

50 Thousand Needles in 5 Million Haystacks

Understanding Old Malware Tricks to Find New Malware Families

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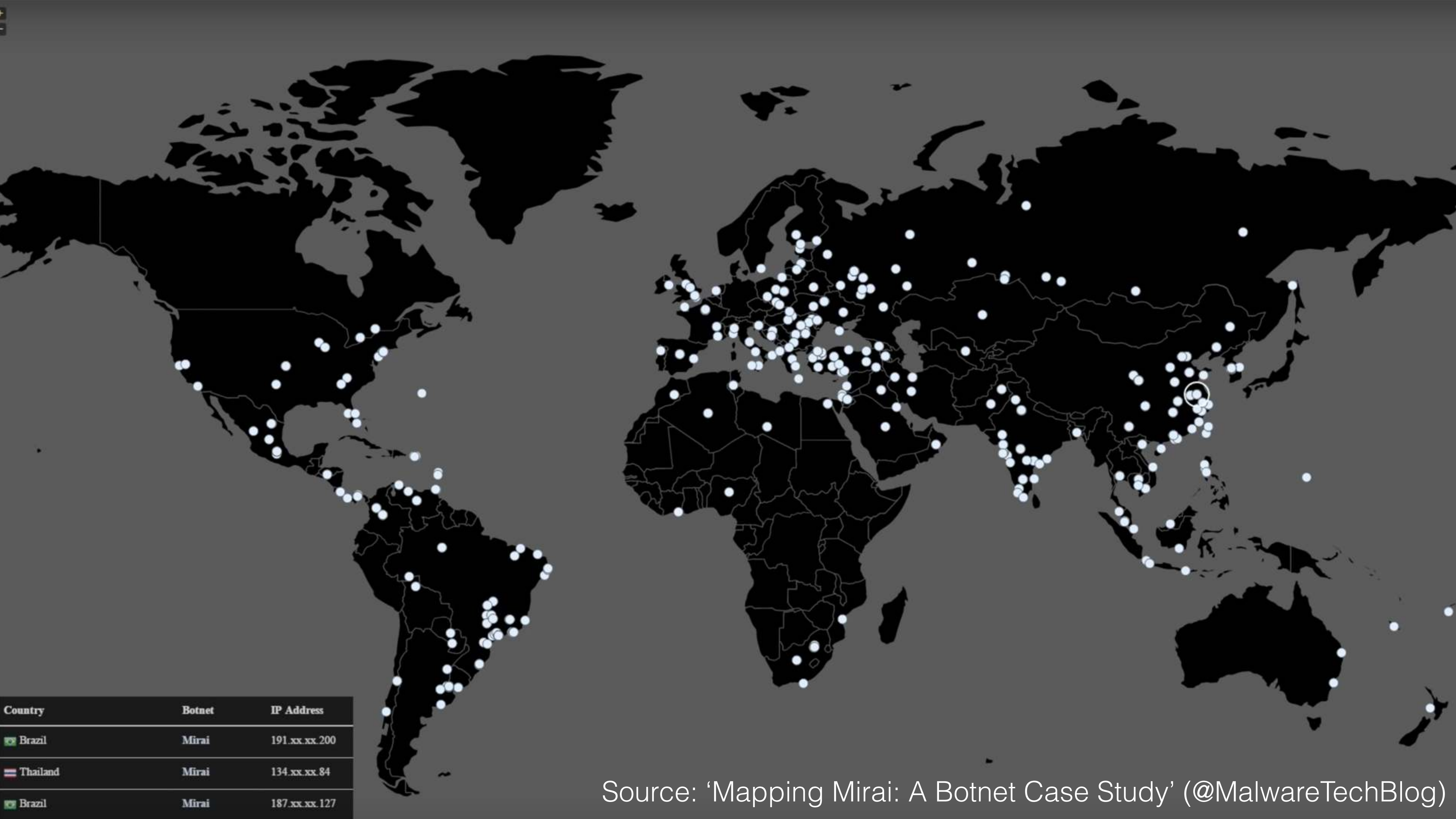
Lukáš Machlica

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Country	Botnet	IP Address
 Brazil	Mirai	191.xx.xx.200
 Thailand	Mirai	134.xx.xx.84
 Brazil	Mirai	187.xx.xx.127

Source: 'Mapping Mirai: A Botnet Case Study' (@MalwareTechBlog)



admin:admin



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 Brazil	Mirai	187.xx.xx.127

Source: 'Mapping Mirai: A Botnet Case Study' (@MalwareTechBlog)

CONGRATULATIONS

en chosen to receive a
away Desktop Computer!

m 4 Processor 2.66 GHz
R-SDRAM, 80GB HD, 48x CD-RW
or CRT Monitor (18-inch viewable)

o Claim Your FREE* Desktop Computer!

FREE!



Microsoft Internet Explorer

Click OK to download our free software while browsing the site

OK Cancel

Setting Started Features Contact Us Help In

ents

Black
Roule
Slot M

Internet

games live, for Fun or Real Money. Chat with Others. 25% Deposit Bo

Online Poker Room T... http://ads1.revenue....

AdWare Punisher

Scan Settings Privacy Recovery

Type	Item	Details
☒ Spyware	cashtoolbar.com	Spyware cookie - cashtoolbar.com
☒ Spyware	hitexchange.net	Spyware cookie - hitexchange.net
☒ Spyware	fastclick.net	Spyware cookie - fastclick.net
☒ Spyware	fastclick.net	Spyware cookie - fastclick.net
☒ Spyware	fastclick.net	Spyware cookie - fastclick.net
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☒ Spyware	fastclick.net	Spyware cookie - fastclick.net
☒ Spyware	fastclick.net	Spyware cookie - fastclick.net
☒ Spyware	mediaplex.com	Spyware cookie - mediaplex.com

Save log Save susp. Select all Select

Checking IE cookies

Sun 4/12/2015 11:55 AM

Internal Revenue Service

[!!Spam KSE]Payment confirmation

To [REDACTED]

Attachments confirmation_75991792.doc (58 KB); AT

Dear taxpayer,

You are receiving this notification because your tax r
Please find attached a copy of the approved 1040A f
On the last page, you can also find the wire transfer

Transaction type : Tax Refund
Payment method : Wire transfer
Amount : \$7592
Status : Processed
Form : 1040A

Additional information regarding tax refunds can be
Please note that IRS will never ask you to disclose pe

Regards,
Internal Revenue Service
Address: 1111 Constitution Avenue, NW
Washington, DC 20224
Website: <http://www.irs.gov>
Phone: 1-800-829-1040

YOUR COMPUTER AND FILES ARE
YOU MUST PAY 0.2 BITCOINS TO UNLOCK
YOUR FILES HAVE BEEN MOVED TO A HIDDEN PA
ESSENTIAL PROGRAMS IN YOUR COMPUTER I
AND YOUR COMPUTER WILL NOT FUNC
— 0 —
ONCE YOUR BITCOIN PAYMENT IS RECEIVED
FILES WILL BE RETURNED TO NORMAL



WARNING!

Your personal files are encrypted!

CRYPT
nts were encrypted!

YOUR BITCOIN P
1G6tQeWw6TU1qu

[COPY THE ADDRESS
[CONFIRM PAYMENT BELOW
IF YOU DO NOT HAVE BITCOINS VISIT
IF YOU HAVE MADE THE BITCOIN PAYMENT CI

I MADE PAYMENT
PLEASE VERIFY
AND UNLOCK MY COMPUTE

BBC

BBC iD

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NEWS

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University pays \$20,000 to ransomware ~~hackers~~ ACTORS

🕒 8 June 2016 | Technology

🔗 Share

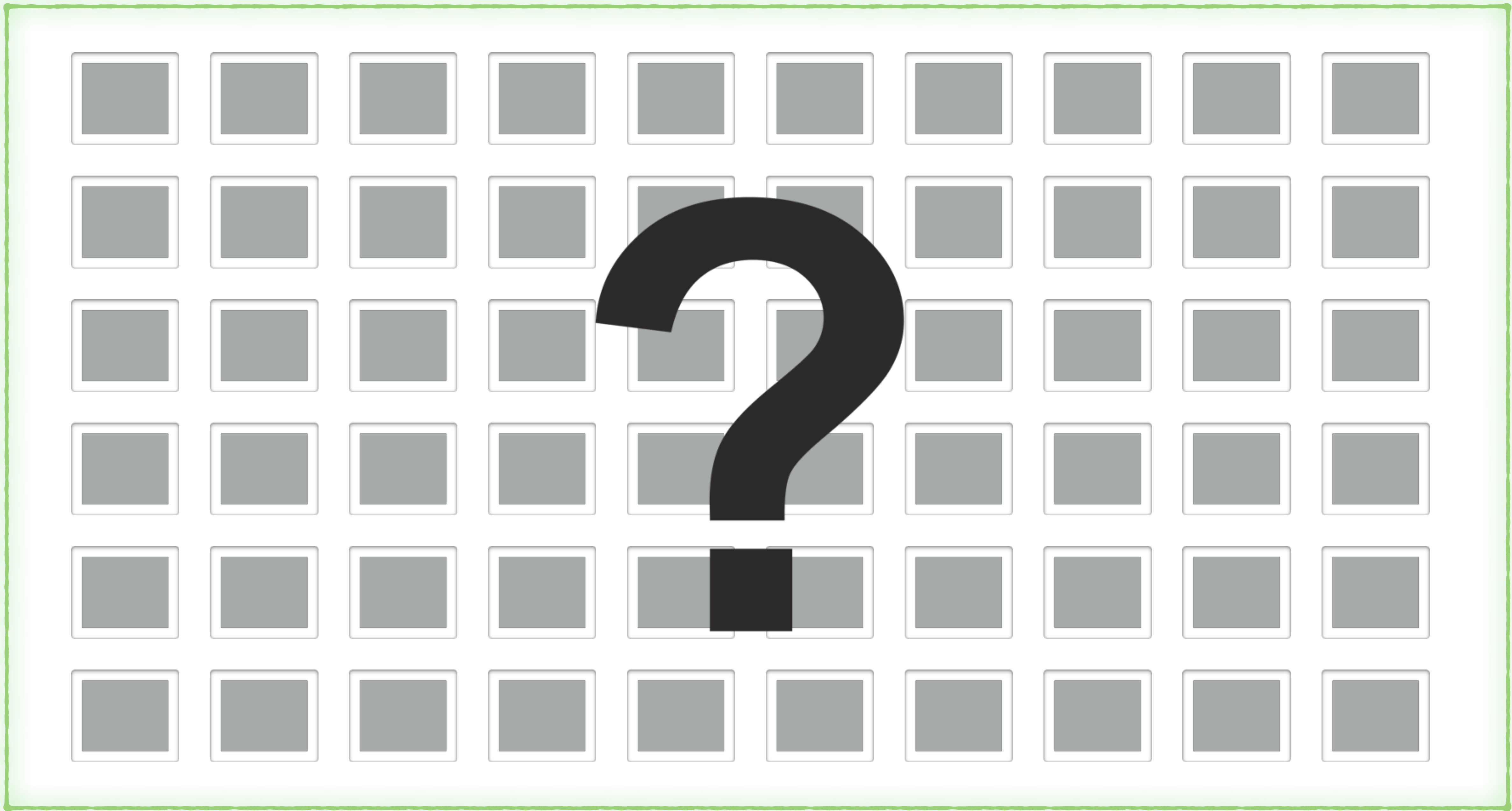
JIGSAW RANSOMWARE

-code!
our special

file.

encrypted forever)

destroy or damage your files!







“Need to communicate” > Our competitive advantage

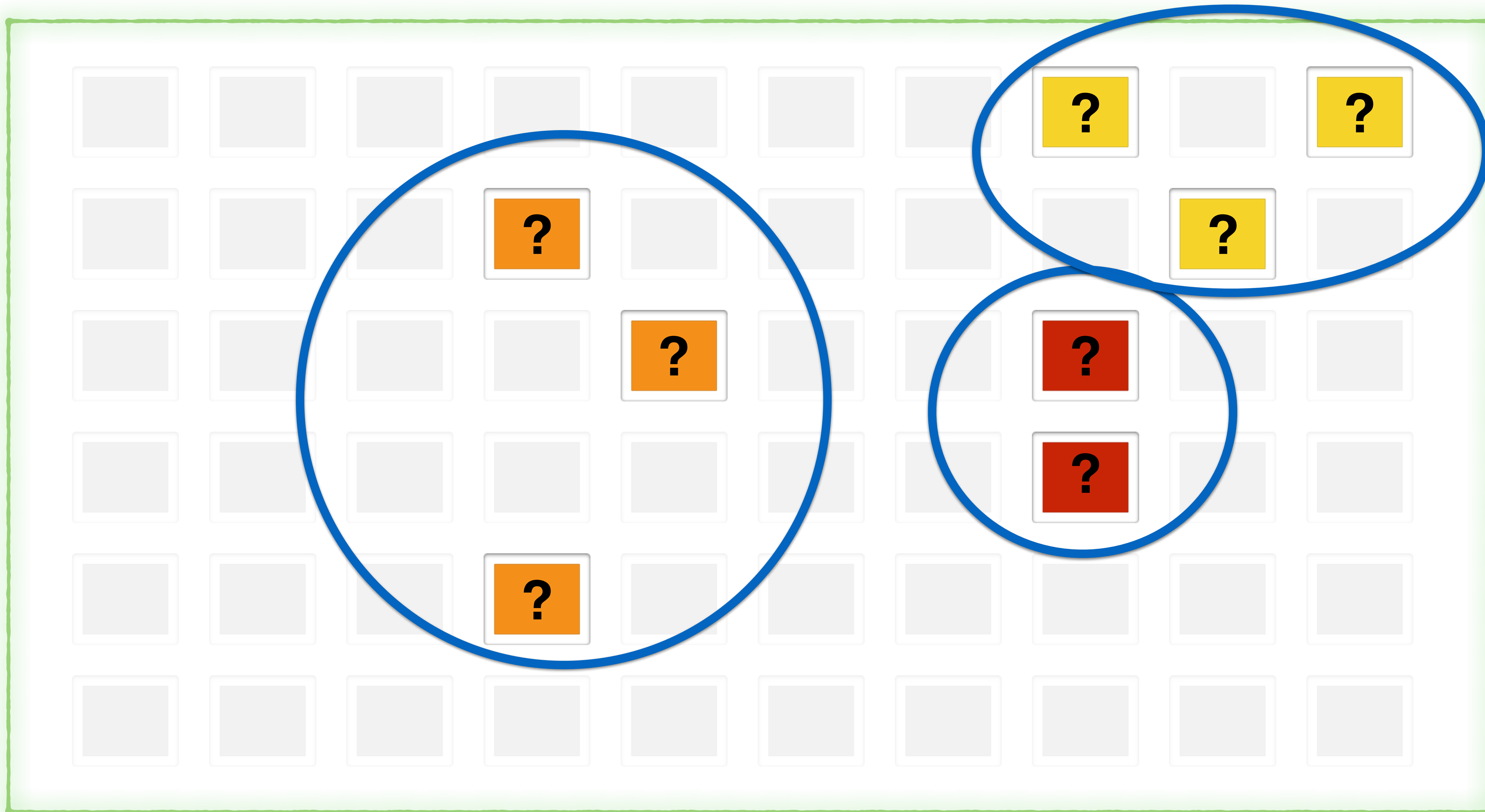
“Need to communicate” > Our competitive advantage

Big Data is no longer a problem nor a challenge

“Need to communicate” > Our competitive advantage

Big Data is no longer a problem nor a challenge

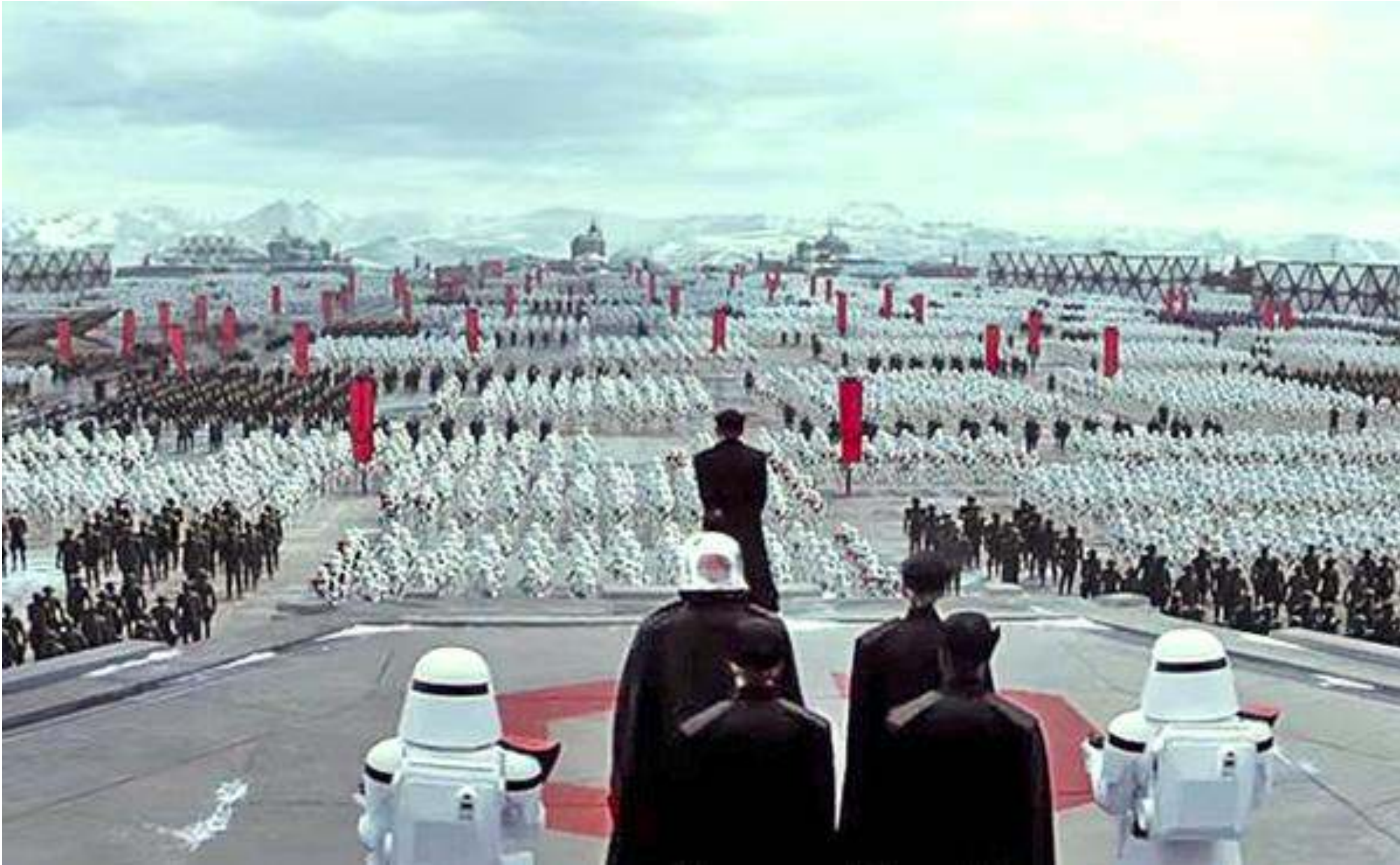
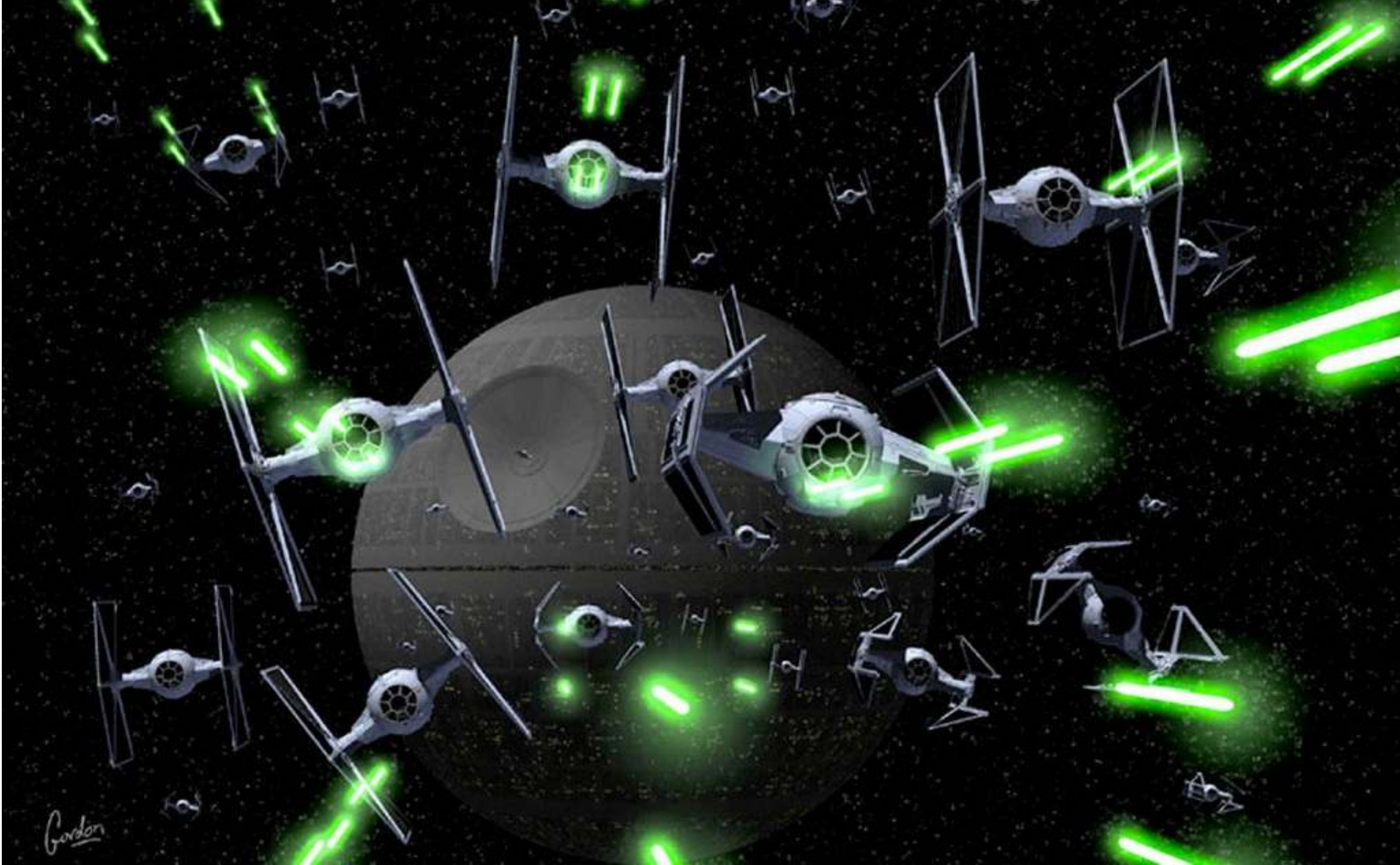
Machine Learning give us the perfect mechanism



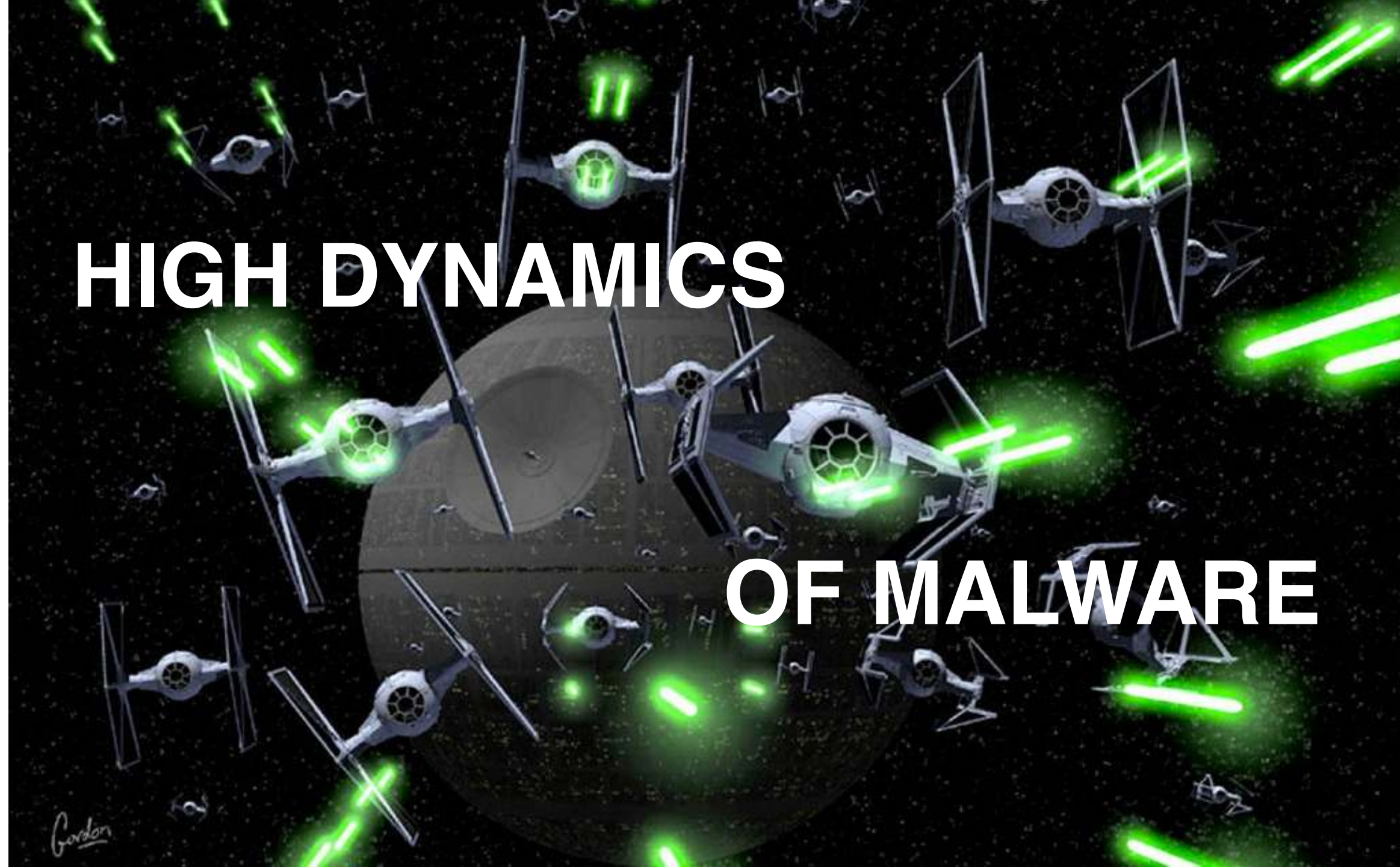


Transparency + Collaboration

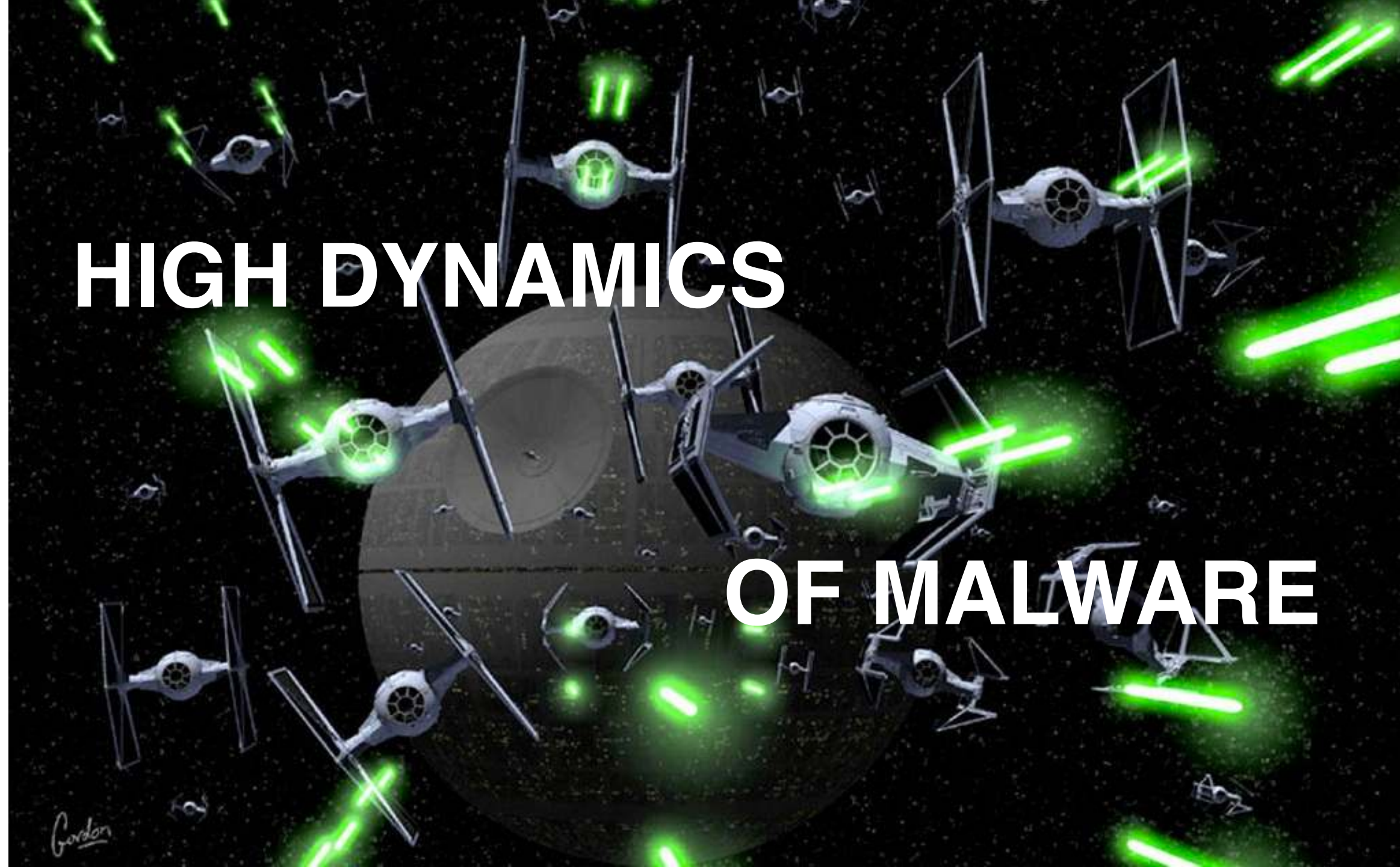
4 CHALLENGES



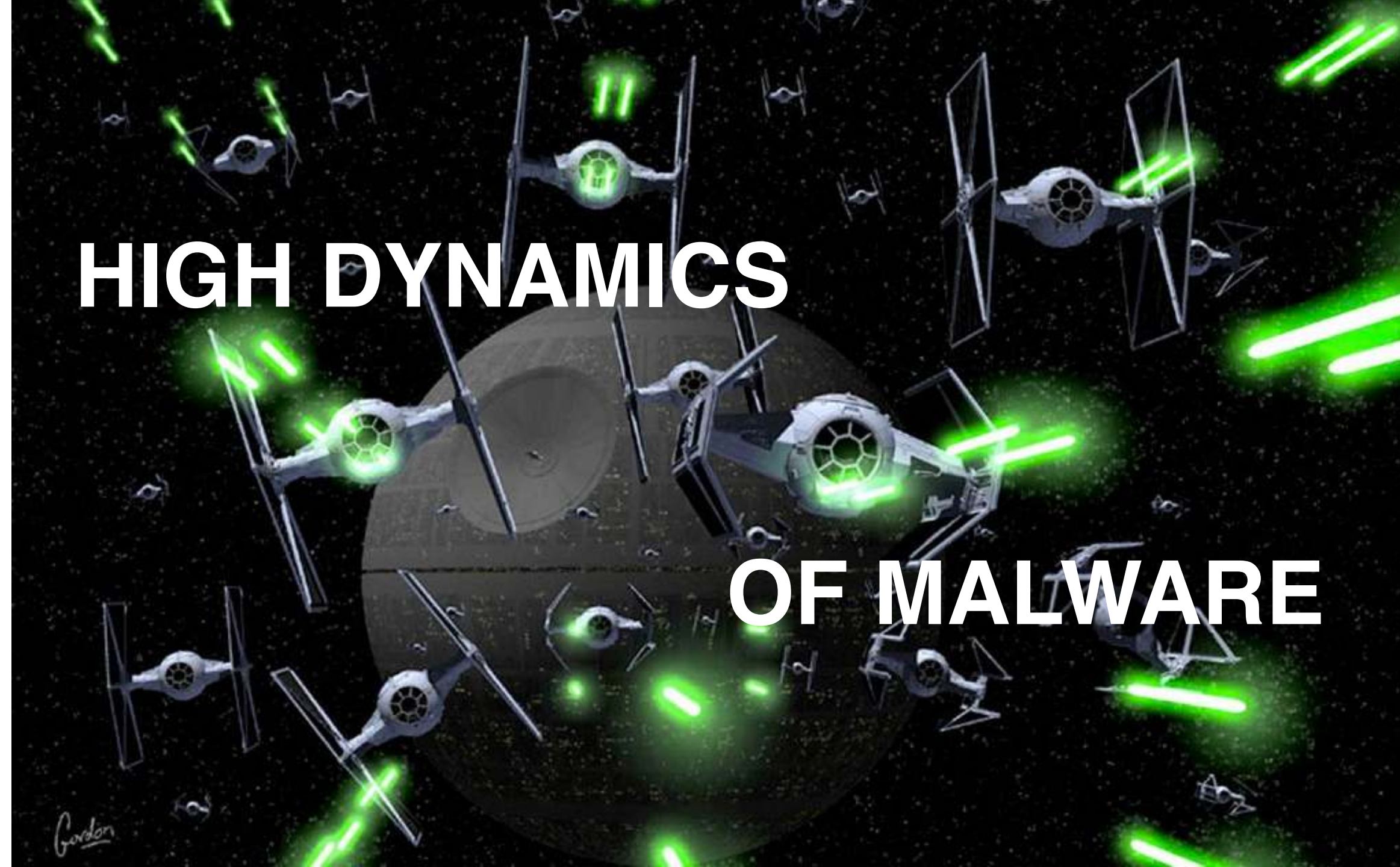
4 CHALLENGES



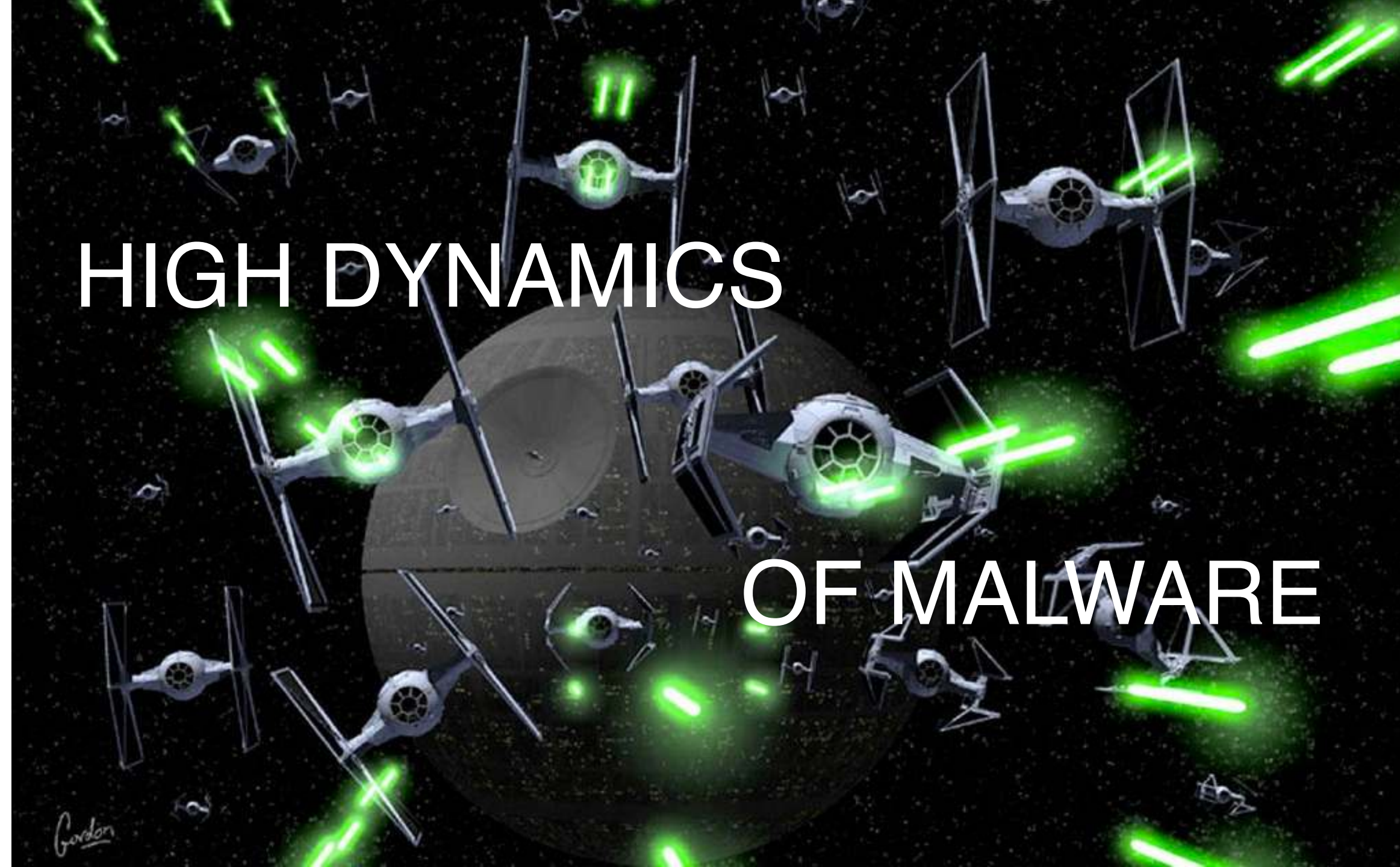
4 CHALLENGES

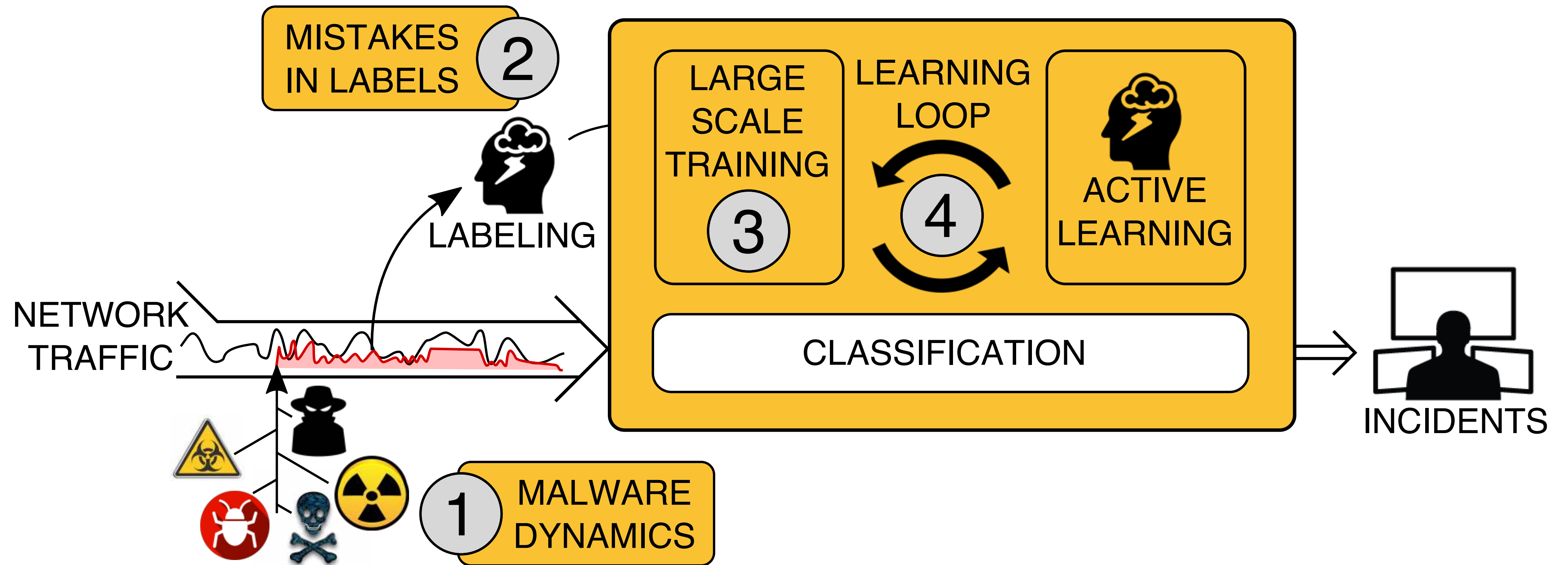


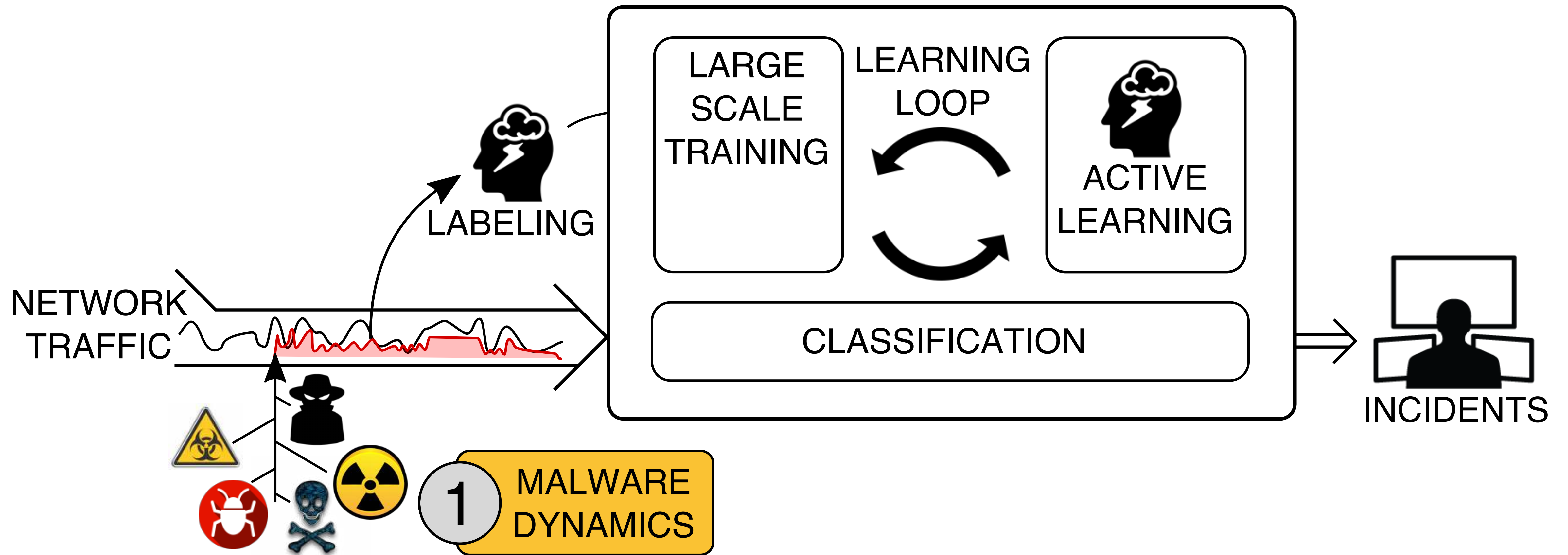
4 CHALLENGES



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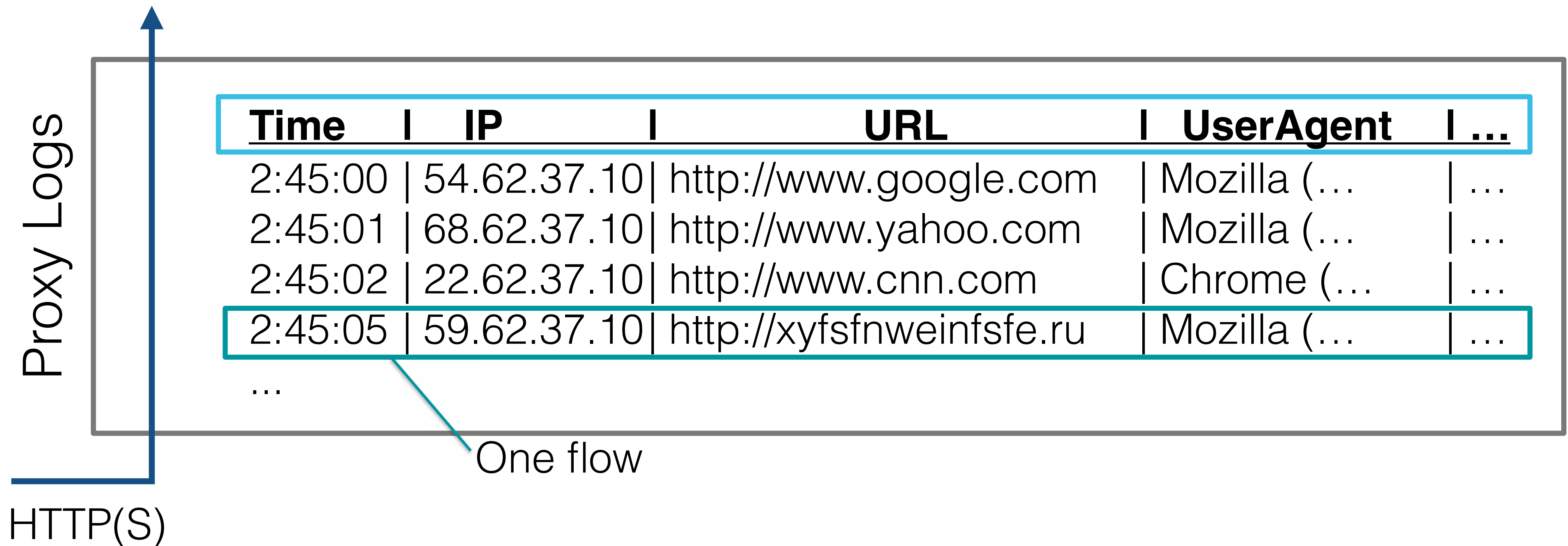




Change in Malicious Code or Payload

```
tion(a); })); $("#User_logged"); function  
if (0 == a.length) { return  
a.replace(/+(?= )/g, ""), a = a.split  
0 == r(a[c], b) || b.push(a[c])  
length; c++) {  
for (var a = $("#  
tion h() {  
    "", a = a.split(  
    a.push(a[c])
```

Countermeasure – Proxy Log Records



Network Traffic Variability

Thinking Time	Server IP Address	Hostname	URL Path/ Resource/ Parameters
02:45:01	185.163.200.15	http://chgk.ge/logo.gif?a99b4ded=-1449439763	
02:45:04	52.28.249.128	http://gim8.pl/images/logos.gif?ed13fa9b=-1269831060	
02:45:09	195.157.15.100	http://althawry.org/images/logosa.gif?ed13e406=-1587317730	
02:48:59	192.185.190.9	http://www.bijibali.com/images/logof.gif?2f18696=148149186	
02:49:04	178.162.203.226	http://kukustrustnet987.info/home.gif?228c09=9056292	
02:49:07	173.193.19.14	http://173.193.19.14/images/xs.jpg?250695=9706068	

Extracted Features

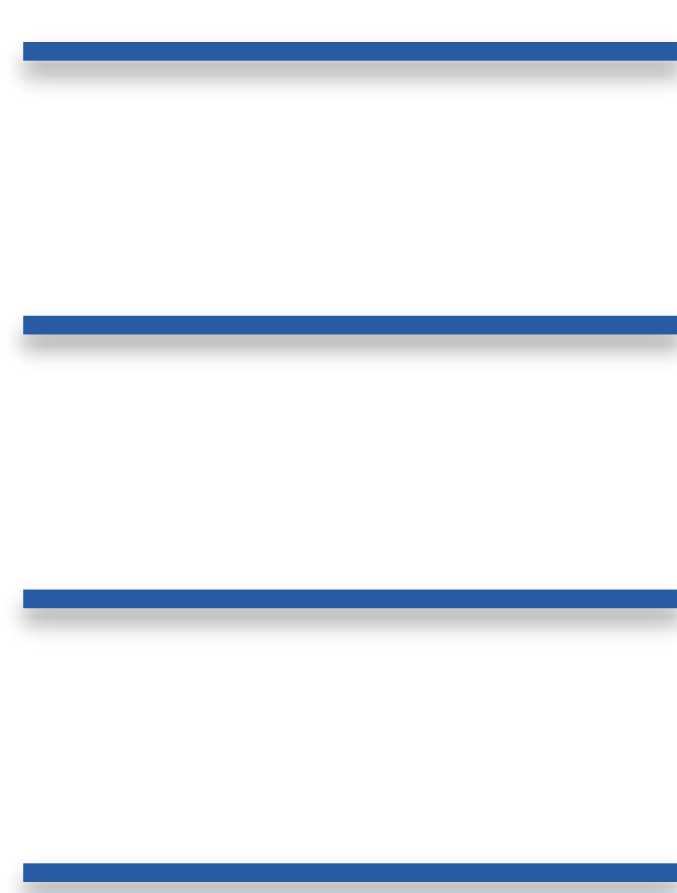
HTTP(S) based (~600):

- URL based – Related to n-grams of letters, distribution of characters, ...
- HTTP(s) request based – HTTP status, Ports, Up/Down Bytes, Referrer, User Agent, Mime Type, ...

Offline per domain/IP (~20):

- Global stats – user-domain popularity, ...
- External sources – domain age (WHOIS), ...

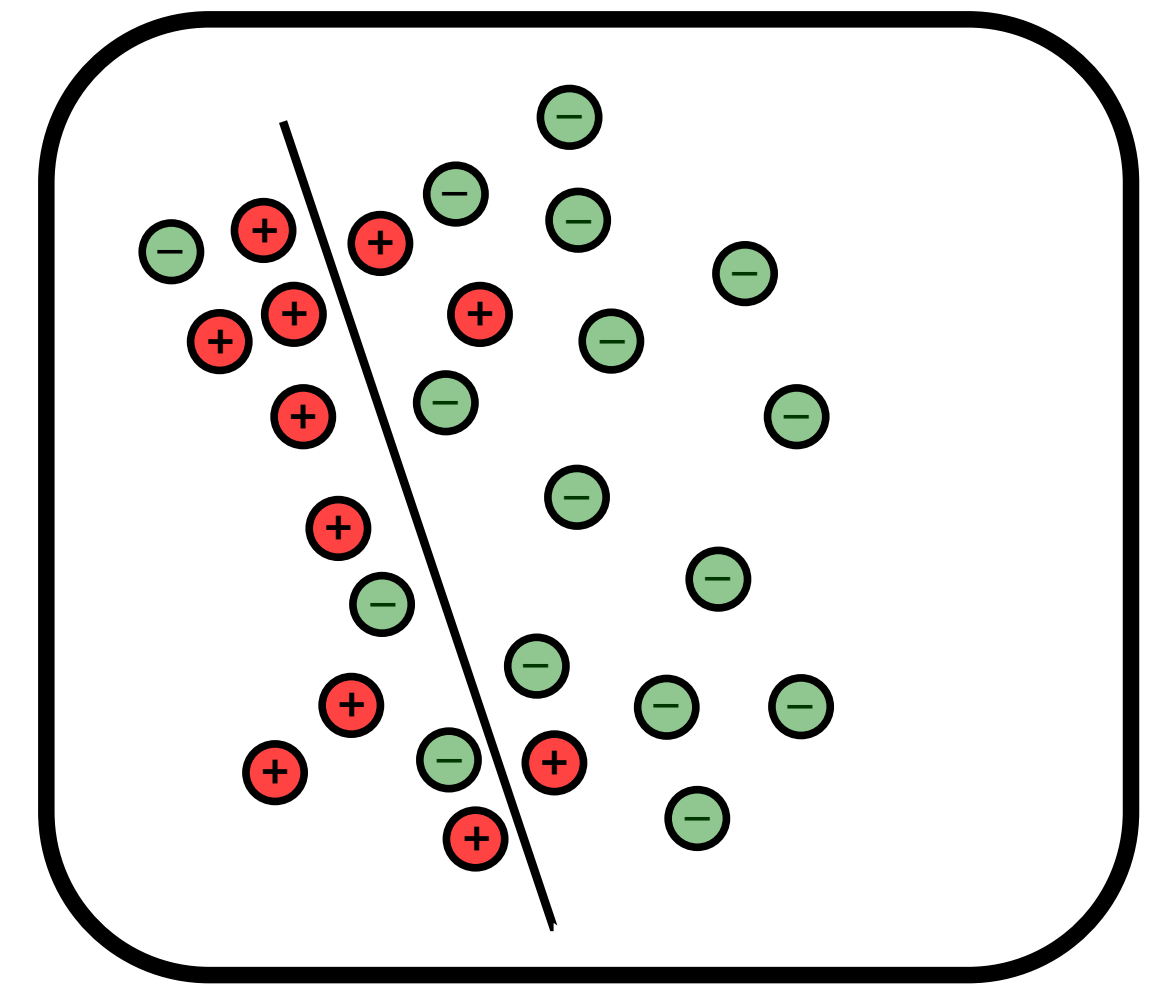
Legacy Approach



Network connection
(flow)

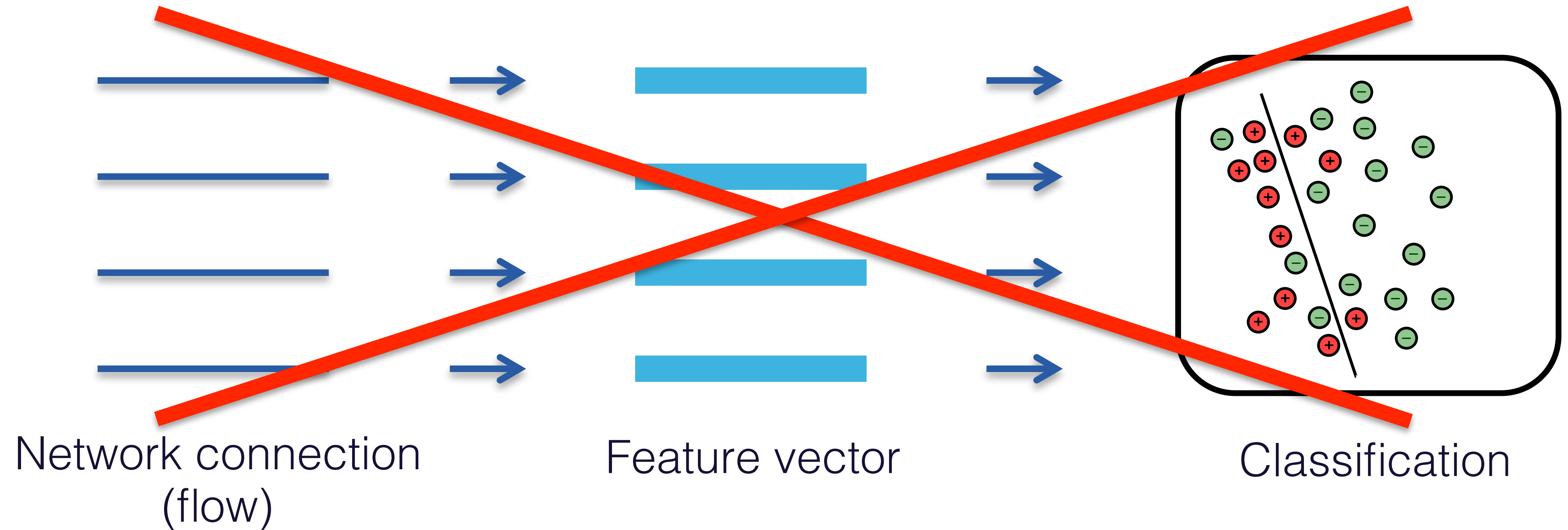


Feature vector

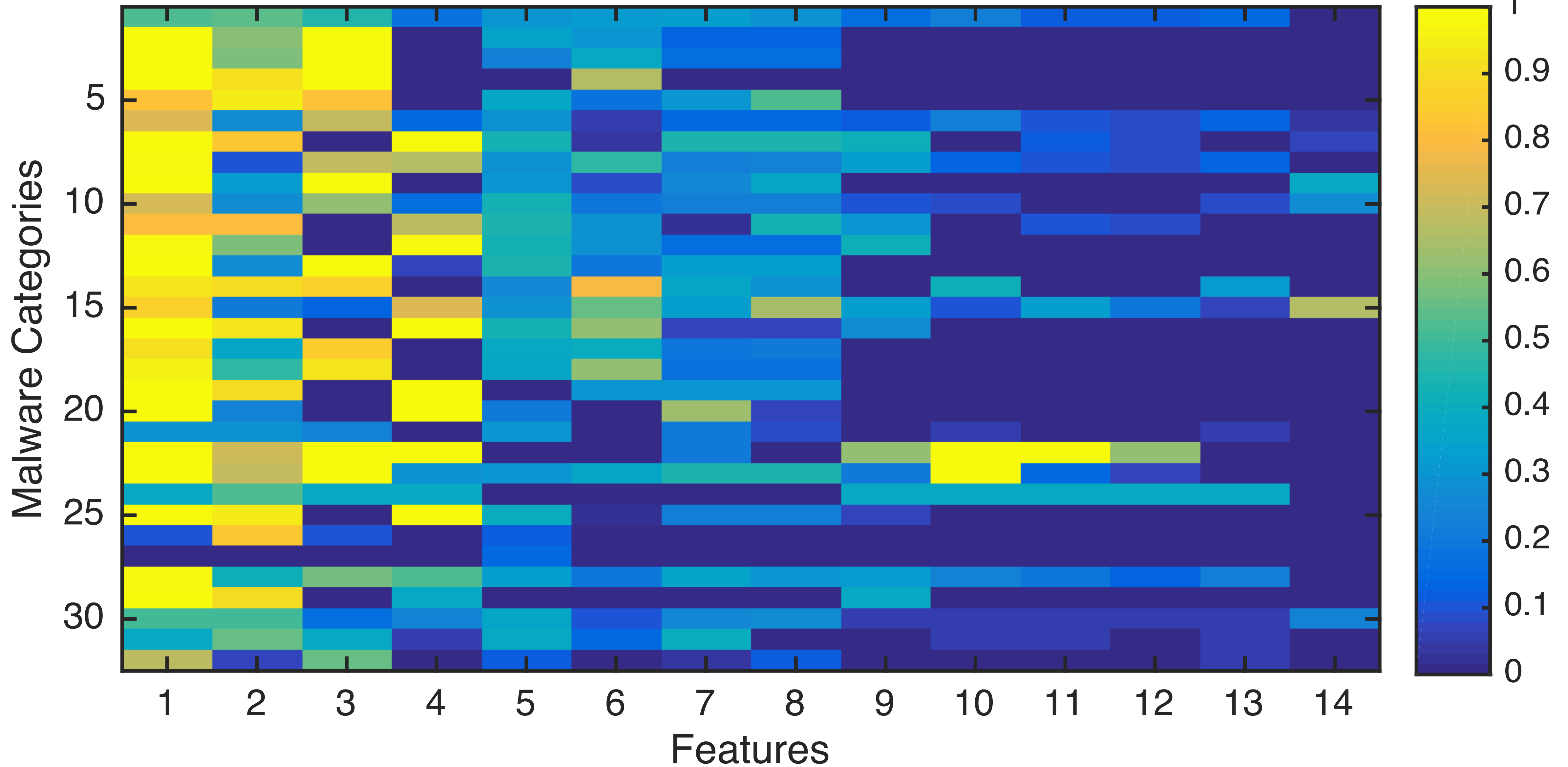


Classification

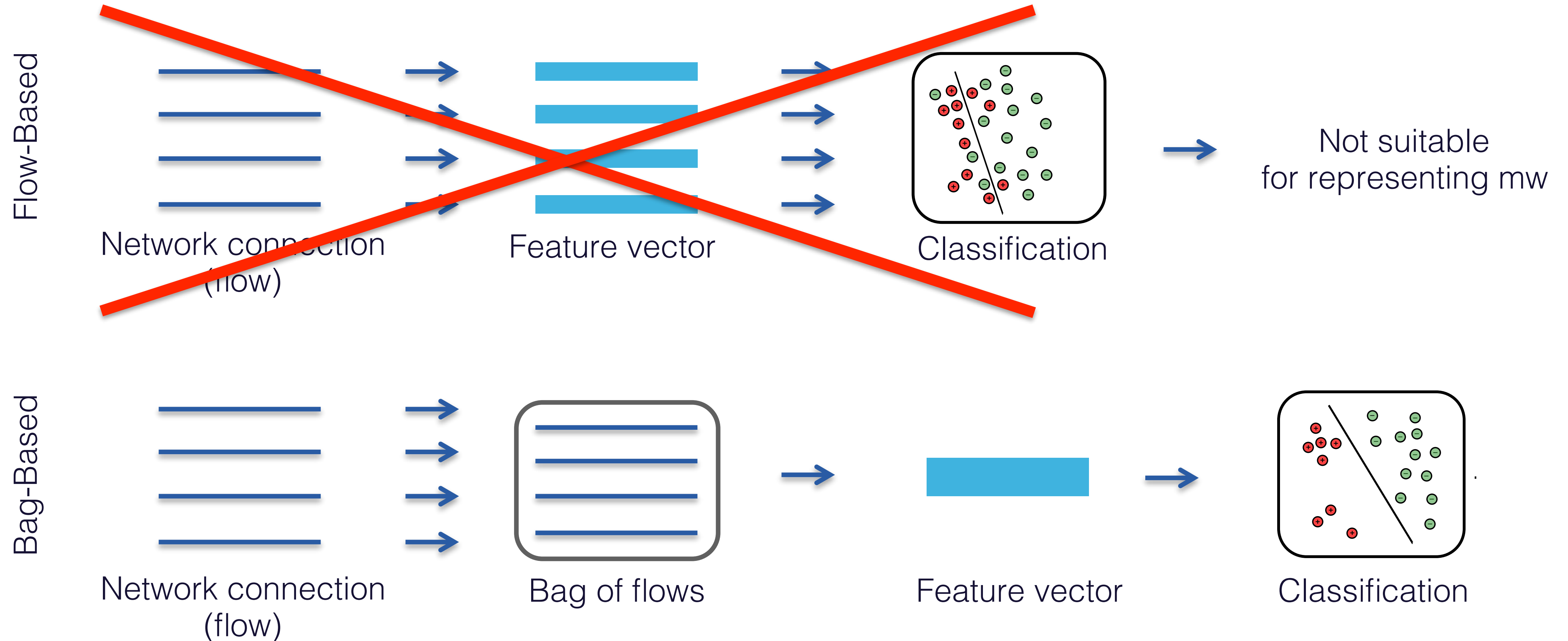
Legacy Approach



The heatmap displays a 100x100 matrix of data. The color scale ranges from dark purple (low values) to bright yellow (high values). The plot shows a complex pattern of high and low values across the matrix, with a prominent diagonal band of high values (yellow) and a large area of low values (dark purple) in the upper right quadrant.



Legacy vs. Proposed Bag Representation

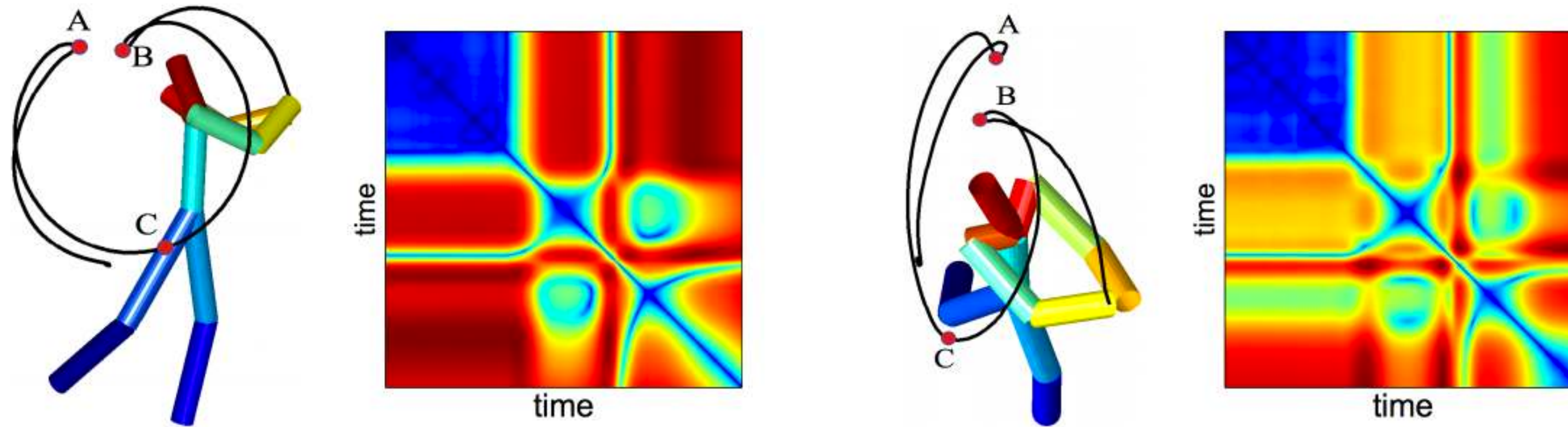


Asterope
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hxxp://194.165.16.146:8080/pgt/?ver=1.3.3753&id=126&r=8955018&os=6.1—2—8.0.7601.18571&res=4—1921—319&f=1
Click-fraud, malvertising-related botnet
hxxp://directcashfunds.com/opntrk.php?tkey=024f9730e23f8553c3e5342568a70300&Email=name.surname@company.com
hxxp://directcashfunds.com/opntrk.php?tkey=c1b6e3d50632d4f5c0ae13a52d3c4d8d&Email=name.surname@company.com
hxxp://directcashfunds.com/opntrk.php?tkey=7c9a843ce18126900c46dbe4be3b6425&Email=name.surname@company.com
hxxp://directcashfunds.com/opntrk.php?tkey=c1b6e3d50632d4f5c0ae13a52d3c4d8d&Email=name.surname@company.com
Poweliks
hxxp://31.184.194.39/query?version=1.7&sid=793&builddate=114&q=nitric+oxide+side+effects&ua=Mozilla%2F5 ... &lr=7&ls=0
hxxp://31.184.194.39/query?version=1.7&sid=793&builddate=114&q=weight+loss+success+stories&ua=Mozilla%2F5 ... &lr=0&ls=0
hxxp://31.184.194.39/query?version=1.7&sid=793&builddate=114&q=shoulder+pain&ua=Mozilla%2F5 ... &lr=7&ls=2
hxxp://31.184.194.39/query?version=1.7&sid=793&builddate=114&q=cheap+car+insurance&ua=Mozilla%2F5 ... &lr=7&ls=2
Zeus
hxxp://130.185.106.28/m/IbQFdXVjiriLva4KHeNpWCmThrJBn3f34HNwsLVVsUmLXtsumSSPe/zzXtlu9SzwjI9zKlxdE ... 3RqvGzKN5
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hxxp://130.185.106.28/m/IbQJFUVjiJwJBX4KHeNpWCmThrJBn3f34HNwsLVVsUmKH7ue2STvSkzzXtlu9SzwjI9zKlxdE ... 3vKwmk0oUi
hxxp://130.185.106.28/m/IbQNtVVji5/7Yp4KHeNpWCmThrJBn3f34HNwsLVVsUmLz4sO6YRvOjzzXtlu9SzwjI9zKlxdE ... 3zB9057quqv
Legitimate traffic 1
hxxp://www.cnn.com/.element/ssi/auto/4.0/sect/MAIN/markets_wsod_expansion.html
hxxp://www.cnn.com/.a/1.73.0/assets/sprite-s1dced3ff2b.png
hxxp://www.cnn.com/.element/widget/video/videoapi/api/latest/js/CNNVideoBootstrapper.js
hxxp://www.cnn.com/jsonp/video/nowPlayingSchedule.json?callback=nowPlayingScheduleCallbackWrapper&_=1422885578476

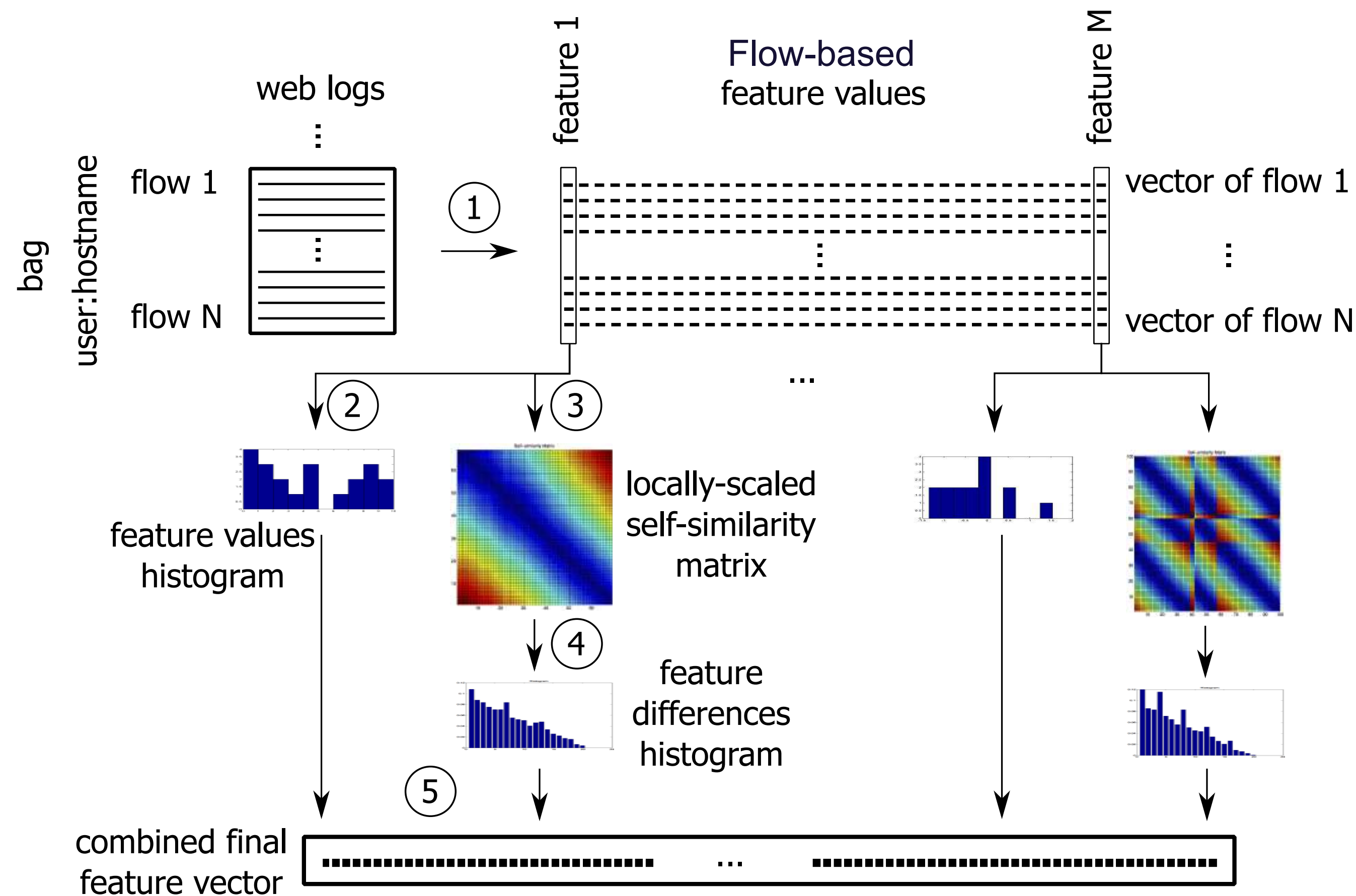
MALICIOUS
BAGS

LEGITIMATE
BAG

Parallel to Action Recognition

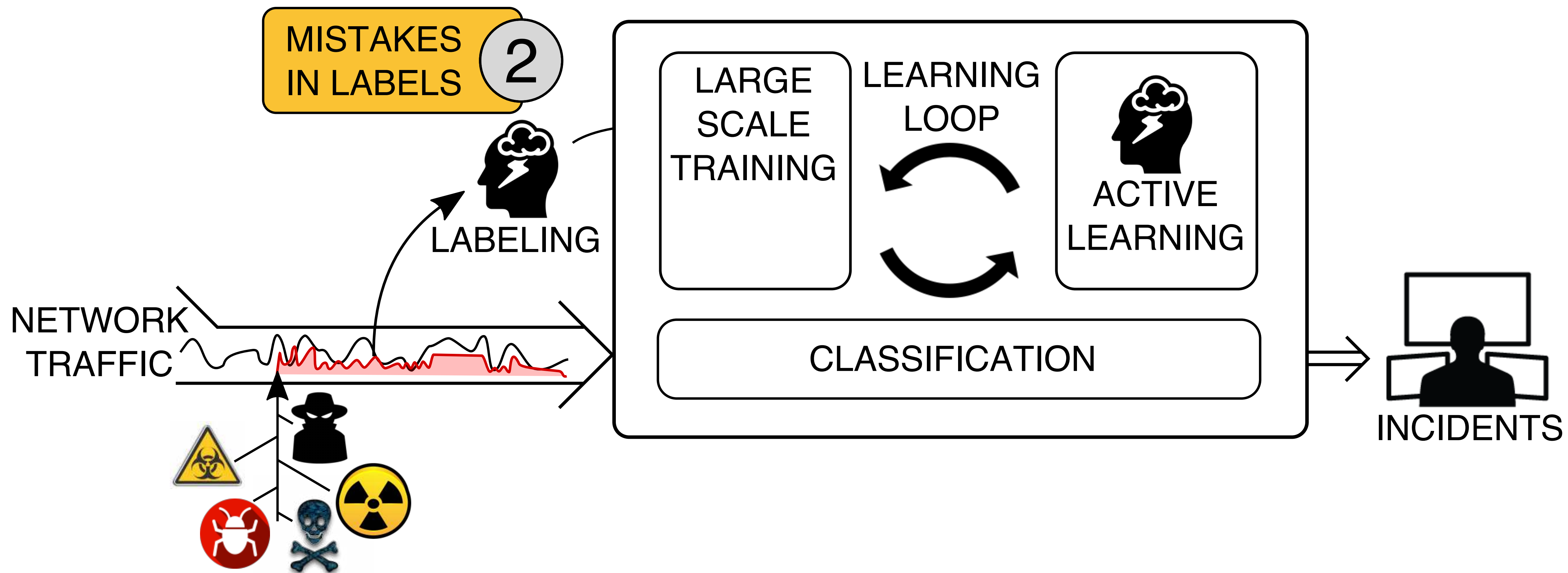


Invariant Representation* – Overview



- 1 – create bag
+ extract flow-based feature vectors
- 2 – create feature values histogram
- 3 – create self-similarity matrix
- 4 – create feature differences histogram
- 5 – combine into final feature vector

* Karel Bartoš, Michal Sofka, Vojtěch Franc



Week Labels for Training?

Small amount of reliable labels



Week Labels for Training?

Large amount of week labels (blacklists, feeds)

Can we use them for training? Mistakes?

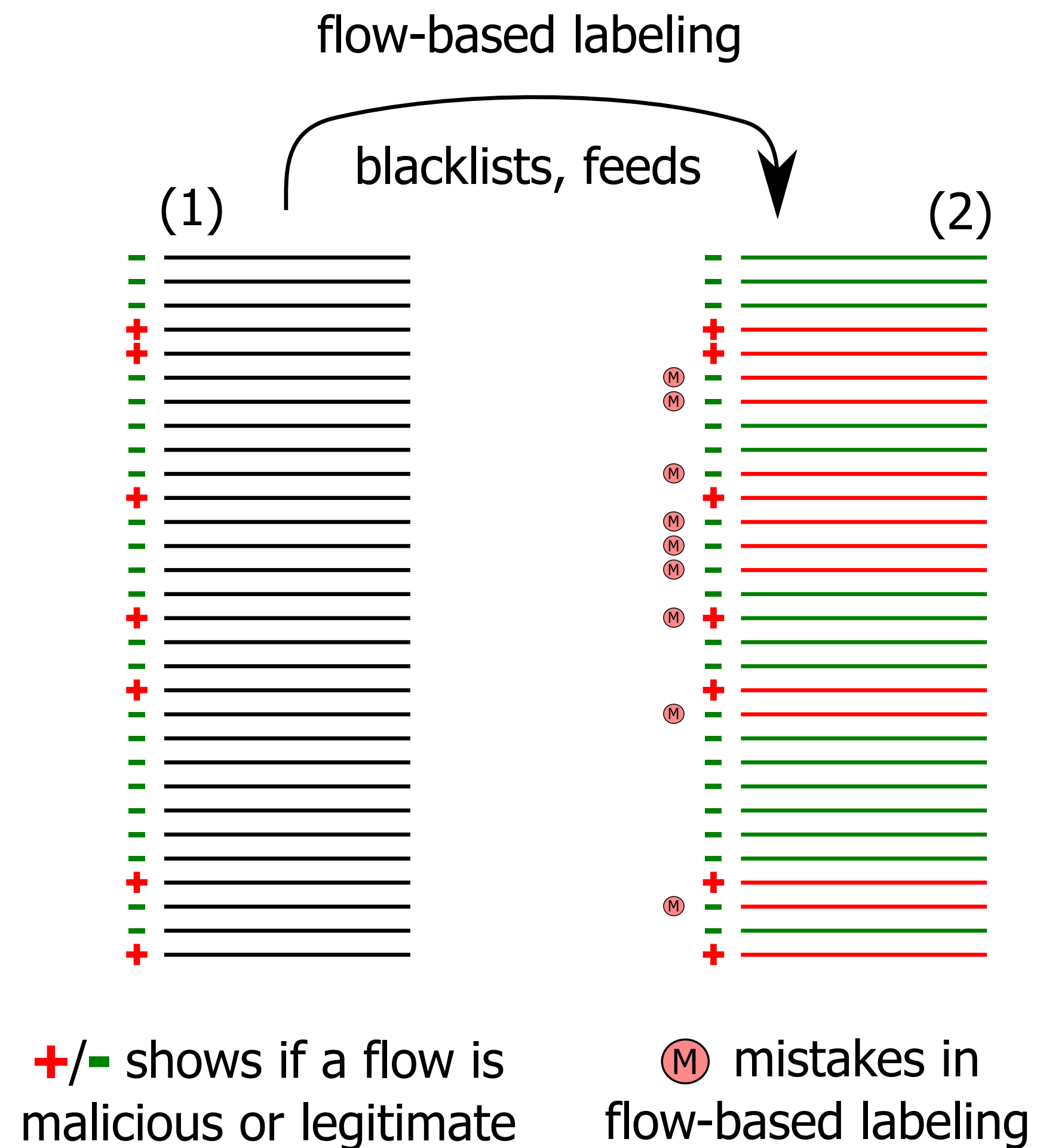


Multiple Instance Learning (MIL)

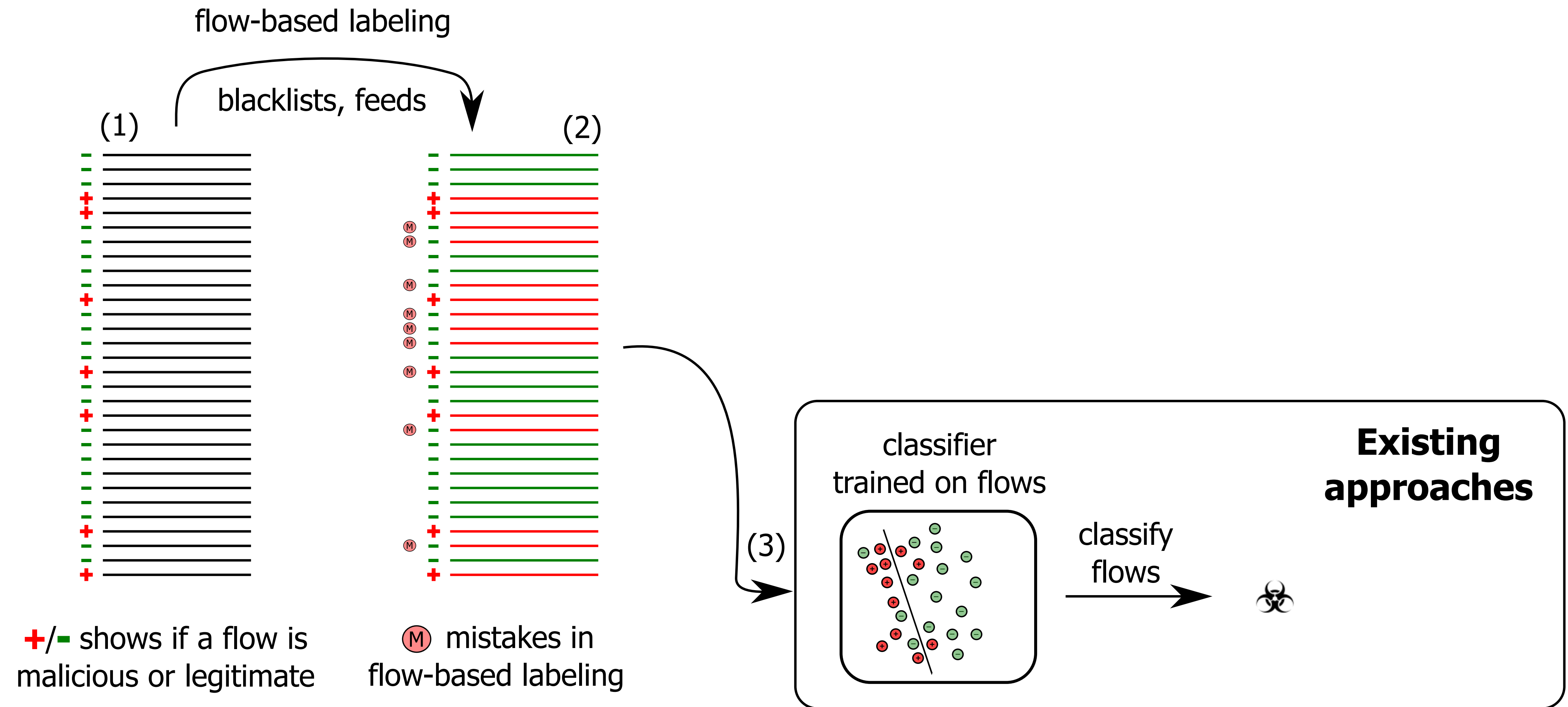


+/- shows if a flow is
malicious or legitimate

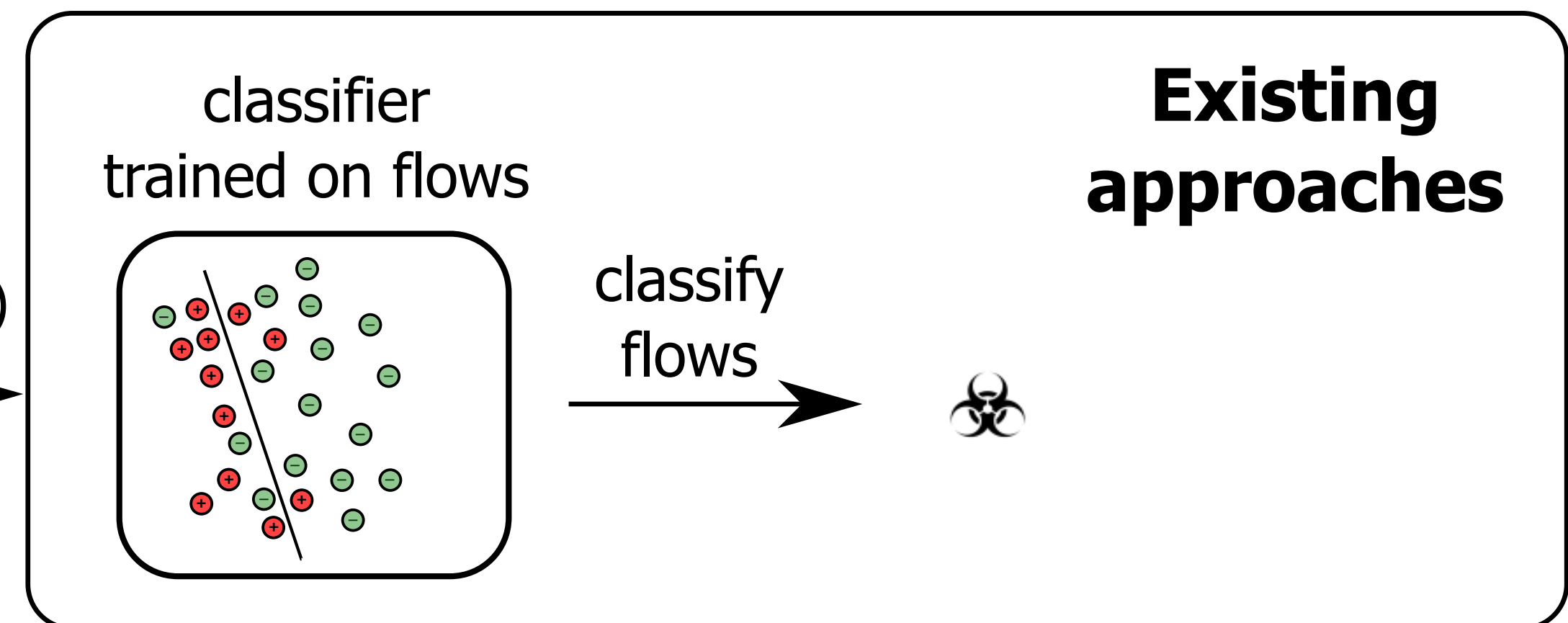
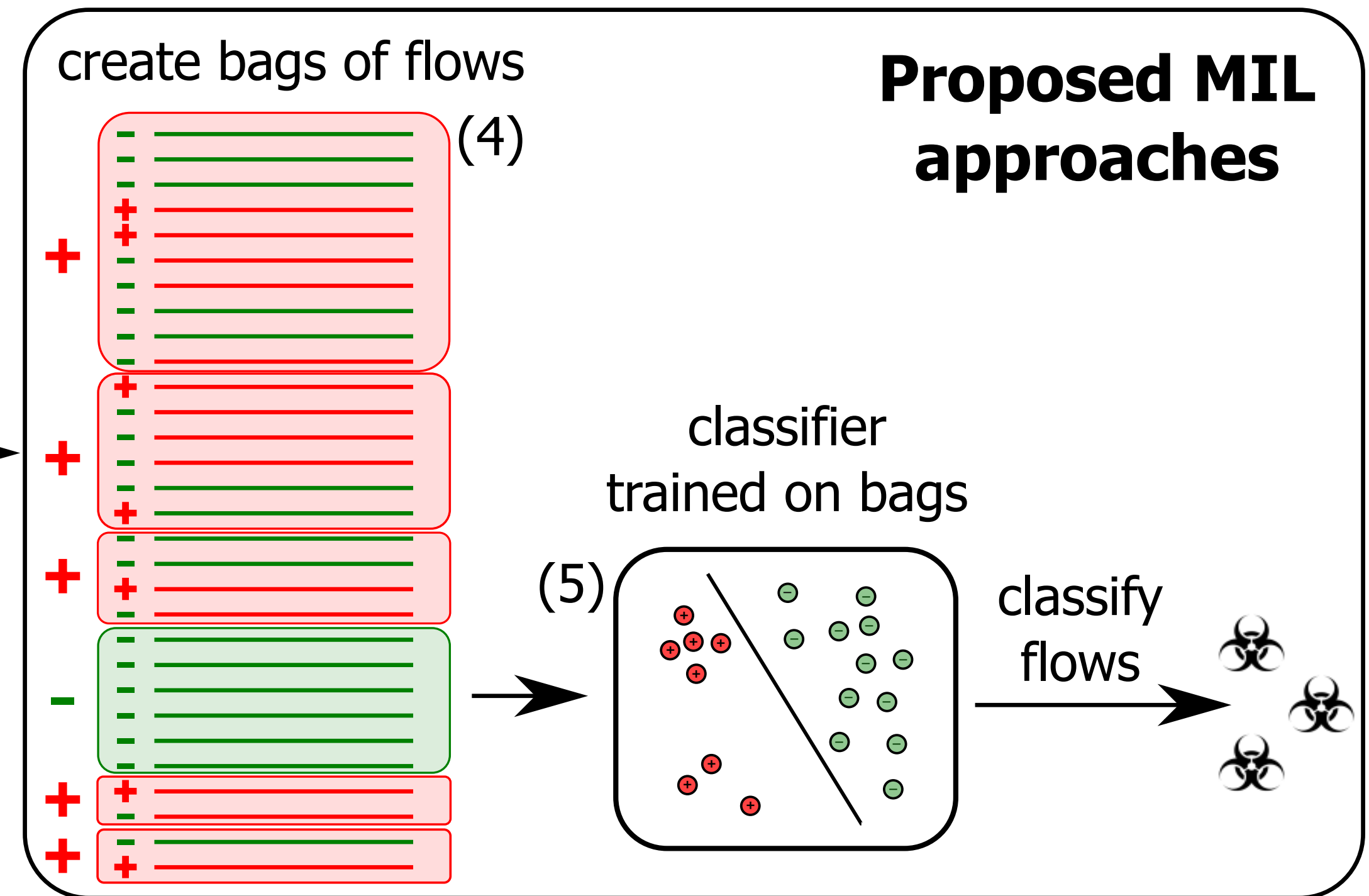
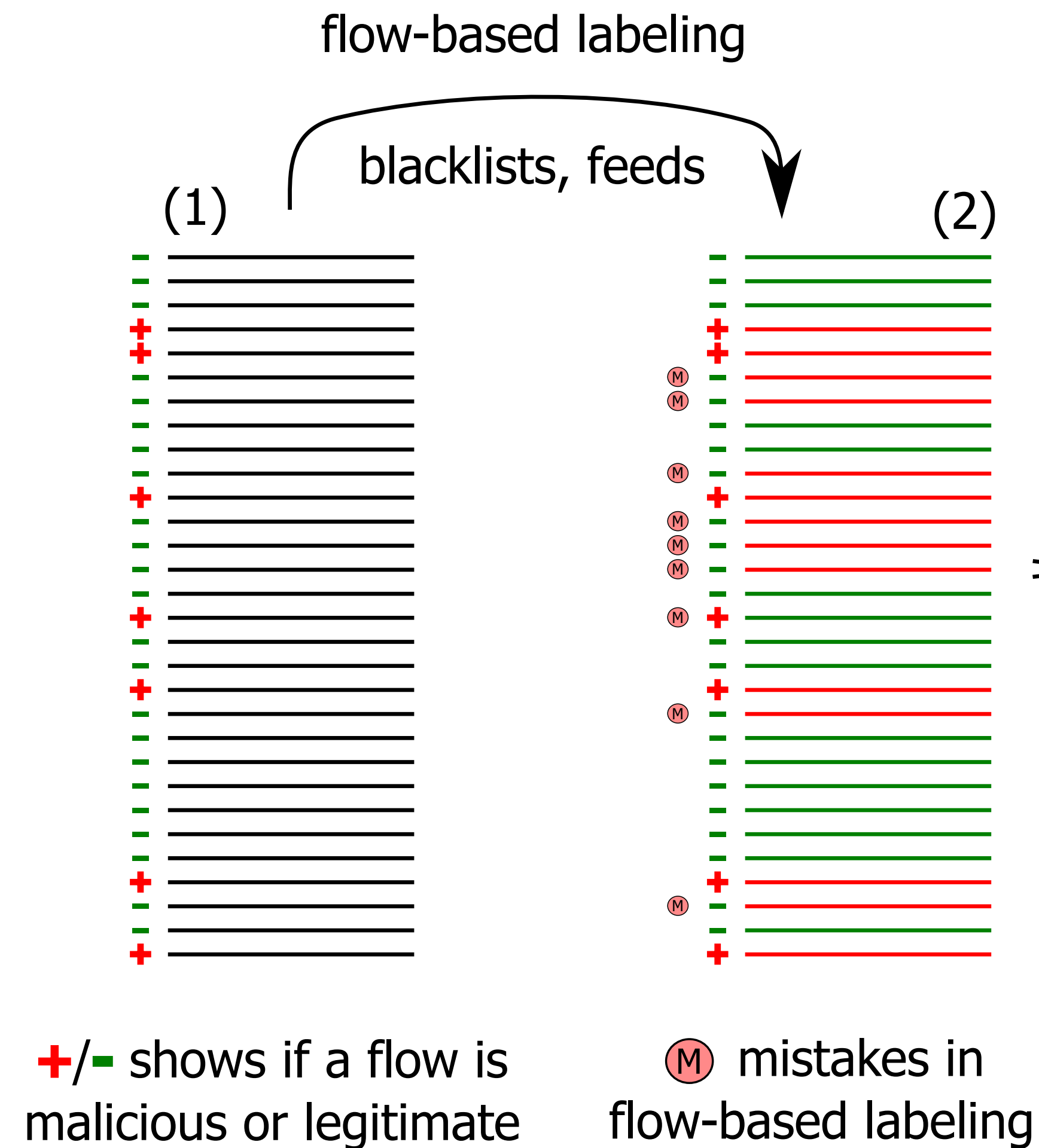
Multiple Instance Learning (MIL)



Multiple Instance Learning (MIL)



MIL*



* Vojtěch Franc, Michal Sofka, Karel Bartoš: Learning detector of malicious network traffic from weak labels. ECML-PKDD 2015

Wide Classification Capability

Cryptowall

<http://zerosumstudio.com/img5.php?z=smnk91cpnmd>

<http://zerosumstudio.com/img5.php?z=sd04vutaog>

<http://zerosumstudio.com/img5.php?z=snmofp2ye0x>

Goznym Banking Trojan

<http://carvezine.com/chdcm.php?gvo=miovlbwds&pbhpuo=03625369&oo...>

<http://carvezine.com/nnlgz.php?pmgl=wyyneckyuok&nlm=vzhuhjachy&nptr...>

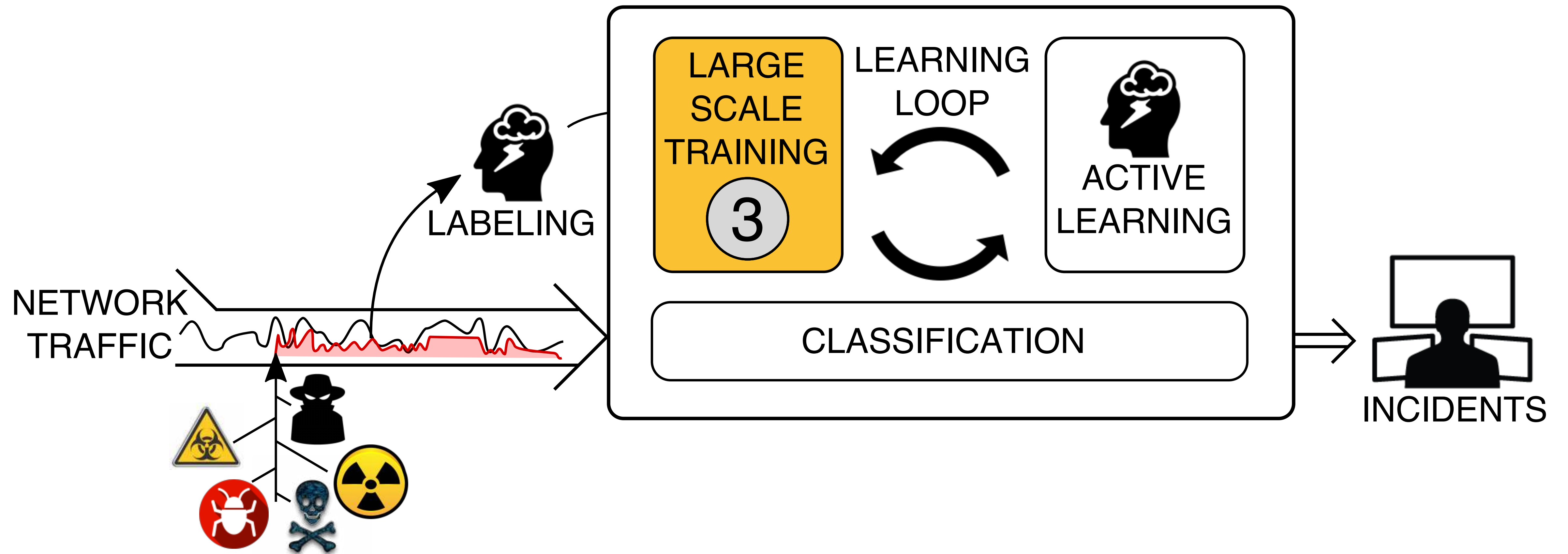
<http://carvezine.com/syajsg.php?lmtzkhhj=xmilzwgox&djax=1PhY8FI2NioY...>

Rig Exploit Kit

<http://ds.revivefl.org/?x3qJc7iZLBrGAoc=13SKfPrfJxzFGMSUb-nJDa9BMEX...>

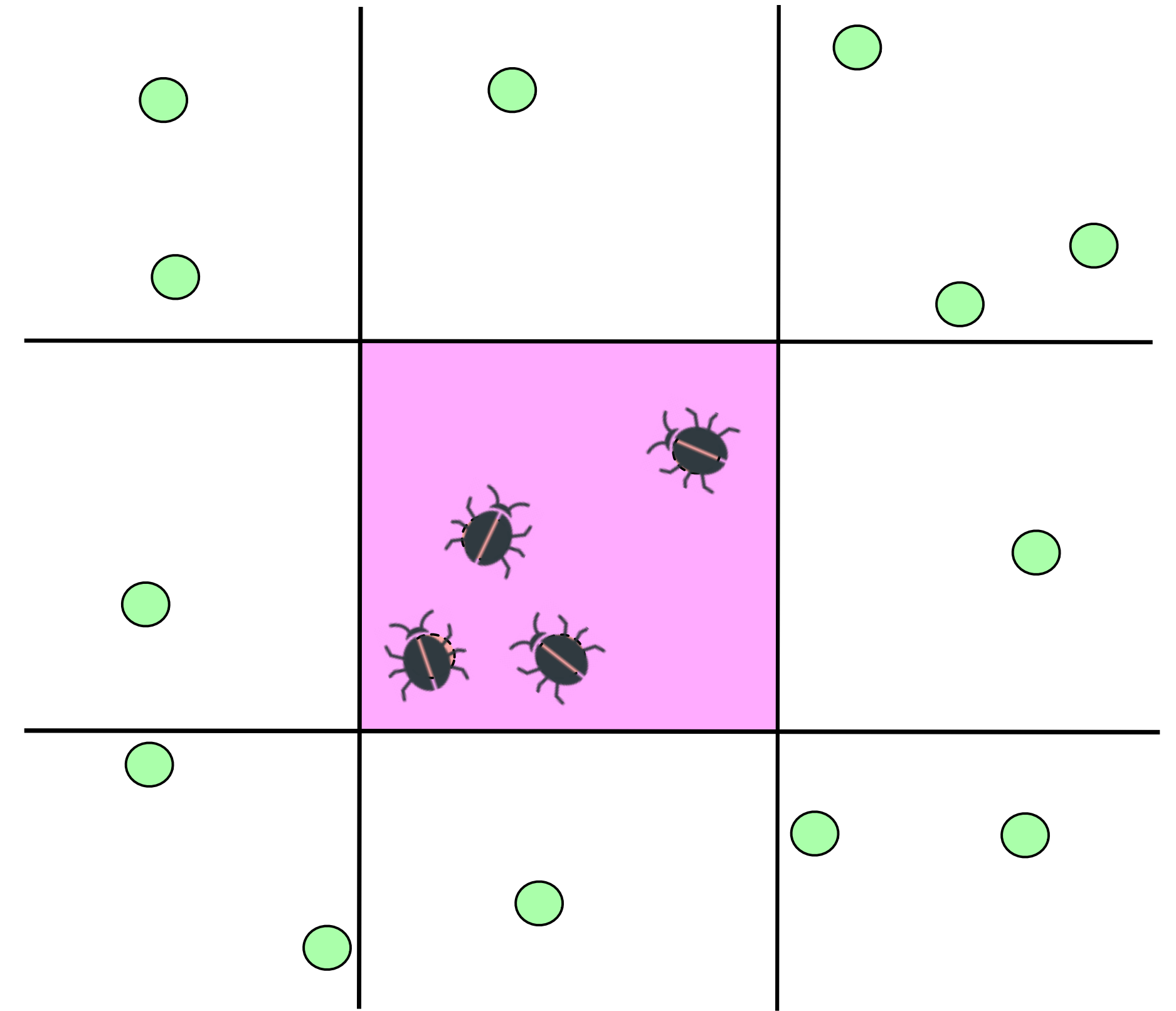
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http://ds.revivefl.org/index.php?h4SGhKrXCJ-ofSih17OIFxzsmTu2KV_Opqxv...



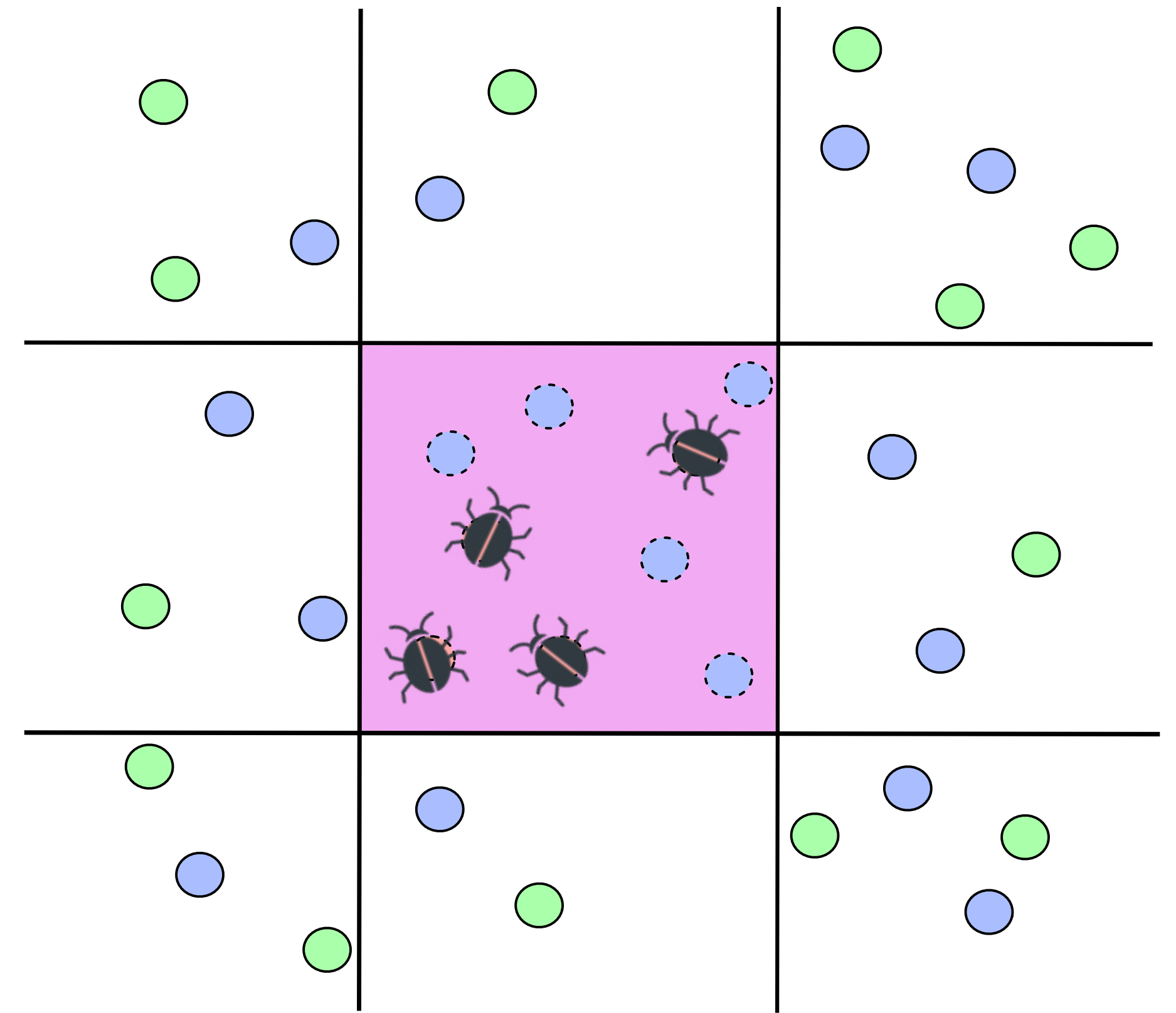
How to Sample Training Data

1 day = +10 billion requests
(millions of users and devices)



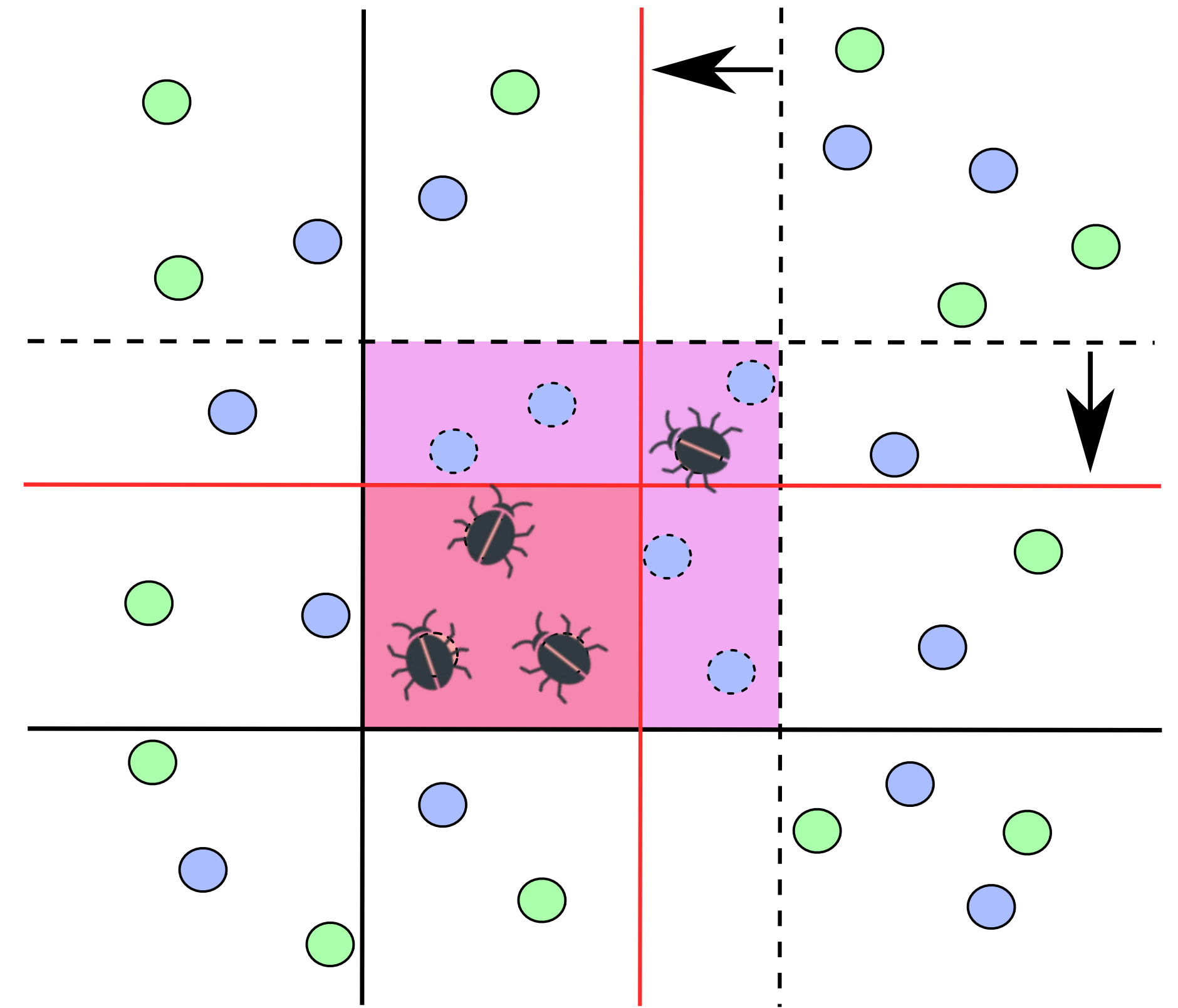
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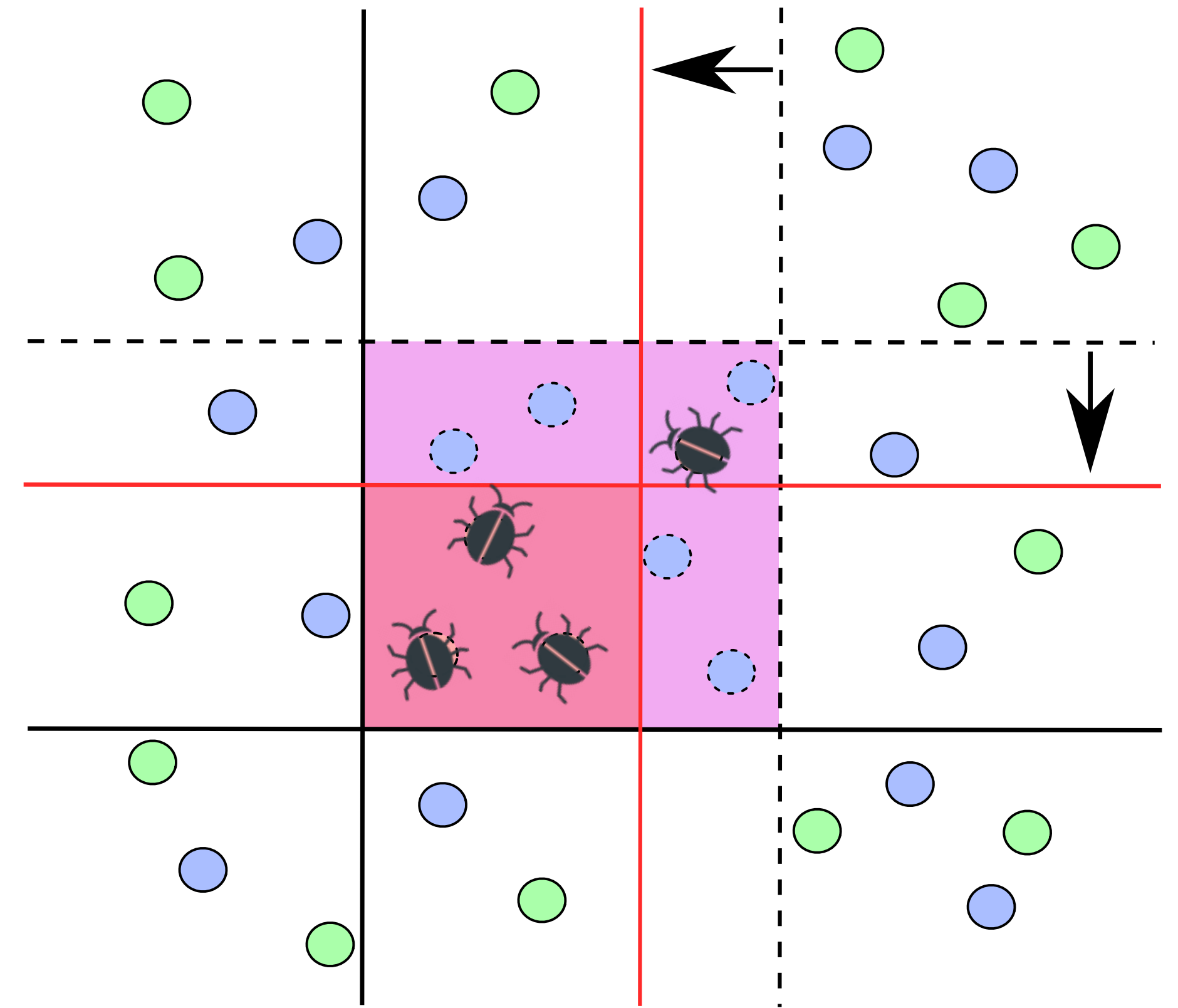
How to Sample Training Data

1. **RANK** the traffic according to the **SCORE** of statistical classifiers
2. Take only **TOP-*N*** samples as the **NEGATIVES**
3. **COLLECT** samples across longer time period



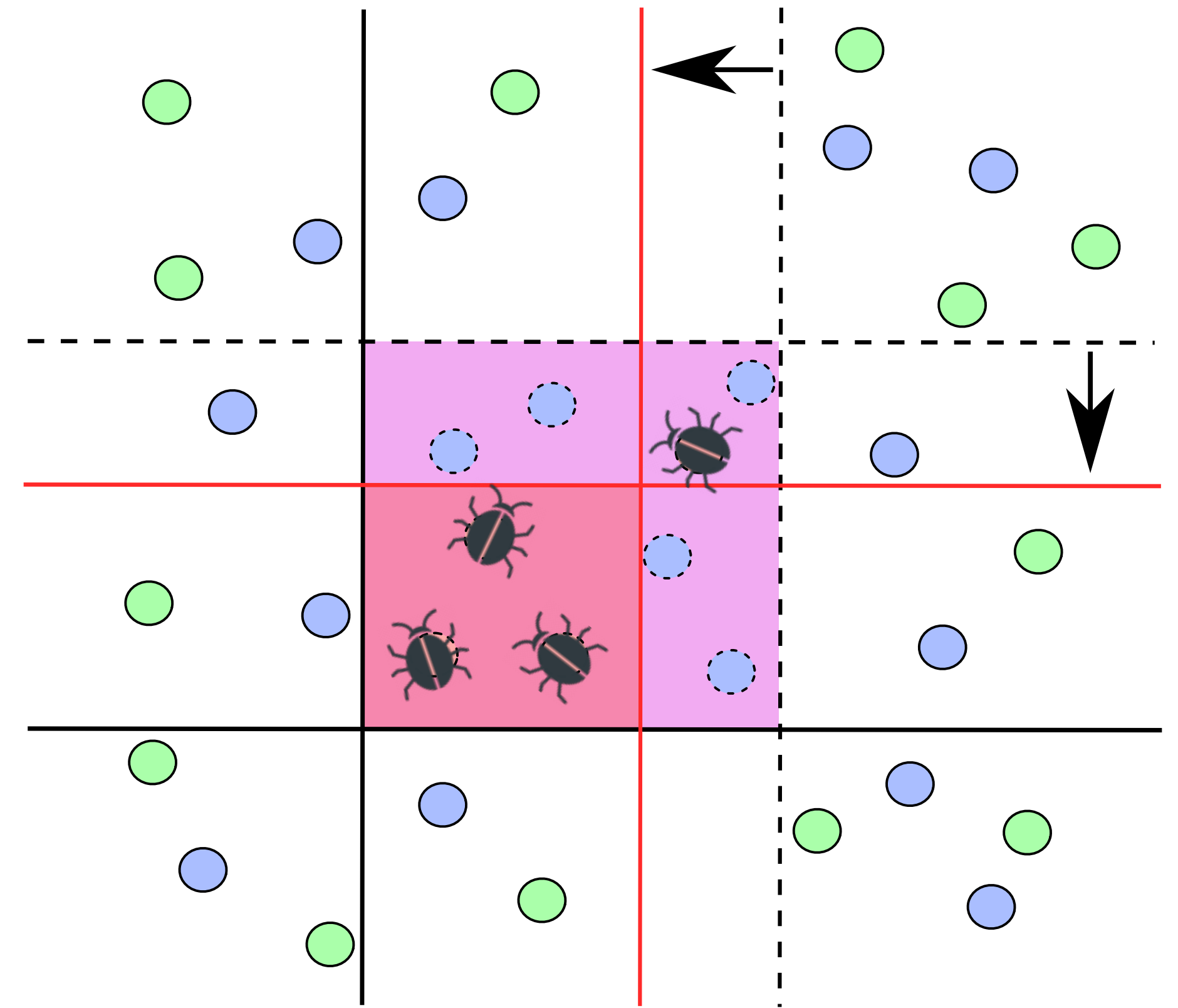
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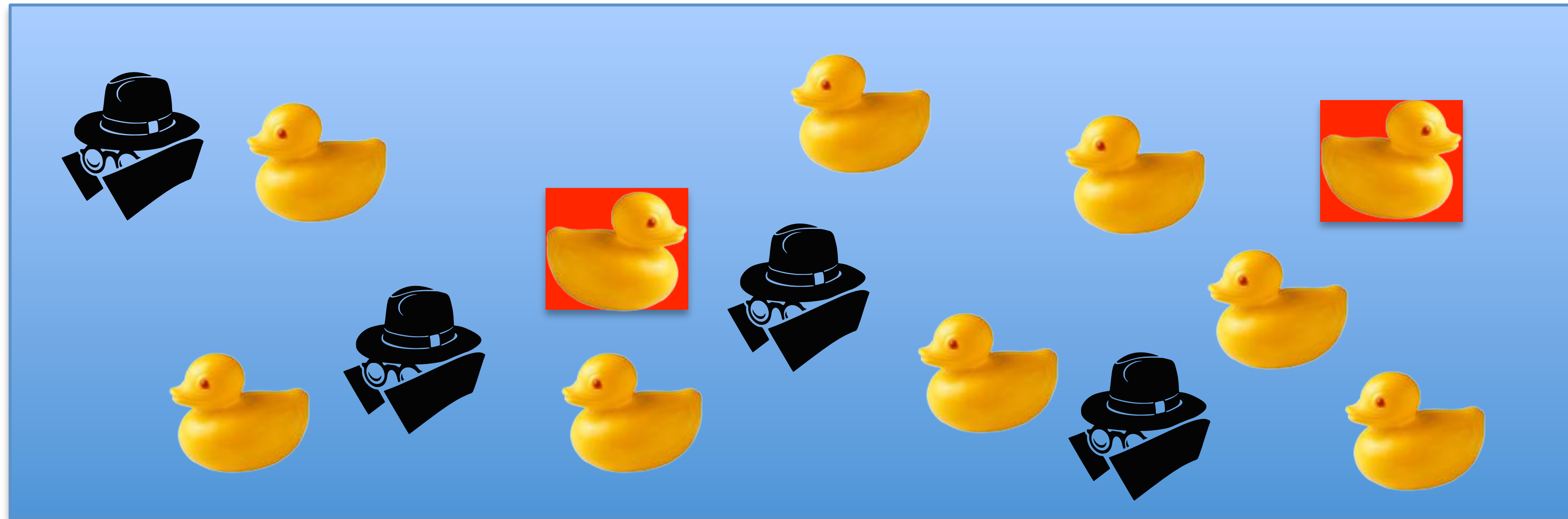
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Positive-Unlabeled Training*

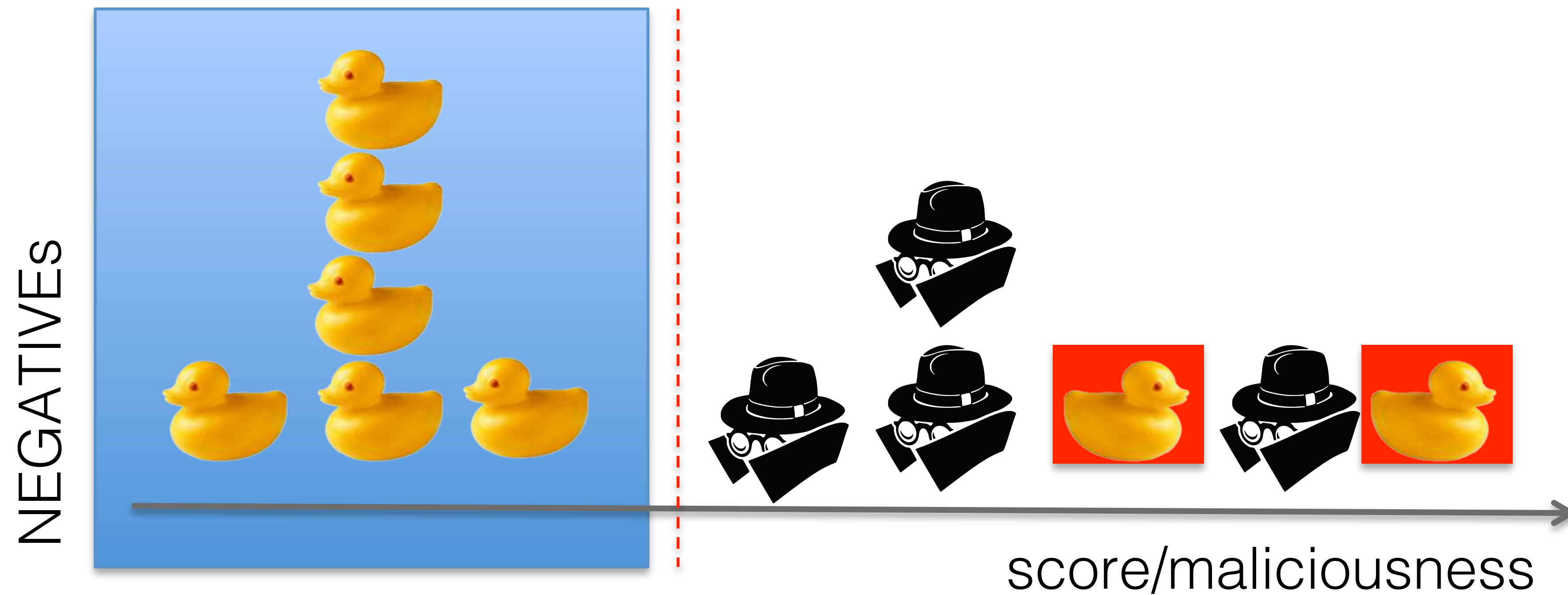
POOL OF NEGATIVES



 = spy/known positive  = malicious duck  = benign duck

* X. Li, B. Liu, S.K. Ng: Negative Training Data can be Harmful to Text Classification, 2010, EMNLP

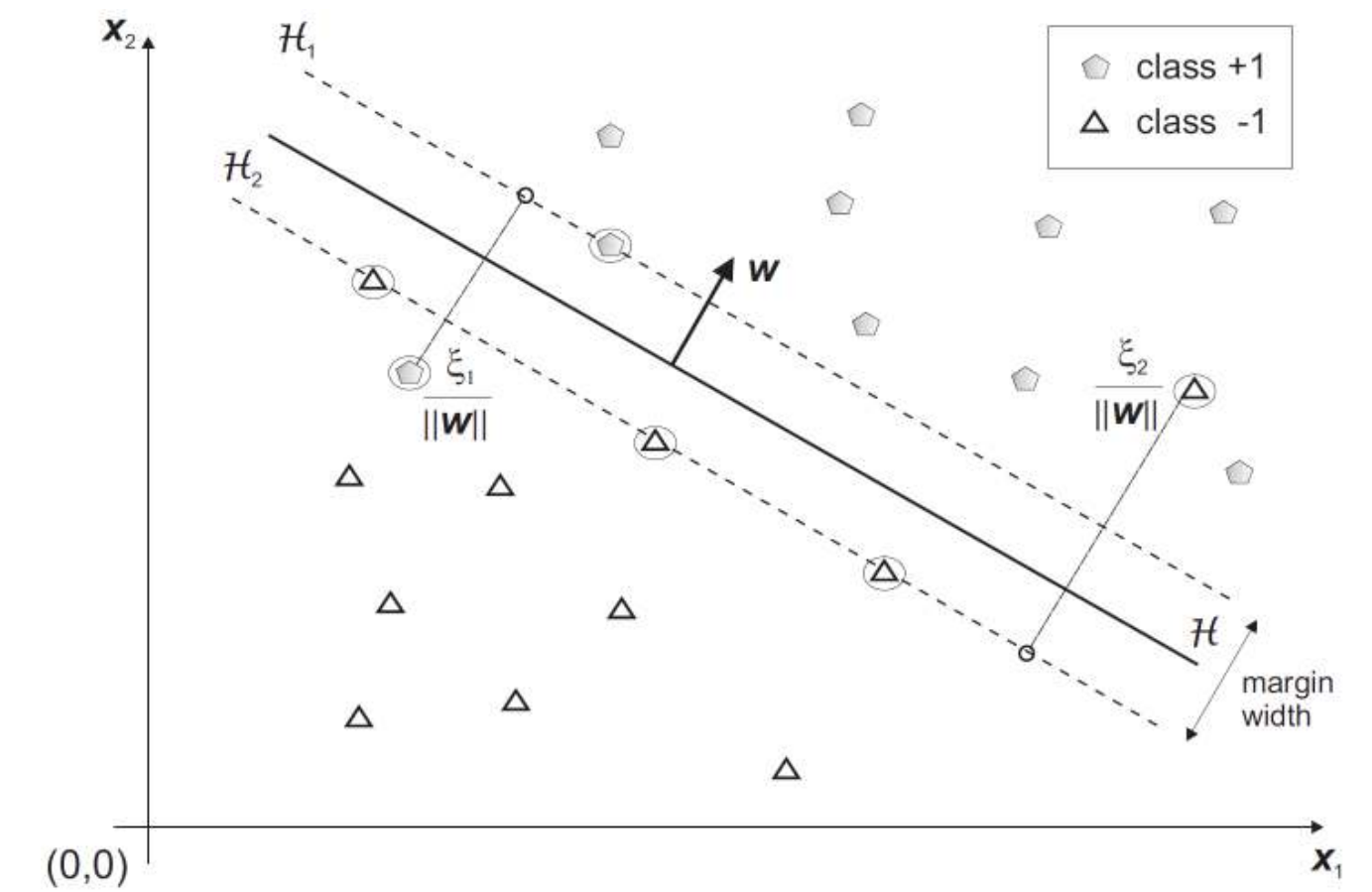
Positive-Unlabeled Training^{*}



^{*} X. Li, B. Liu, S.K. Ng: Negative Training Data can be Harmful to Text Classification, 2010, EMNLP

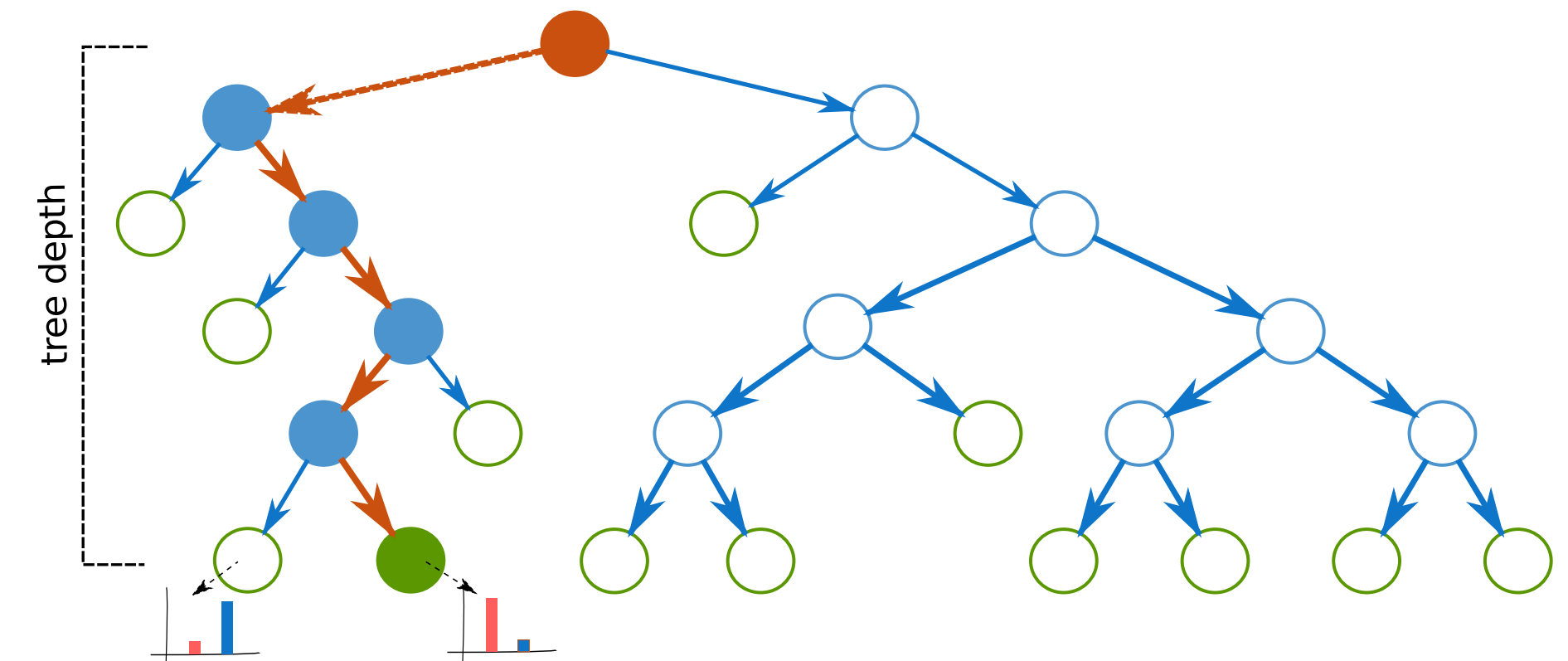
Classifiers

- **SVM alternative** – MIL representations: Challenge #1



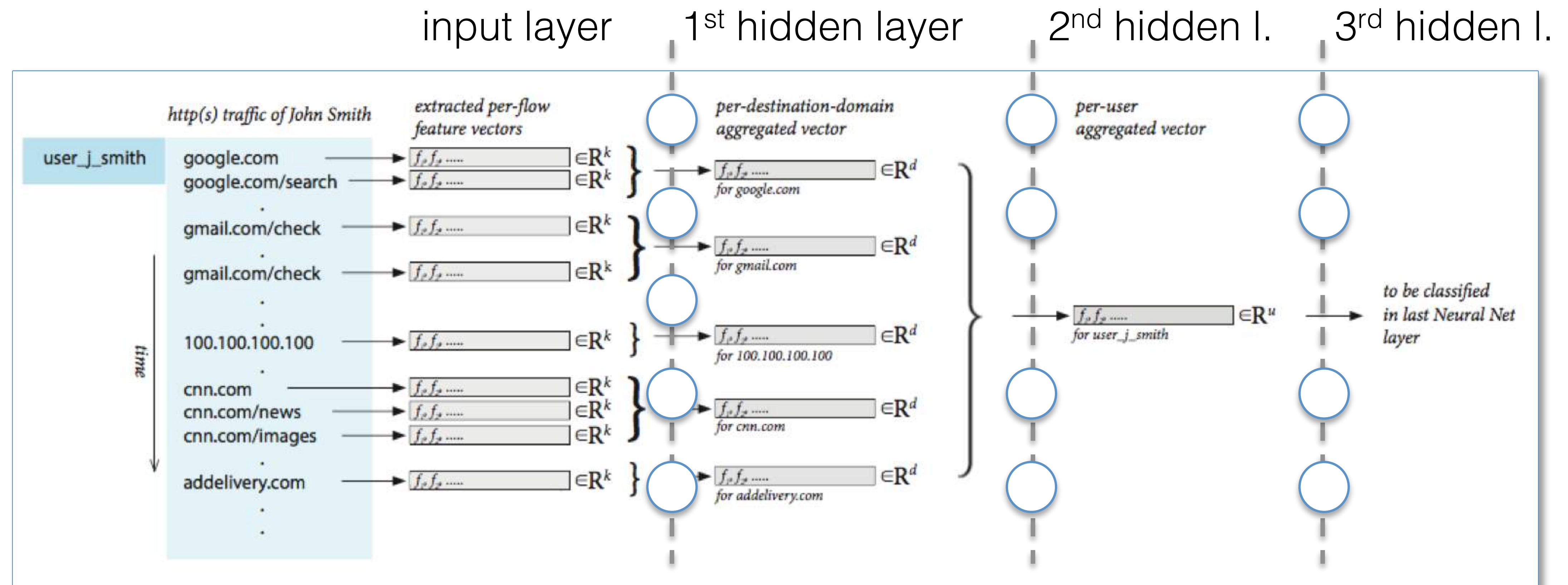
- **Random Forests**

- Randomness involved = more robust against evasion
- Multi-class classification
- Easy to train and run efficiently on big data
- Used prevalently for per-vector classification

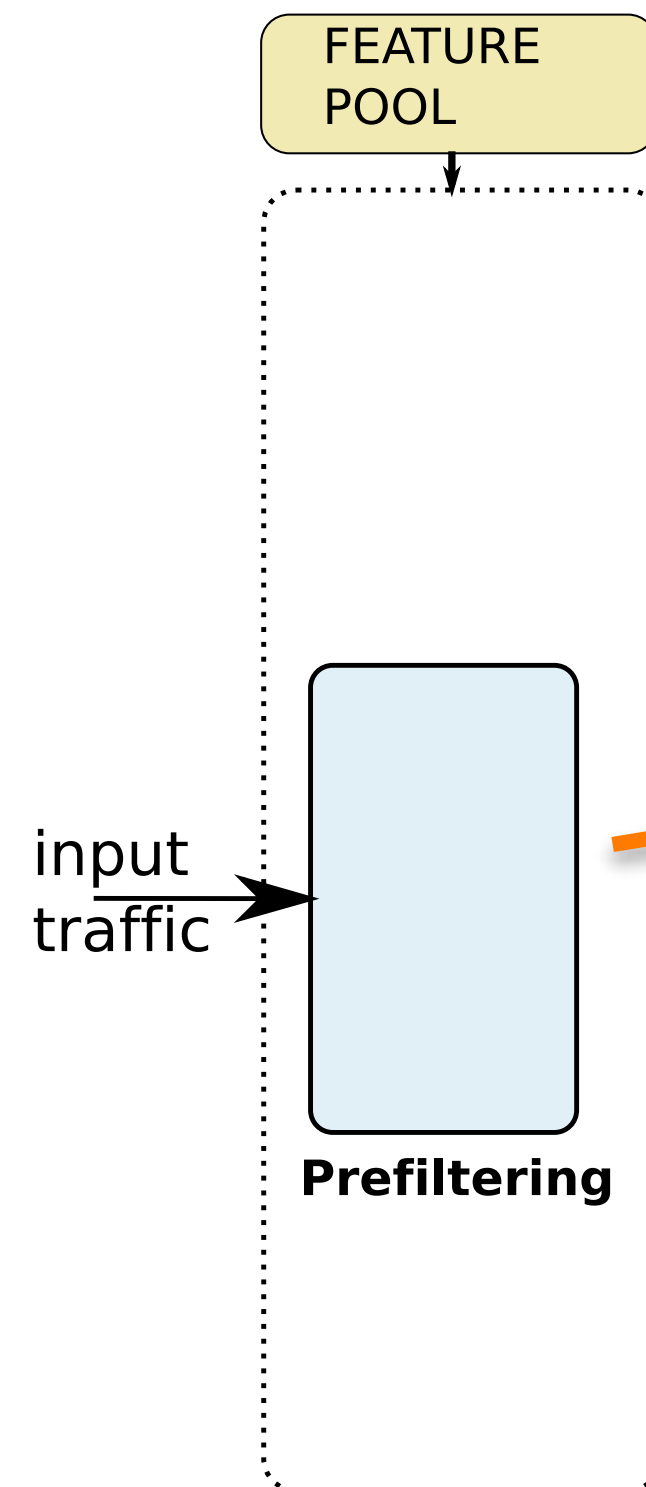


Neural Networks*

Used to classify the traffic on the level of users

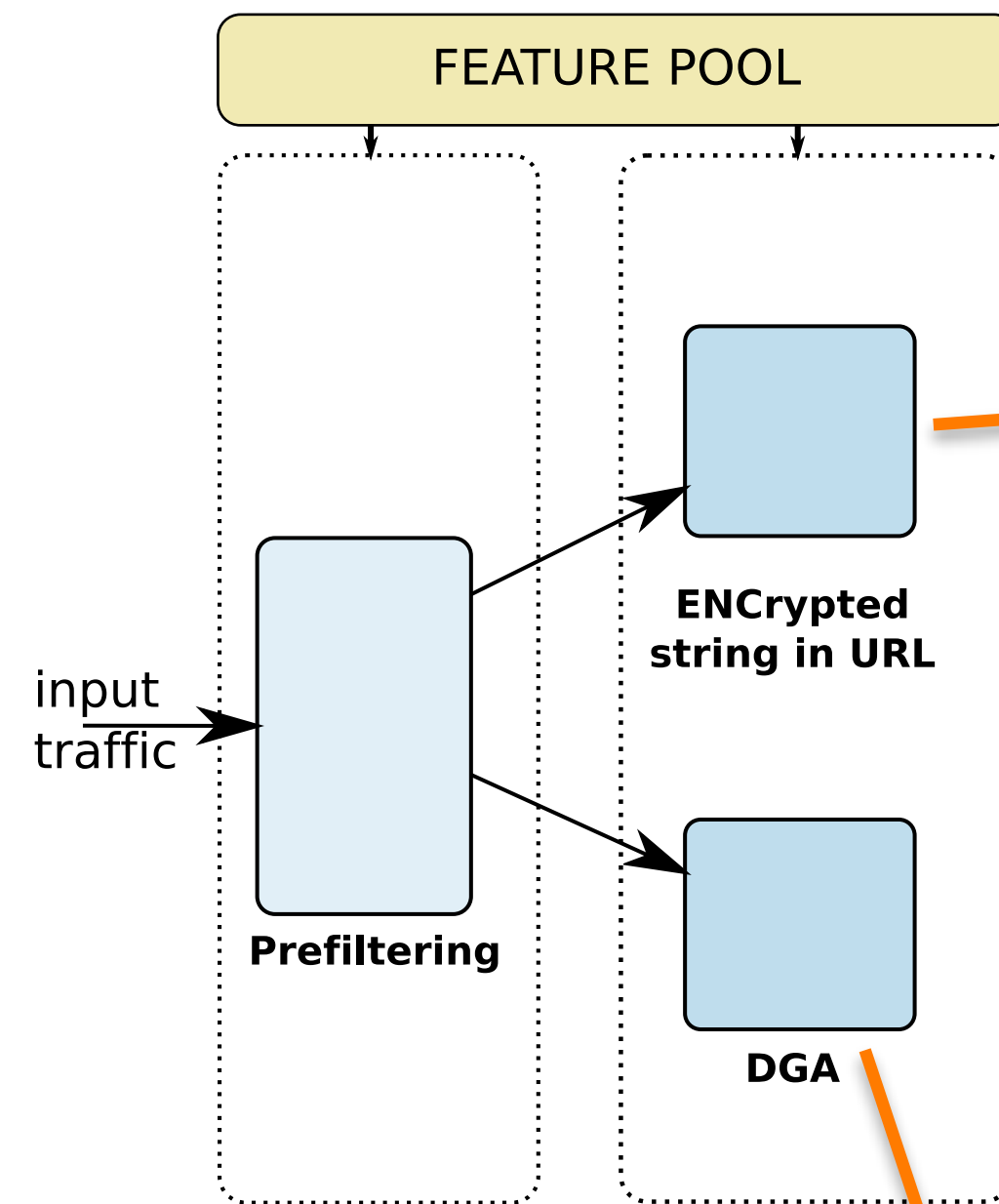


* T. Pevny, P. Somol: Discriminative models for multi-instance problems with tree structure, 2016 9th ACM Workshop on AISec with the 23rd ACM Conference on Computer and Communications (CCS)



*hxxp://cohostro[.]com/keyJjIjogMjM4MiwgImYiOiAwLCAibSI6IDI2M..
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hxxp://lkckclckl1i1i[.]com/zKG2ZB1X6M5xt5c1Y2xrPTEuNyZiaWQ9..
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Malicious

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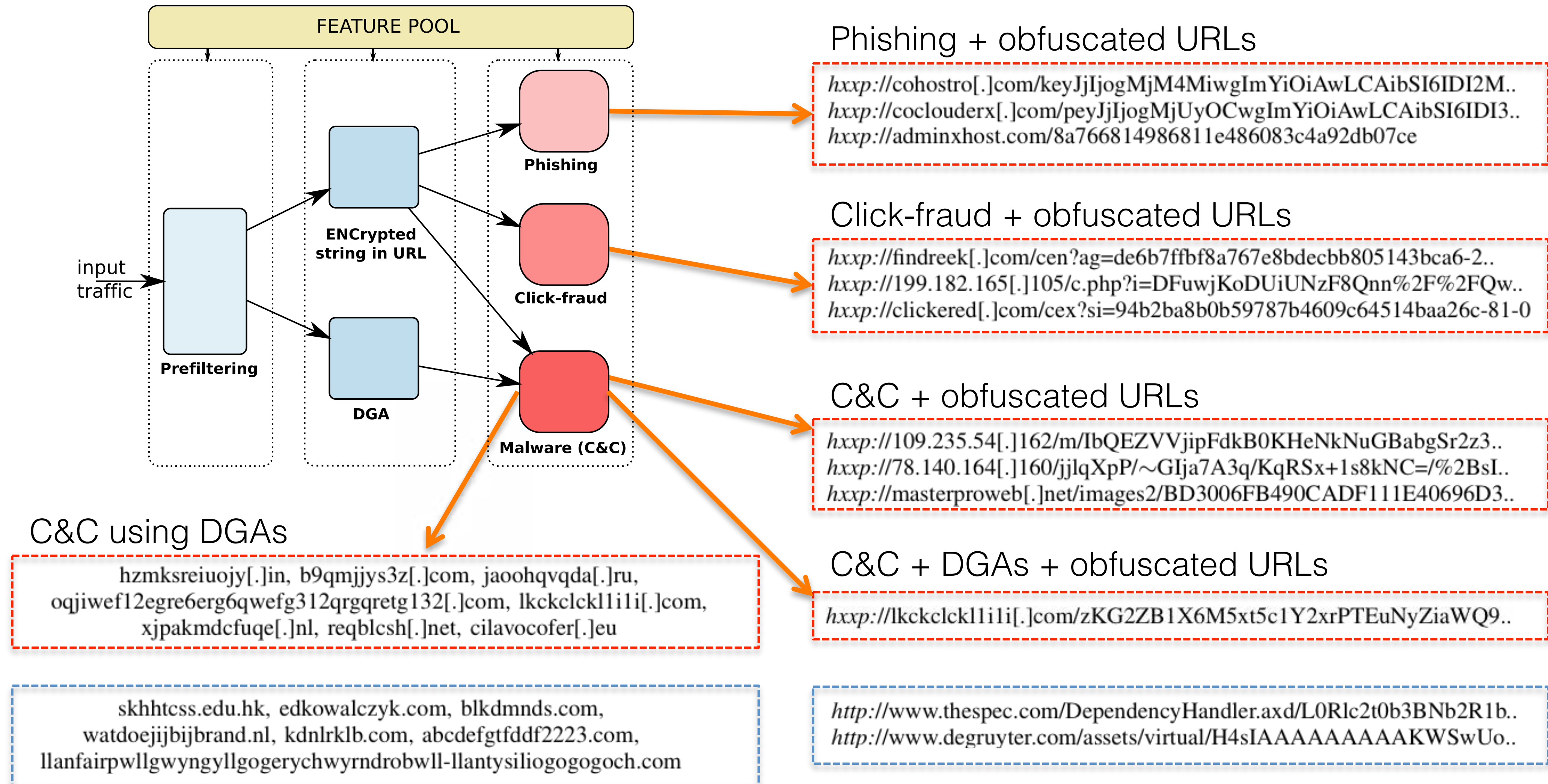
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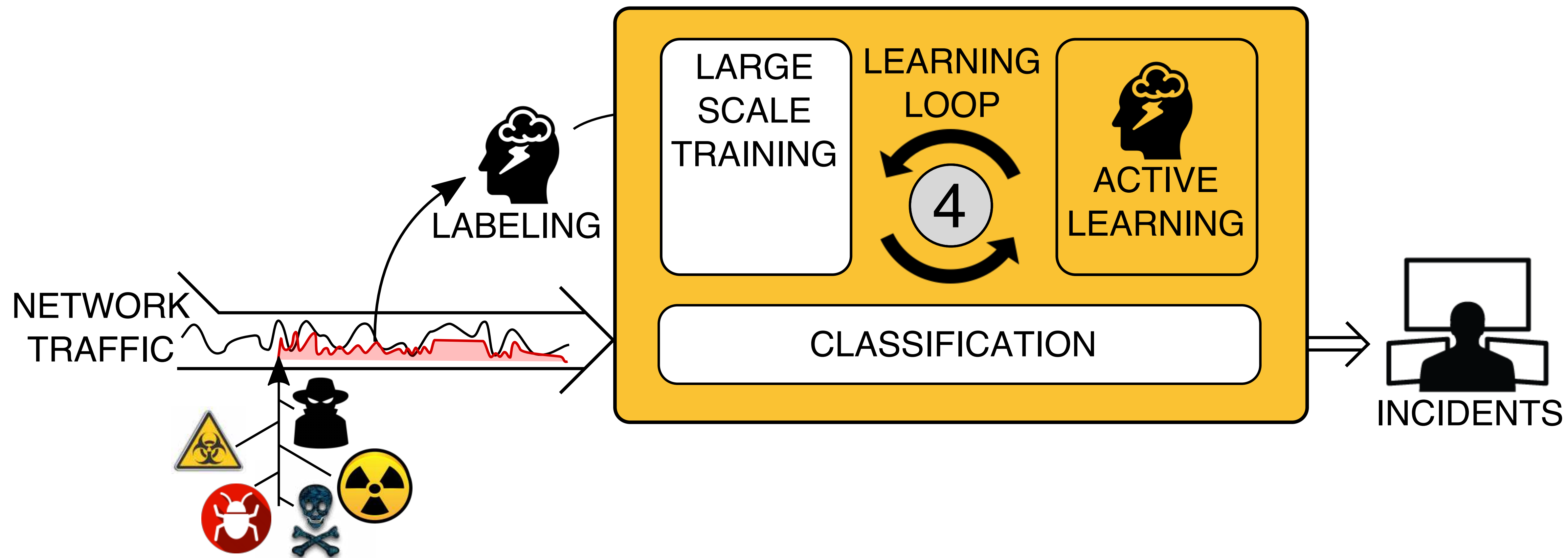
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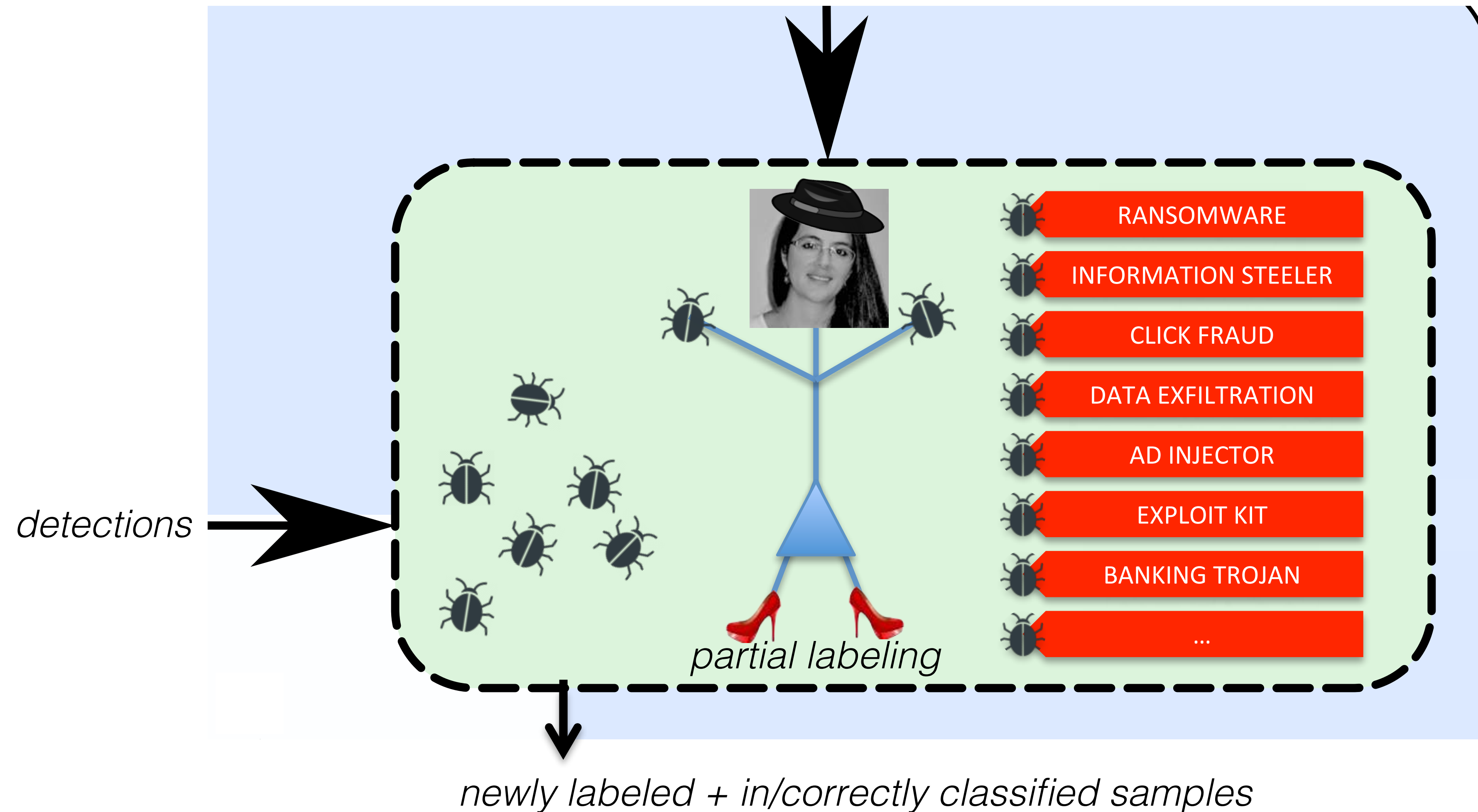
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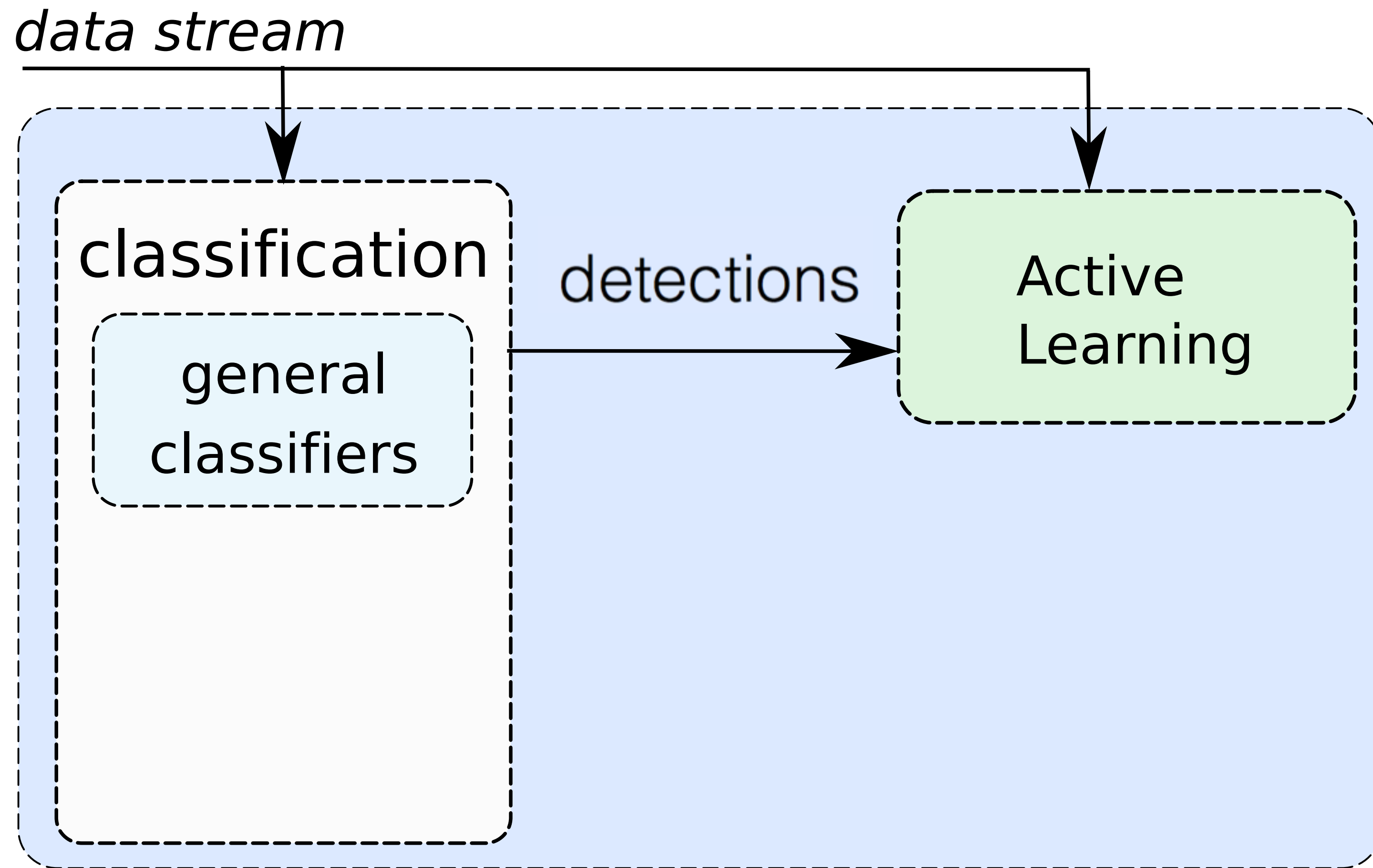




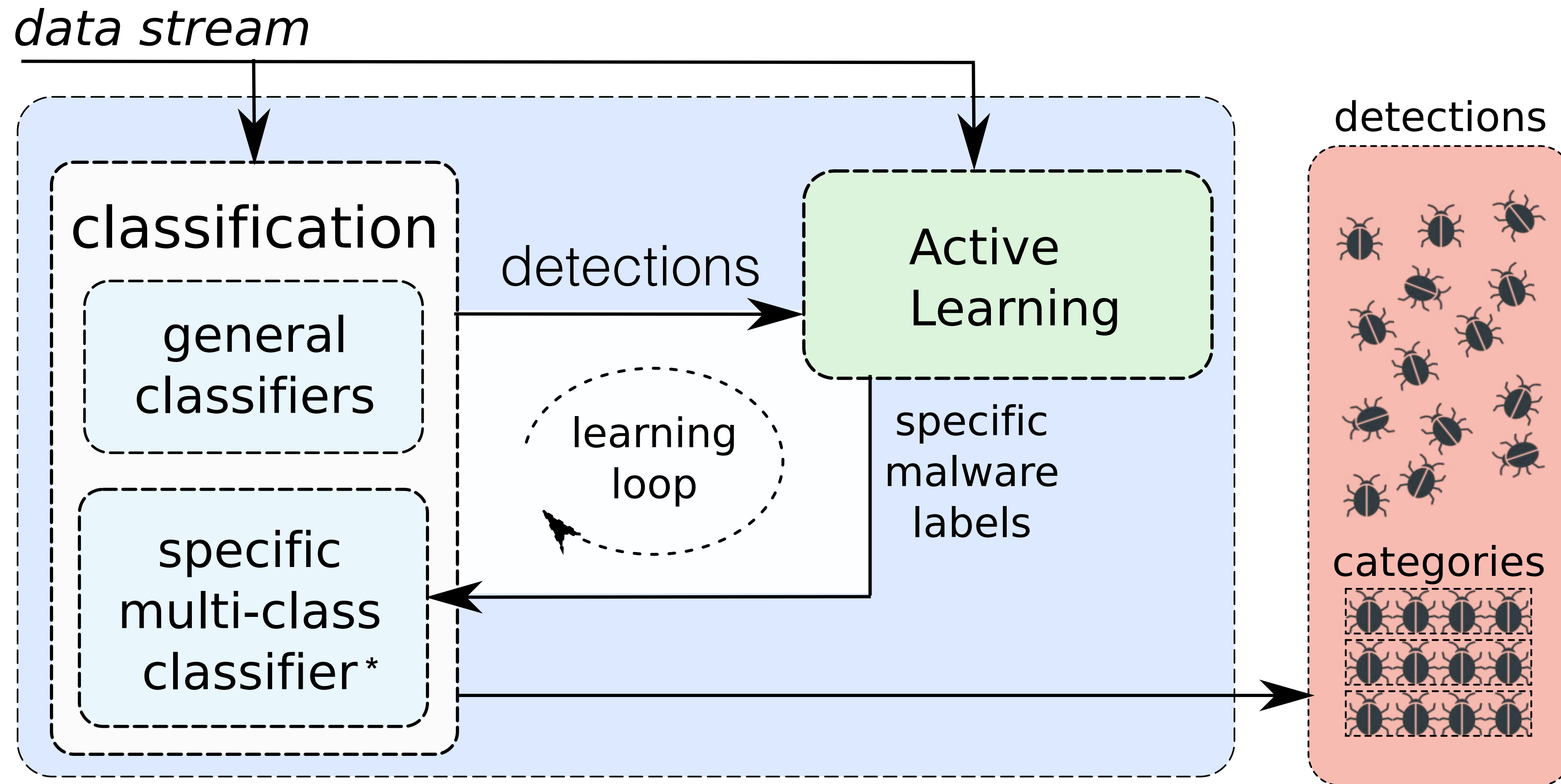
Active Learning – exploration vs. exploitation



CTA Classification and Learning Loop

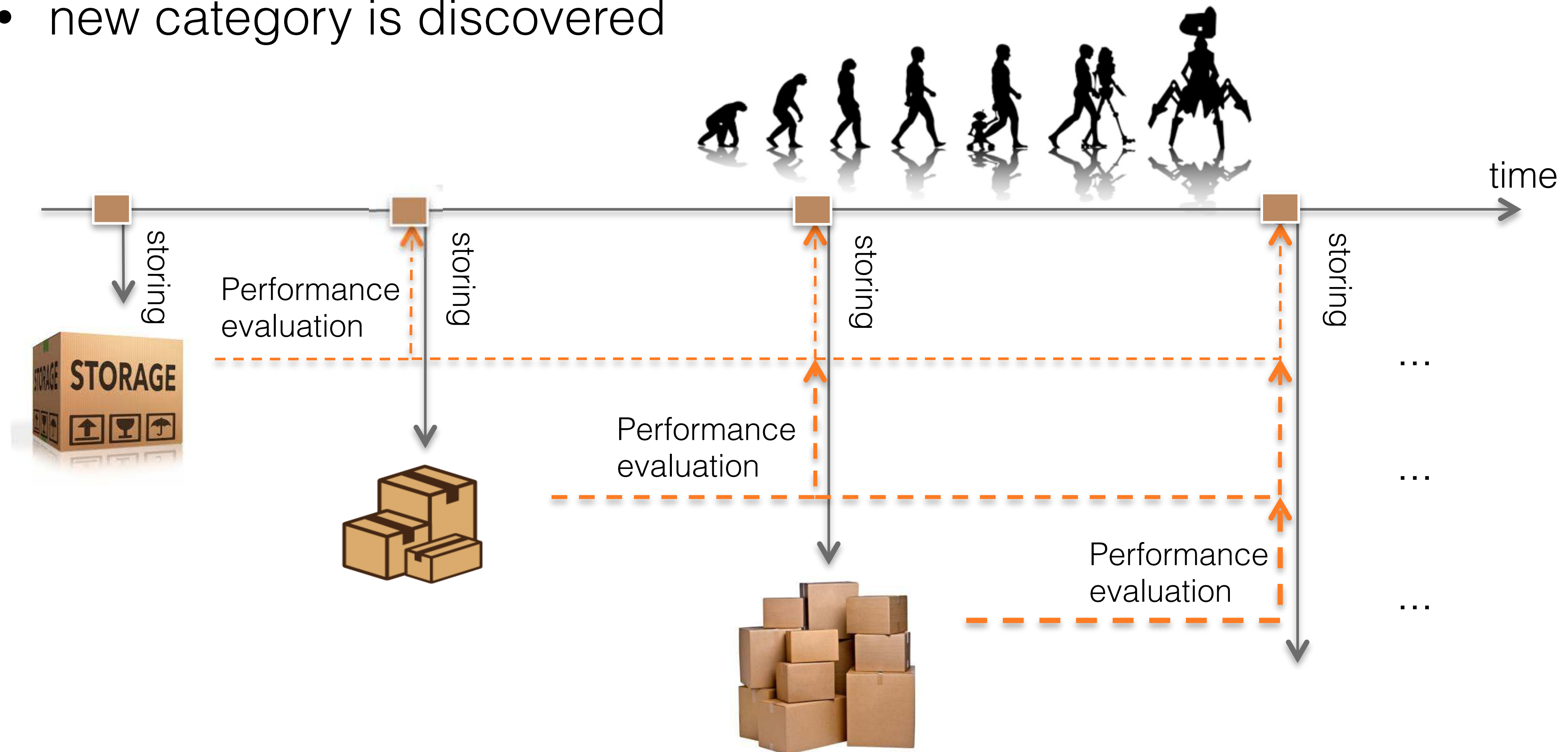


CTA Classification and Learning Loop



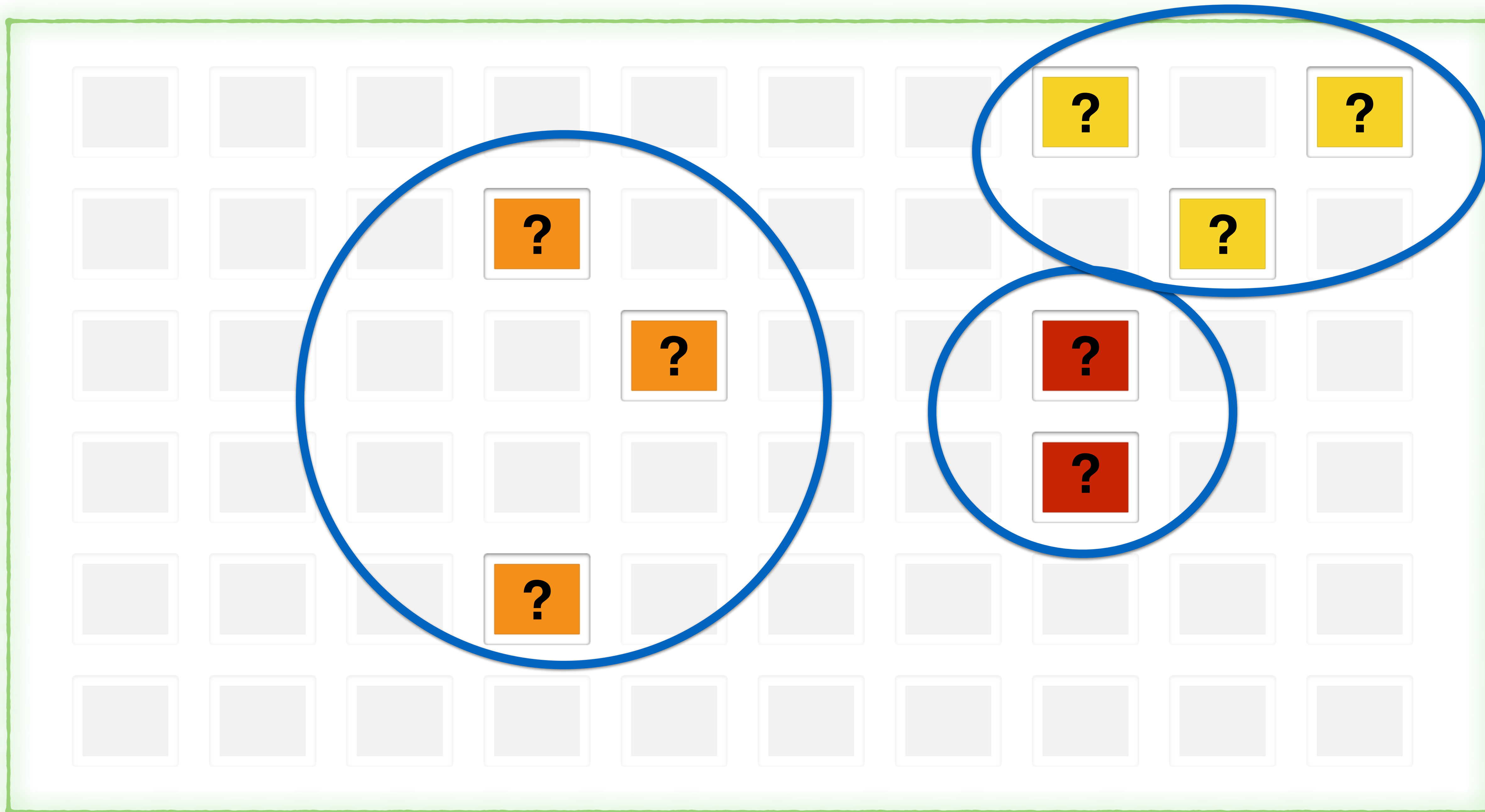
* We use SPARK to train the model (with 200 CPUs it takes approx. 1-2 days)

- **Automatic retraining of the classifier**
 - based on **new samples** in already observed categories
 - new category is discovered

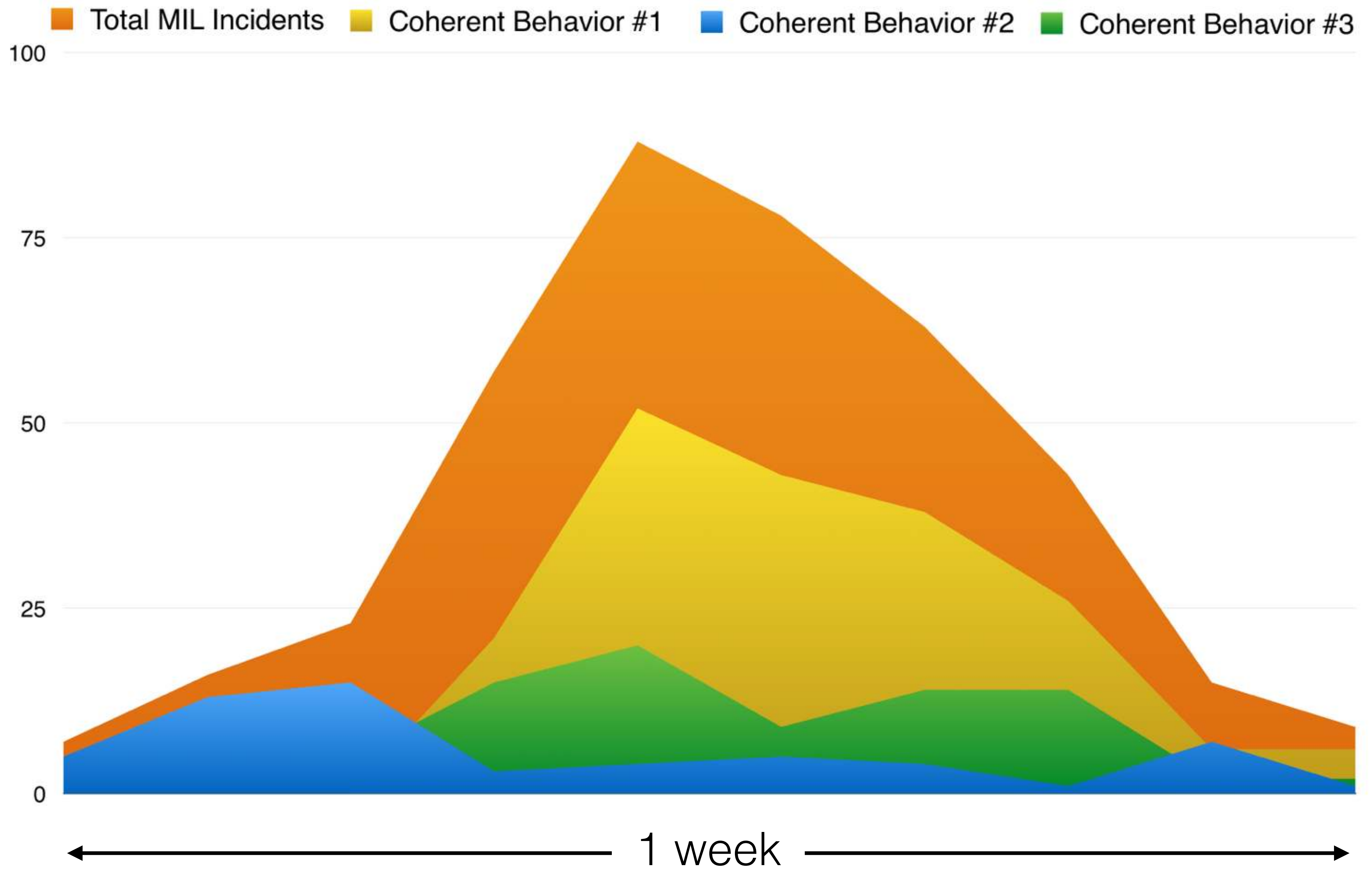


Real Life Example





DNSChanger



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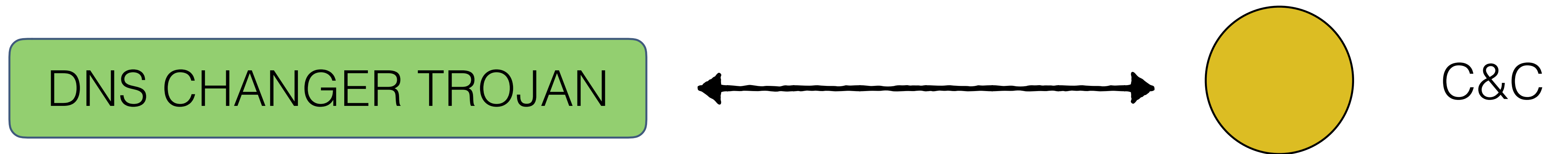
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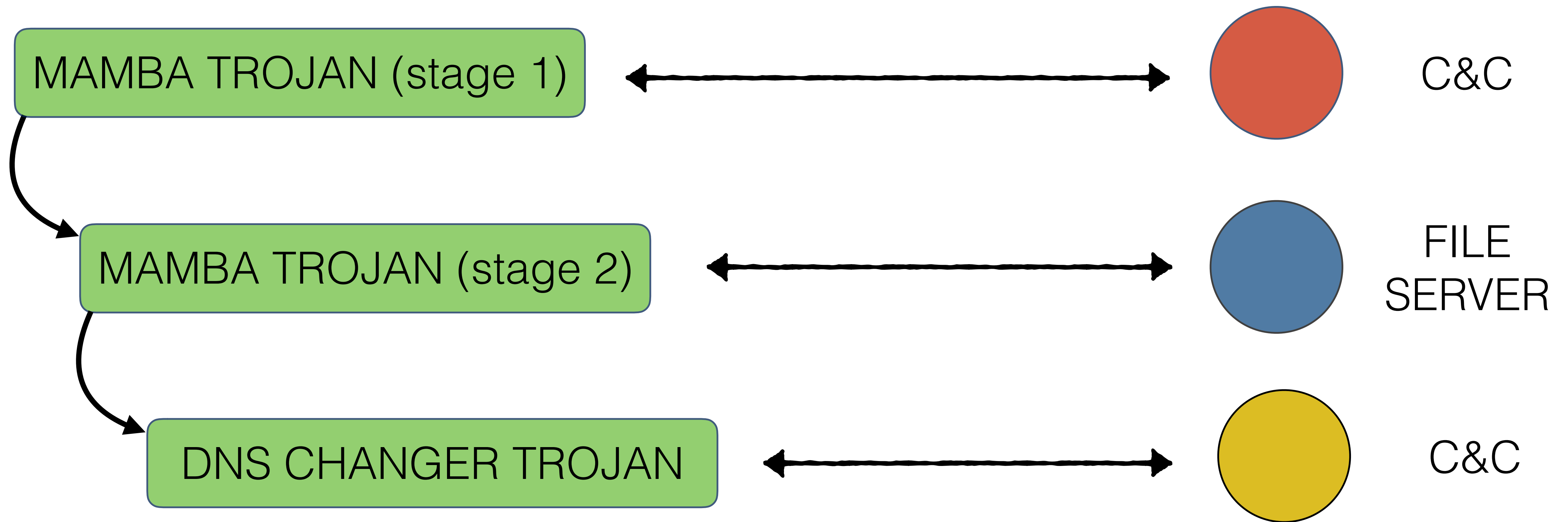
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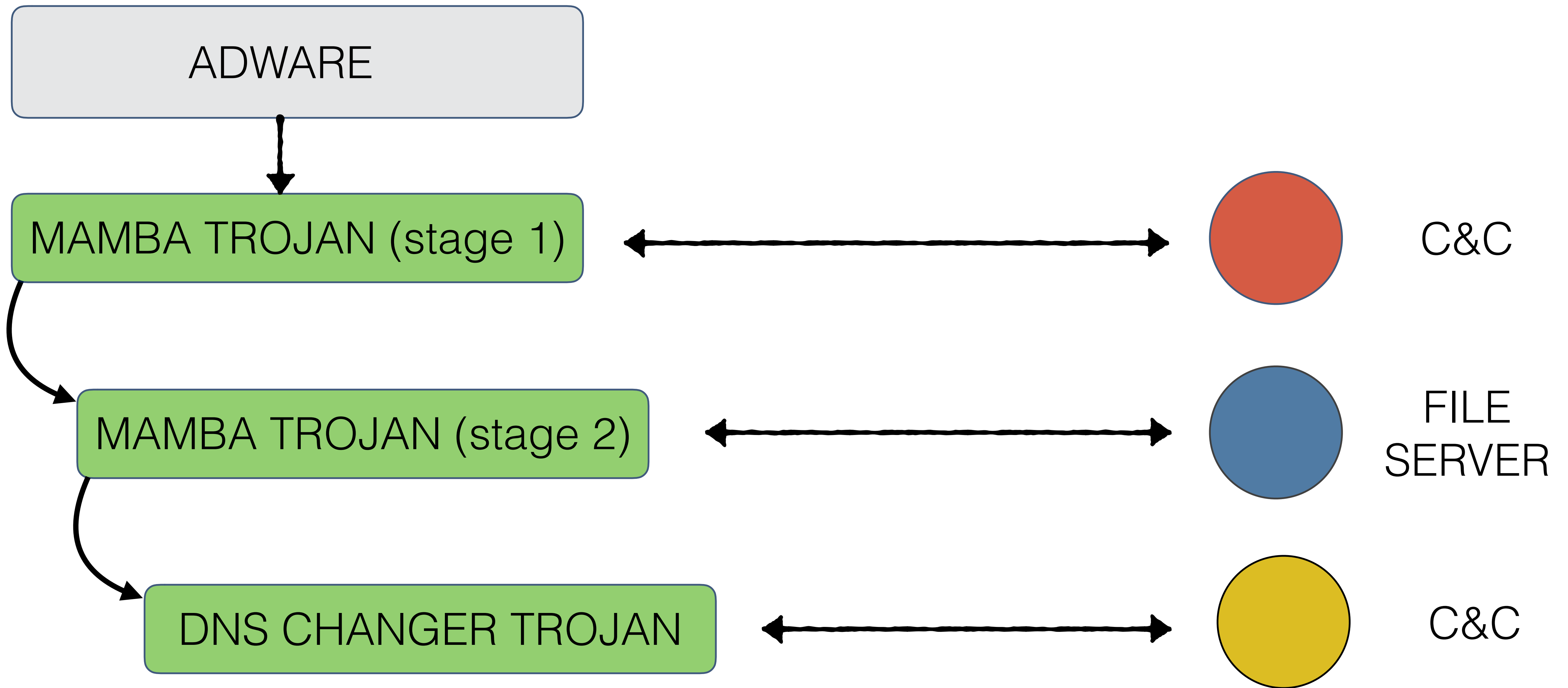
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Thanks to Ross Gibb (Cisco AMP Threat Grid)!



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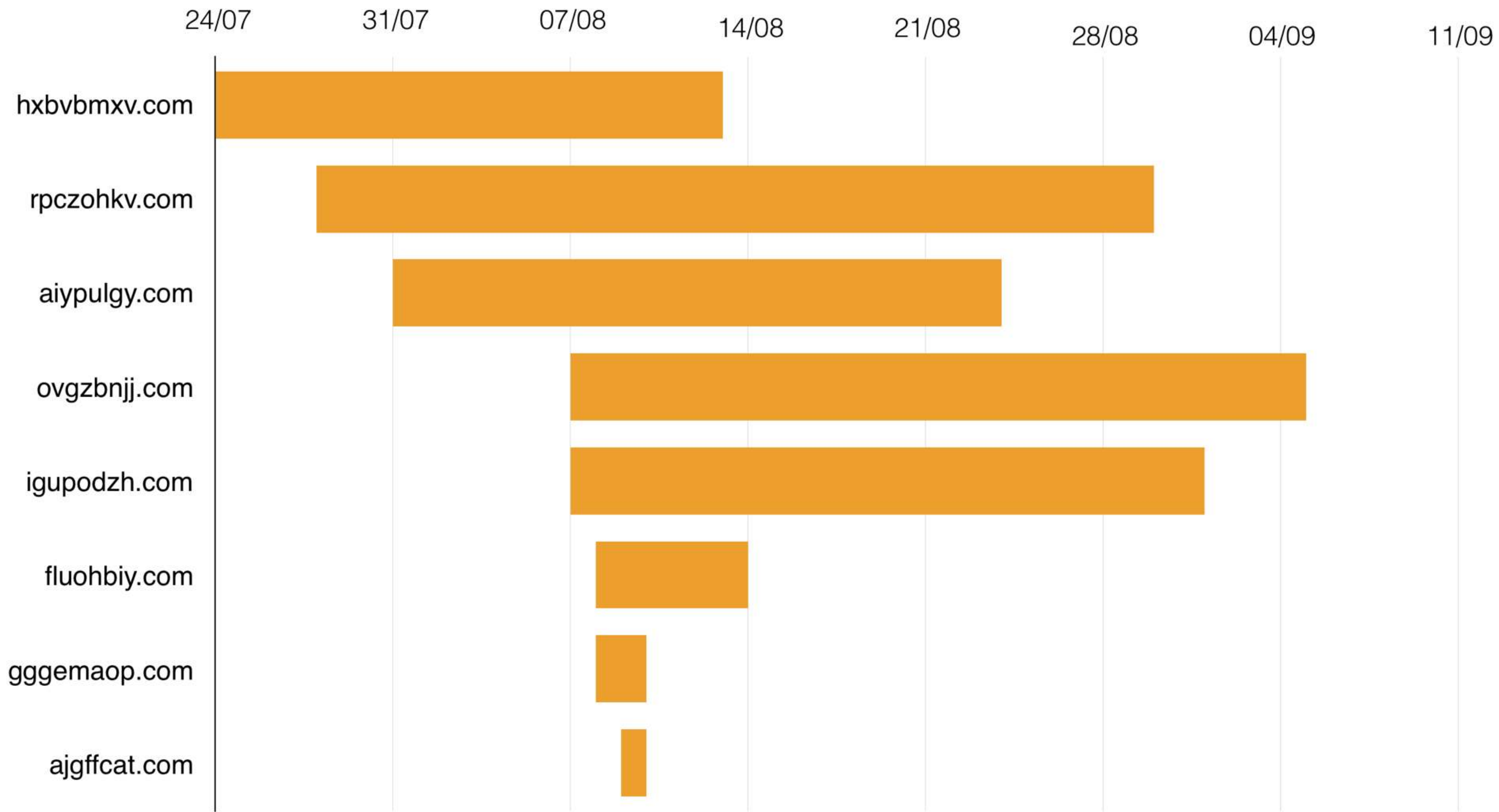
RIG Exploit Kit

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Detection ratio: 16 / 54

Analysis date: 2016-11-02 11:20:47 UTC

Thanks to Ross Gibb (Cisco AMP Threat Grid)! & Avast Team!



24/07

07/08

21/08

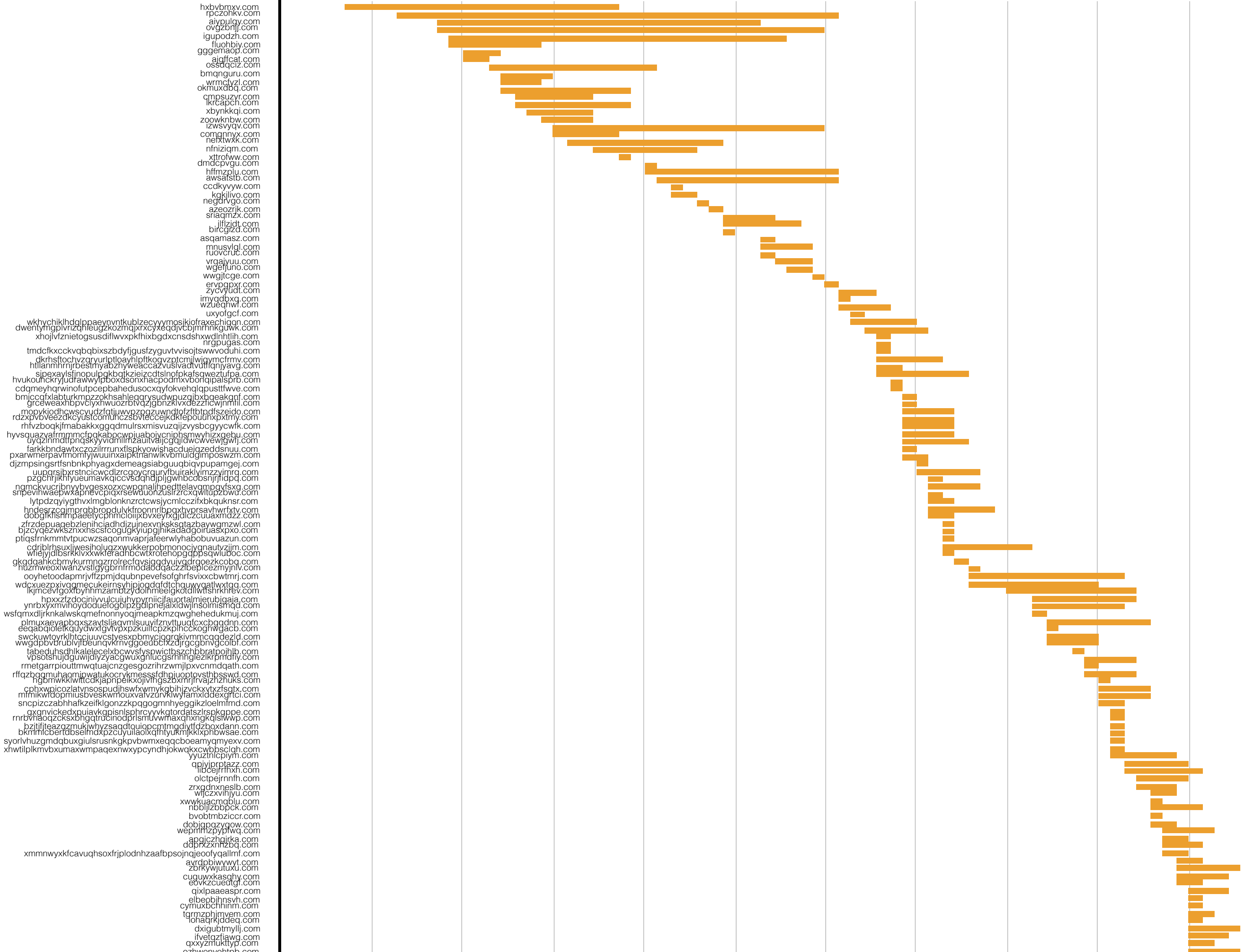
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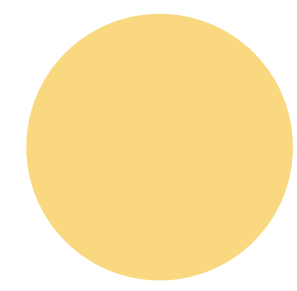
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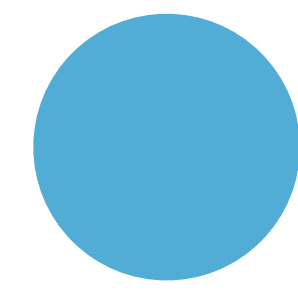
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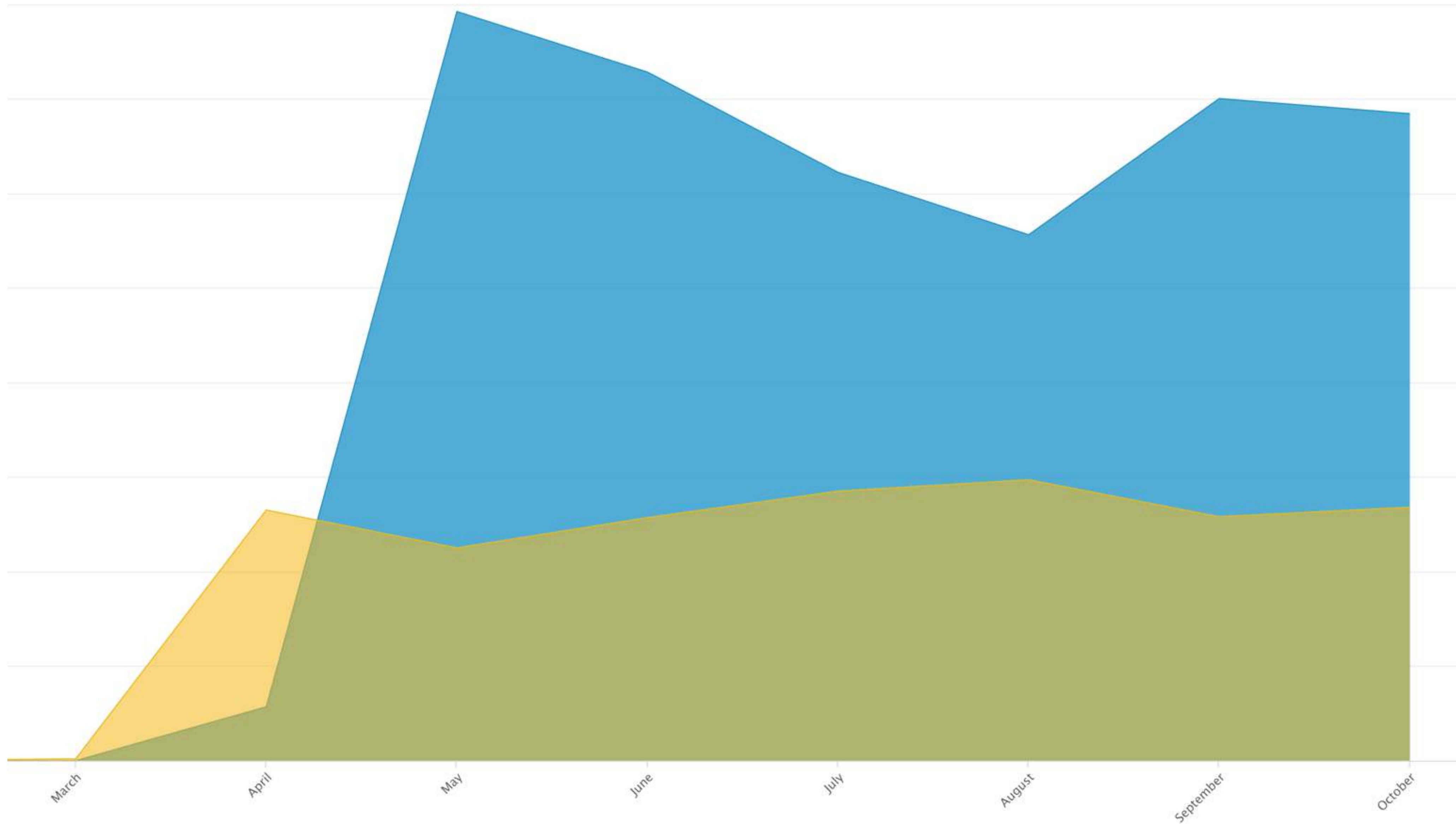
Automated Threat Hunting



Initial Malicious Traffic (training)



New Malicious Traffic



3x more detections

Tracking hundreds of malicious
campaigns

So

Designed representation
invariant to rapidly evolving
malware

Large scale learning
from weak labels

Active learning for automated malware tracking

Millions of users

Tens of thousands of infections

What got us here
won't take us there.



Thanks!

Veronica Valeros
vvaleros@cisco.com

Karel Bartoš
kbartos@cisco.com

Lukáš Machlica
lumachli@cisco.com

The end.