Cisco CEO tweet:

- https://twitter.com/ChuckRobbins/status/861961430559371264

- https://twitter.com/ChuckRobbins/status/869319371398586368

- Frank Palumbo, Cisco SVP, Worldwide Sales tweet:

- https://twitter.com/fpalumbo/status/861738133196480512

- https://twitter.com/fpalumbo/status/870346475439566848

- Network Computing about our innovations:

- http://www.networkcomputing.com/cloud-infrastructure/meet-best-interop-itx-2017-finalists/1224184367

References

- [iCAM config guide](#) https://www.cisco.com/c/en/us/td/docs/switches/datacenter/nexus9000/sw/7-x/security/configuration/guide/b_Cisco_Nexus_9000_Series_NX-OS_Security_Configuration_Guide_7x/b_Cisco_Nexus_9000_Series_NX-OS_Security_Configuration_Guide_7x_chapter_011010.html

- http://blogs.cisco.com/datacenter/icam

- nxos-icam@cisco.com

Thank You