



# SAPPAN Innovation in DGA Detection

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*SHARING AND AUTOMATION FOR  
PRIVACY PRESERVING ATTACK  
NEUTRALIZATION*



Co-funded by the Horizon 2020 programme  
of the European Union

**IT|SEC** Research Group  
IT-Security

**RWTHAACHEN**  
UNIVERSITY

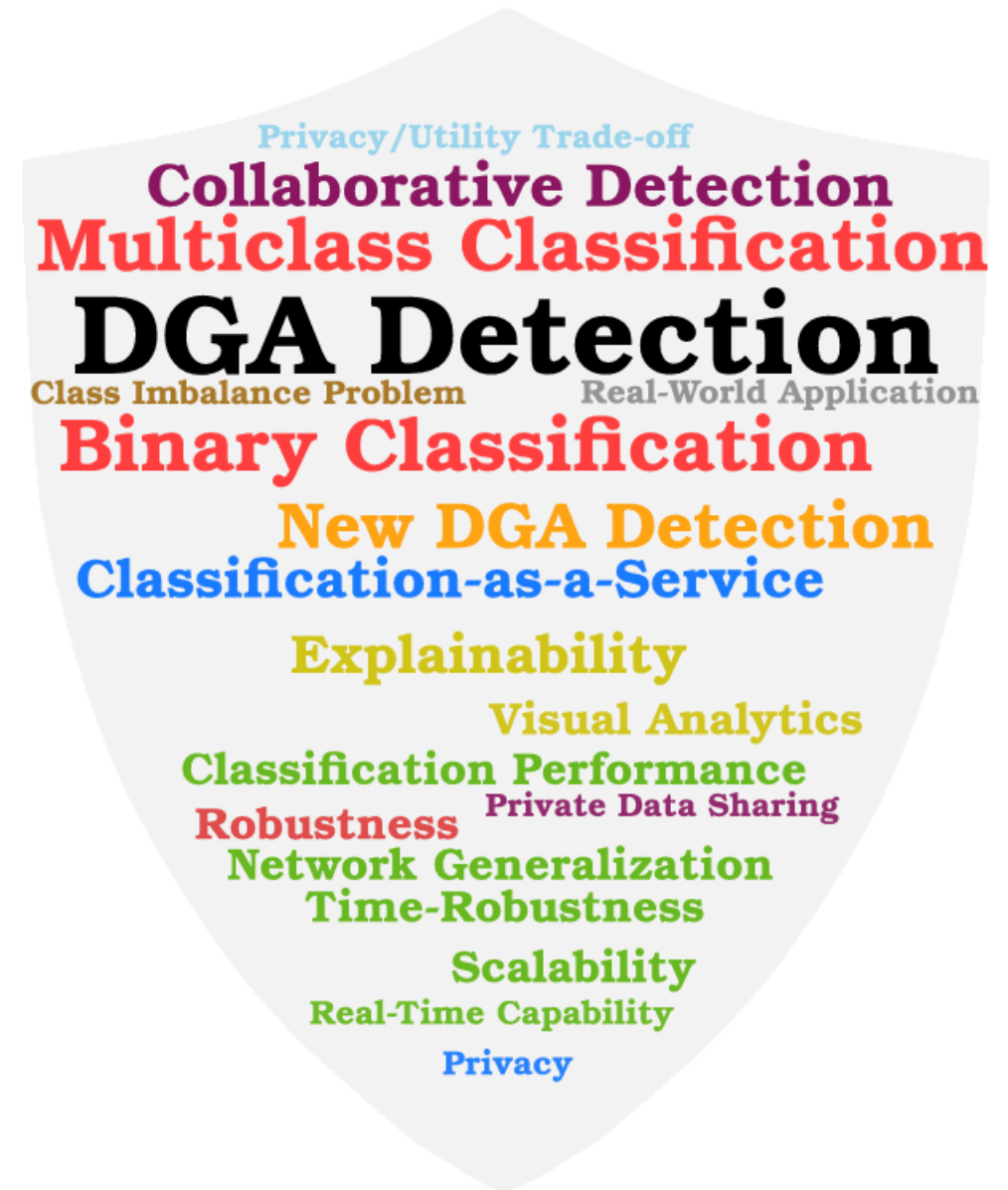
## Use-case DGA Detection in SAPPAN

### Research driven approach

- 6 peer-reviewed accepted papers on DGA detection
- 1 paper currently under review

### Real-world application of research results

- Classifiers are real-time capable & scalable
- Integration of research into existing Security Information and Event Management (SIEM) solutions



# DGA Binary Classification

Problem:

- How to separate benign from malicious domains?

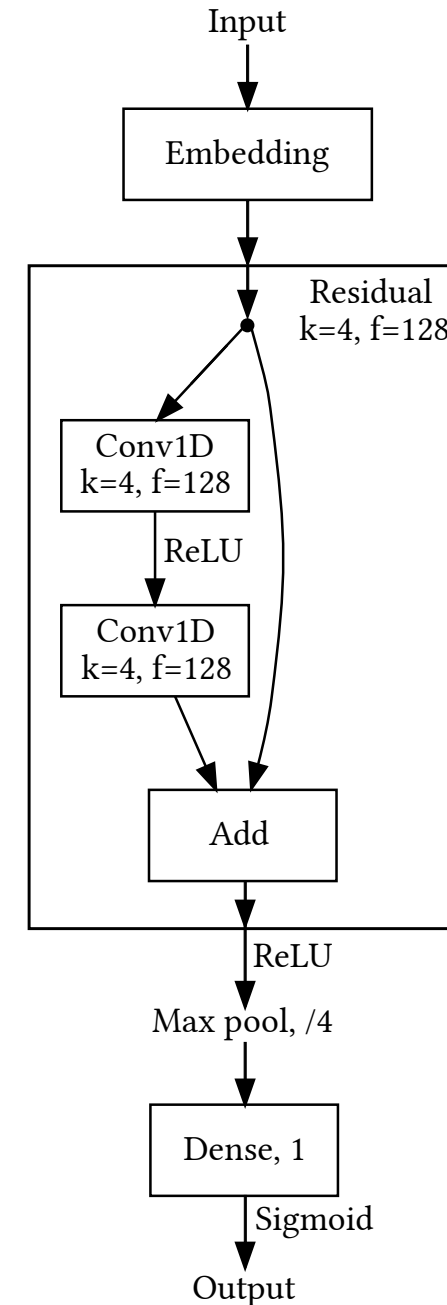
B-ResNet: ResNet-based DGA binary classifier

- Introduction of skip connections between convolutional layers  
→ eases training and counteracts vanishing gradient problem

Comparative study with the state-of-the-art

- Reduction in false positive rate (FPR)
- B-ResNet generalizes well to different networks  
→ Classification can be outsourced as a service
- B-ResNet is time-robust (even after 17 months)

→ Classifier is real-time capable



# DGA Multiclass Classification

## Problem:

- How to attribute domains to either the benign class or to the DGA that generated the domain?

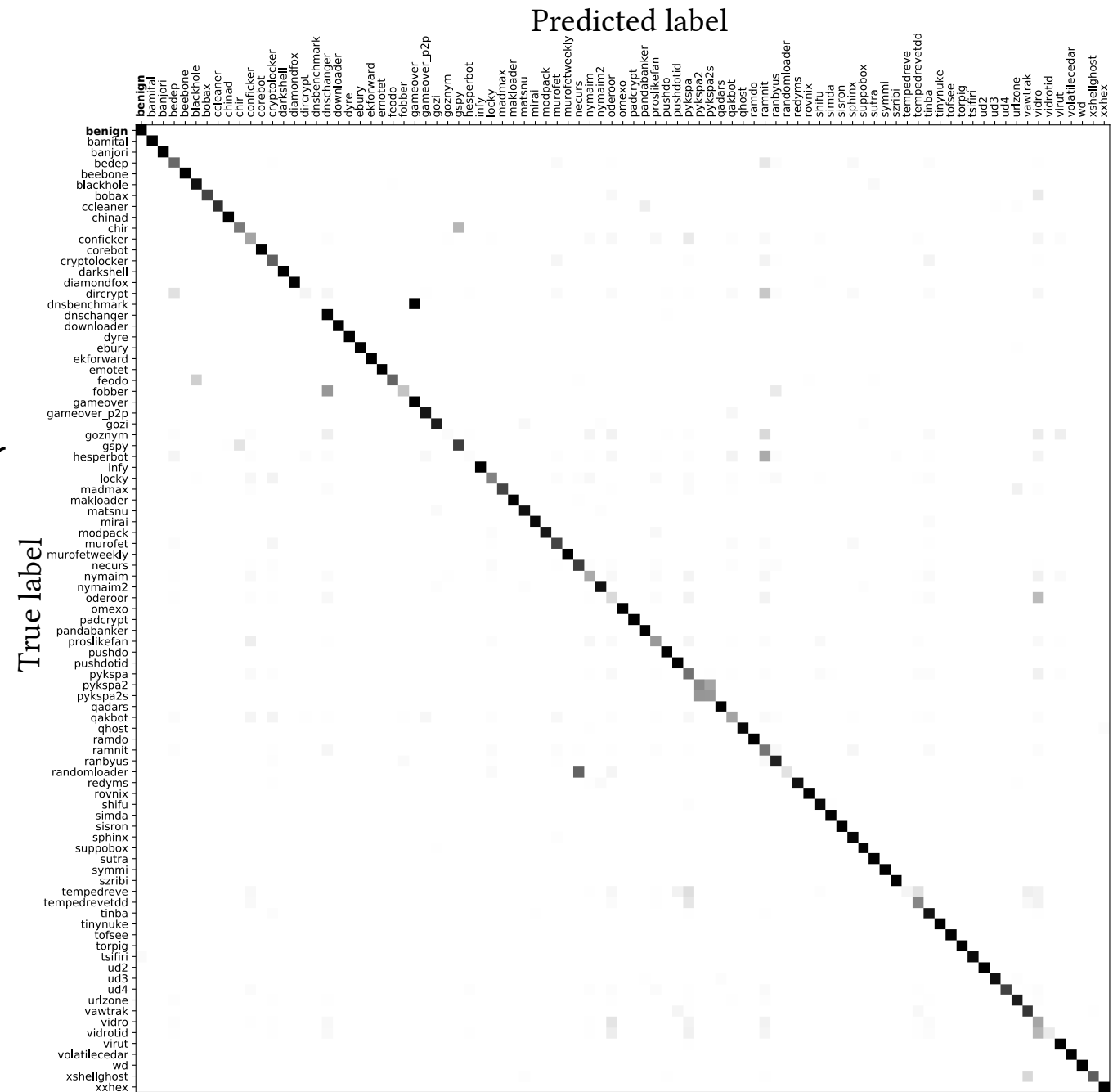
## M-ResNet: ResNet-based DGA multiclass classifier

- Build up of 11 residual blocks

## Comparative study with the state-of-the-art

- 30% less training time
  - Improvement of over 5% in macro f1-score
- Enables detection of several classes with high confidence

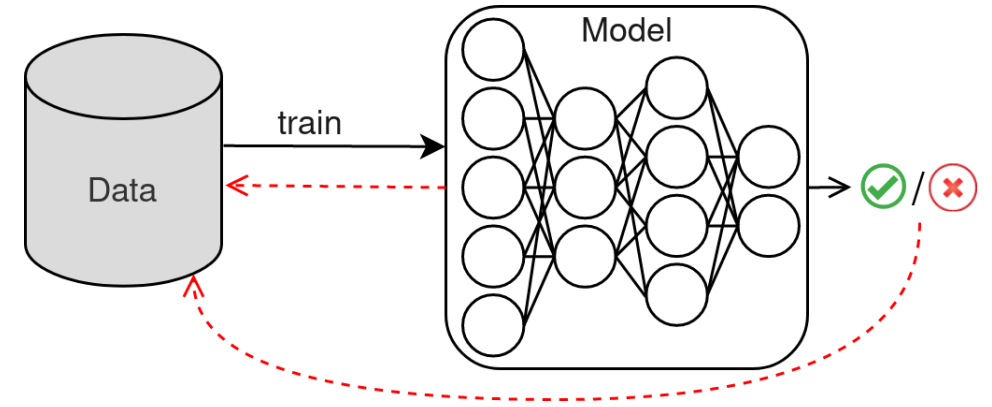
→ Classifier is real-time capable



# Class Imbalance Problem I

## Problem:

- Performance of a classifier heavily depends on the used training data
- Sample distribution is heavily imbalanced
- Including underrepresented DGAs:
  - Effect on overall classification performance?
  - Ability to detect/attribute samples of underrepresented DGAs?



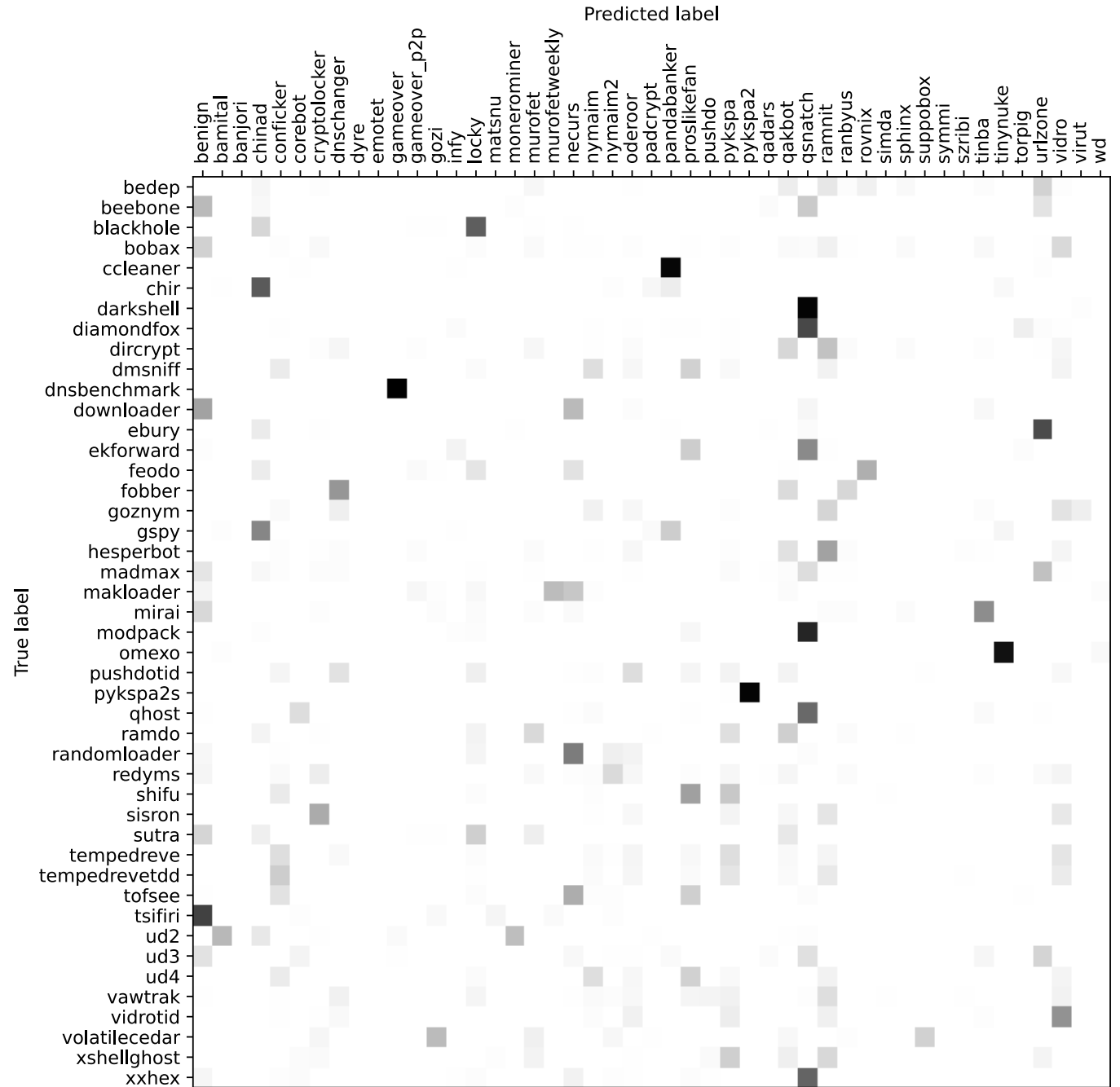
## Comprehensive study

- Both classification tasks benefit from samples of weakly represented DGAs
  - Binary classification:
    - Improvement of over 10% in detection performance
  - Multiclass classification:
    - For 22/46 classes f1-score > 90%
    - For 11 classes f1-score > 99%
- No significant influence on the classification of well represented classes

## Class Imbalance Problem II - Out-Of-Distribution (OOD) Classification

## Experiment:

- Train on samples of well represented group
- Classify samples of weakly represented group





# Explainability I - Explainable AI Research

## Problem:

- State-of-the-art deep learning classifiers behave like black boxes
- Difficult to evaluate their line of reasoning
  - Lack of confidence



# Explainability I - Explainable AI Research

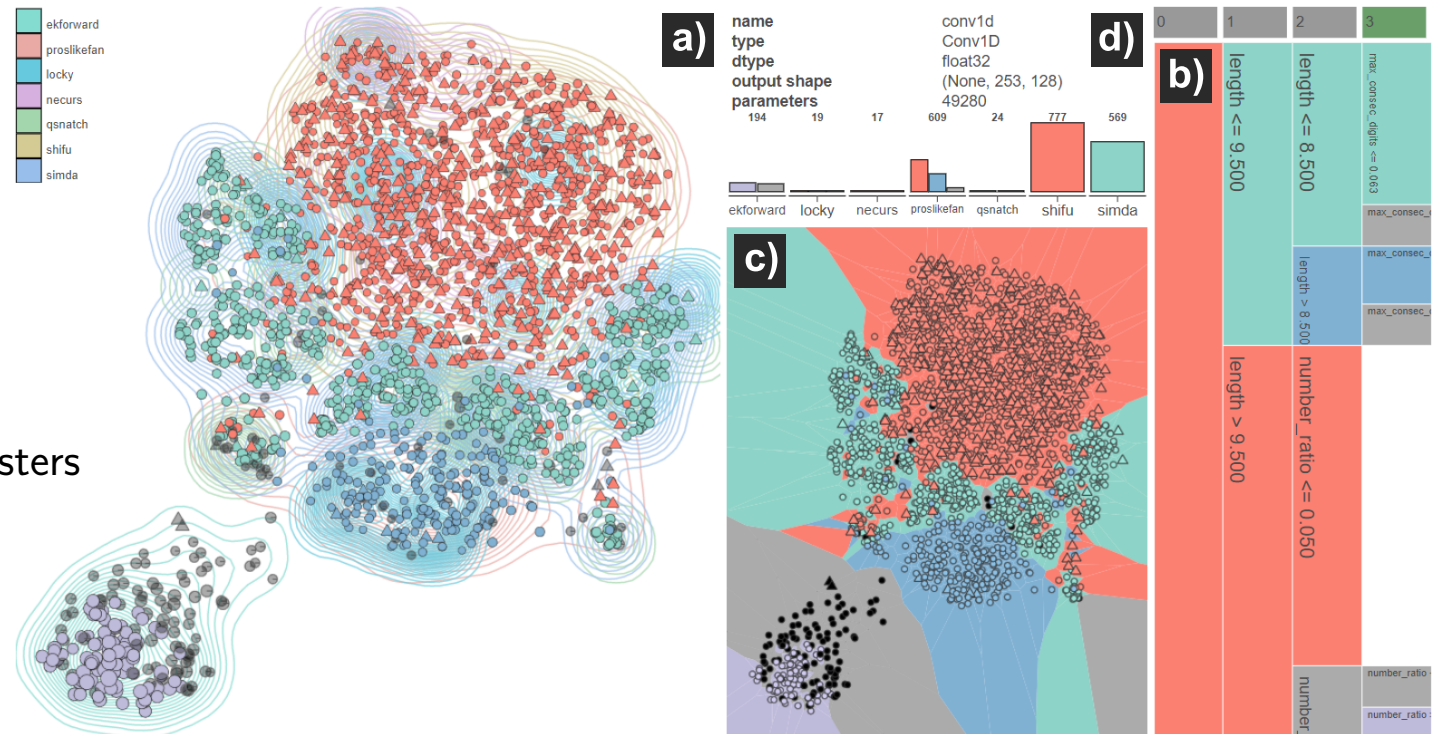
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## Two approaches in SAPPAN:

### 1. Visual analytics system:

- Provide understandable interpretations for predictions of deep learning classifiers
- Cluster activations of a model's neurons
- Leverage decision trees in order to explain clusters





# Collaborative Machine Learning - Privacy-Preserving Intelligence Sharing

## Problem:

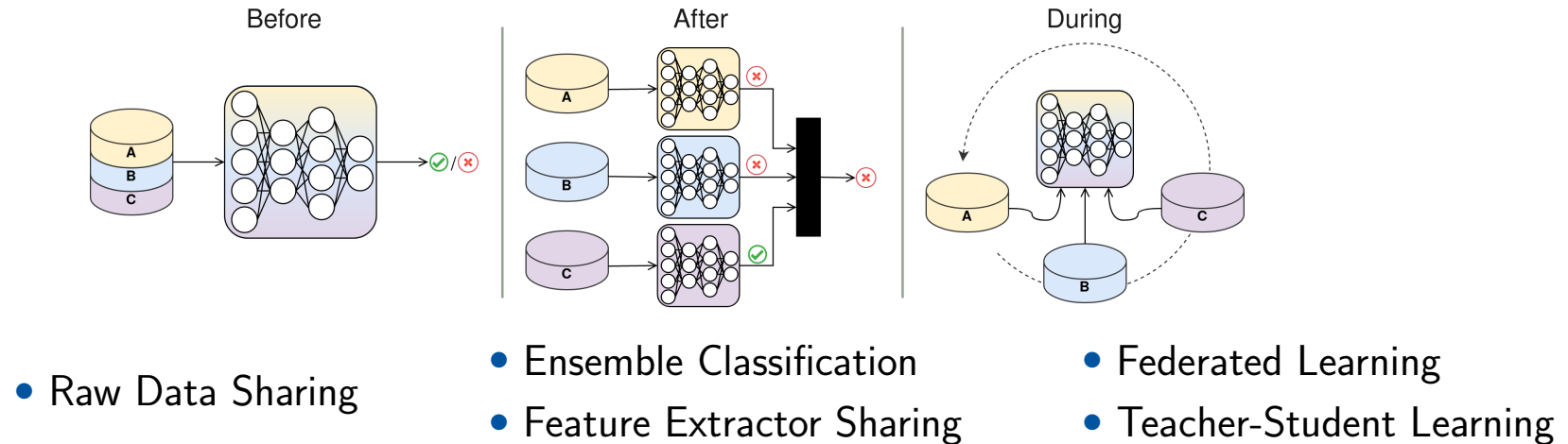
- How to improve detection by collaboration?
- Decision models are directly influenced by sensitive training data
- Models are susceptible to leak such sensitive information

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Improve generalization and performance by sharing intelligence at different stages of model training:

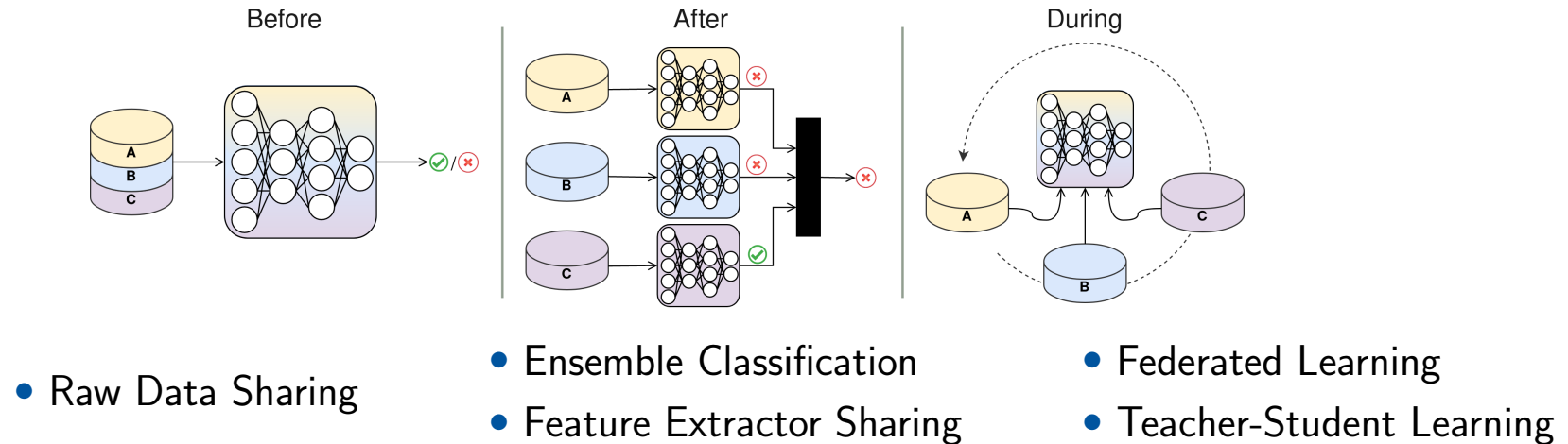


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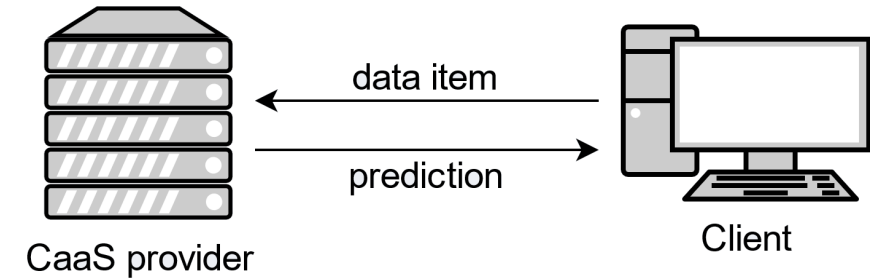
Our empirical study shows Feature Extractor Sharing and Federated Learning perform best:

- Significant reduction of false positive rate (FPR), up to 50% compared to single-party
- Reduction rate of FPR correlates with increasing number of parties
- Preliminary privacy-utility trade-off study

# Privacy-Preserving Classification as a Service (CaaS)

## Problem:

- Real-world training data is mandatory for well performing classifiers
- What about resource constrained devices?
- Domain names / trained models may contain privacy-critical information



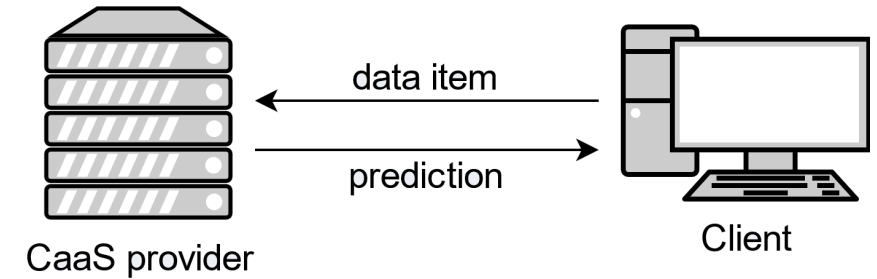
Naive application of privacy-preserving ML frameworks to existing DGA detection classifiers

→ Single inference can cost additional: 13 min inference latency, 234 GB communication

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## Comprehensive study & proposed model simplifications:

- Reduction in inference latency of up to 95%
- Reduction in communication complexity of up to 97%
- Accuracy penalty of less than 0.17%

→ Still, future work is required to make privacy-preserving CaaS feasible!

# DGA Detection - Current Research & Future Work

## Robustness

- NX-classifiers more robust against adversarial attacks
- Usage of adversarial machine learning to improve robustness



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## New DGA detection

- Real-world experiment: 6 unknown DGAs, 1 unknown Bamital seed
- Adaptive new DGA detection system

manipulation-want-date.pw  
refers-spare-criticism.pp.ua  
fashioned-achieve-disable.pro

**(a) Unknown DGA 1**

dv4050fc.co.ir  
thrsssk05.co.ir  
thrl0pg13.co.ir

**(c) Unknown DGA 3**

go2mysuite.eu  
citrixgo2mypc.co.uk  
gotomobileaccess.com

**(b) Unknown DGA 2**

www.c75ff6bd.com  
www.94e47d25.com  
www.41019163.com

**(d) Unknown DGA 4**

2b4b1d67-b38a-40c1-ba3e-af73245d7b14.com  
86a94dd8-5724-4b9a-8a7a-bea8733f7e60.com  
adcb3f60-d260-478a-99f2-ac24eea1de16.com

**(e) Unknown DGA 5**

egbva1b5pmgh7fb.jmrbqoa6i67zdlrwhj.com  
27422j8tqot.8chcu-tza86fxaz-df70y9-t0o.com  
bt-7hb7k0aqyyr-61d8o5d.dg08rz6qobme421f.com

**(f) Unknown DGA 6**

02836ae5435c57300fc95bf13e9ba7bb.info  
073fcdb286615c7a6ac348f9a1ab0250.info  
08211a534fad3885624a92573cc2af44.info

**(g) Unknown seed of *Bamital***

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## DGA detection on resolving traffic

- Detecting active C&C server

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dv4050fc.co.ir  
thrsssk05.co.ir  
thr10pg13.co.ir

**(c) Unknown DGA 3**

2b4b1d67-b38a-40c1-ba3e-af73245d7b14.com  
86a94dd8-5724-4b9a-8a7a-bea8733f7e60.com  
adcb3f60-d260-478a-99f2-ac24eea1de16.com

**(e) Unknown DGA 5**

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073fcdb286615c7a6ac348f9a1ab0250.info  
08211a534fad3885624a92573cc2af44.info

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go2mysuite.eu  
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**(e) Unknown DGA 5**

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→ Combining all research to a single detection system

## **Impact of SAPPAN Innovations**

# Impact of SAPPAN Innovations I

## Research impact

- Improved state-of-the-art in various aspects
- 6 peer-reviewed accepted papers on DGA detection
- 1 paper currently under review

## Open source software

- Binary & multiclass ResNet-based DGA models
- EXPLAIN: Feature-based multiclass classifier (<https://gitlab.com/rwth-itsec/explain>)

→ Classifiers are real-world applicable

E

EXPLAIN

Project ID: 20714557

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33 Commits 2 Branches 0 Tags 481 KB Files 1.5 MB Storage

master explain History Find file Close

Add missing parameter and None check in WeightedRandomForestClassifier.

Nils Faerber authored 3 months ago

6fe28c4b

README GNU GPLv3 CI/CD configuration

Name	Last commit	Last update
data	Update code base to v2.	3 months ago
docs	Fix FeatureReturnType documentation.	3 months ago
explain	Add missing parameter and None check in WeightedRandomFor...	3 months ago
models	Update code base to v2.	3 months ago
.gitignore	Update documentation with code cross-references, increase rea...	3 months ago
.gitlab-ci.yml	Update docs generation script to use conda environment.	3 months ago
LICENSE	Add LICENSE	3 months ago
README.md	Update README.md	3 months ago
demo.py	Make destination folder parameter in demo.py optional.	3 months ago
demo_optimization.py	Update code base to v2.	3 months ago
demo_selection.py	Update code base to v2.	3 months ago
environment.yml	Add conda environment file.	3 months ago

README.md

### First Step Towards EXPLAINable DGA Multiclass Classification

This repository contains the source code of EXPLAIN, a classification system and library using random forests to perform multiclass classification of malware families that utilize domain generation algorithms (DGAs).

EXPLAIN is presented in the paper *First Step Towards EXPLAINable DGA Multiclass Classification*<sup>[1]</sup>. The version used for the paper can be found in the branch `paper`, while the `master` branch tracks a revised version with improvements and bugfixes.

*Note that the following information refers to the latest version if not stated otherwise.*

#### Requirements

- Python 3.8 or higher
- Conda 4.8.5 or higher
- Use `conda env create -f environment.yml` to create a conda environment with all dependencies
- Activate the environment using `conda activate explain` (use `conda activate explain_paper` for the `paper` version)

#### Documentation

Please refer to either the source code or *Overview over EXPLAIN's functions and data types* for the documentation of the implementation.

#### References

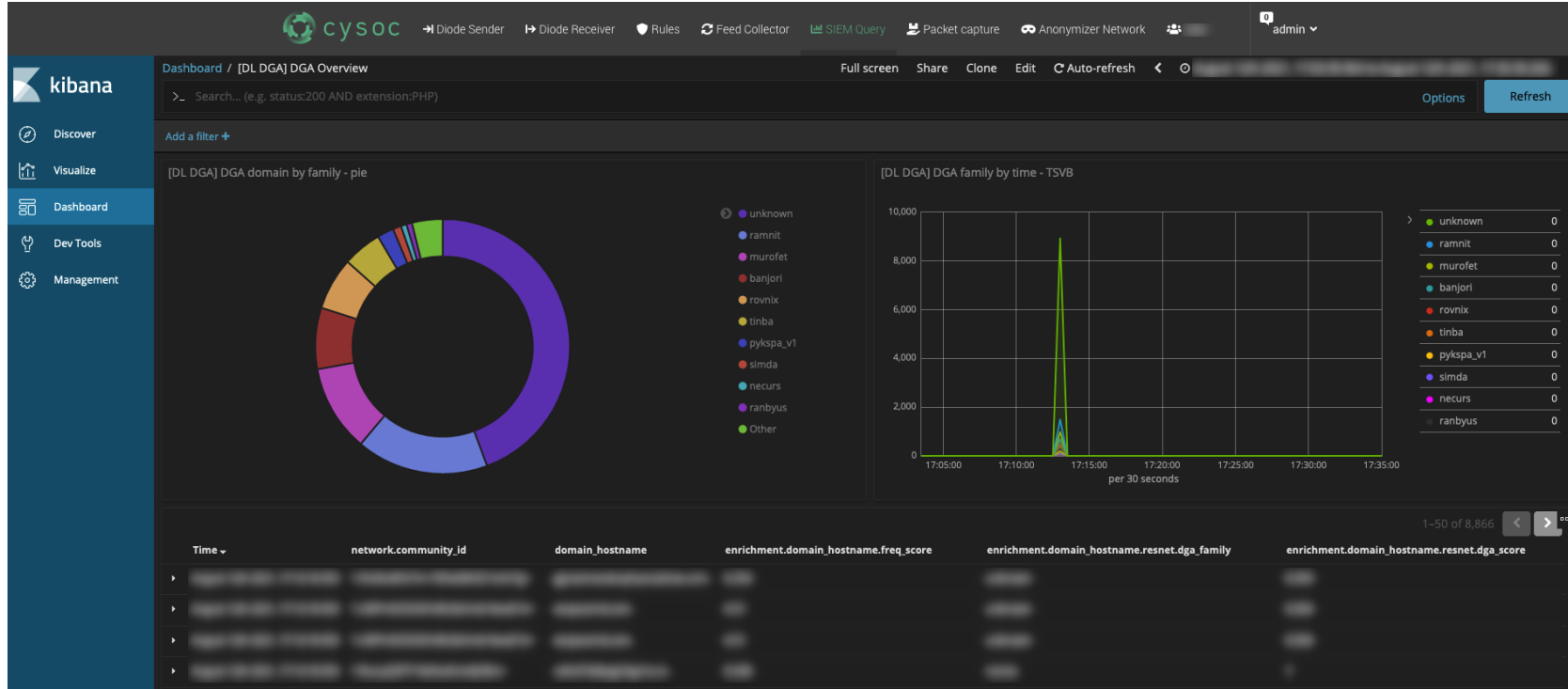
[1] Arthur Driemel, Nils Faerber, and Ulrike Meyer. 2021. First Step Towards EXPLAINable DGA Multiclass Classification. In *The 16th International Conference on Availability, Reliability and Security (ARES 2021)*, August 17–20, 2021, Vienna, Austria. ACM, New York, NY, USA, 13 pages. <https://doi.org/10.1145/34625481.3462749>

#### Acknowledgments

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 833418.

# Impact of SAPPAN Innovations II

Integration of research into existing SIEM solutions:



Facilitating the work of Security Operation Center (SOC) analysts

- Improvement of detection performance
- Reduction of false positives
- Providing explanations for predictions

Thank You  
For Your Attention

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