Image-based Neural Network Models for Malware Traffic Classification using PCAP to Picture Conversion

Georgios Agrafiotis[1], Eftychia Makri[1], Ioannis Flionis[1], Antonios Lalas[1], Konstantinos Votis[1], Dimitrios Tzovaras[1] and Nikolaos Tsampieris[2]

[1]Information Technologies Institute / Centre for Research and Technology Hellas
6th km Xarilaou – Thermi, Thessaloniki, 57001, Greece

[2]Infitheon Technologies
Patriarchou Grigoriou & Neapoleos 27, Athens, 15310, Greece

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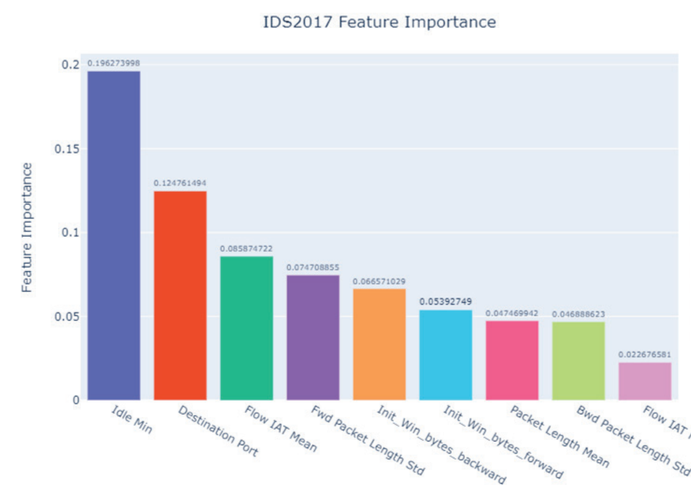
Background

- The 5th generation (5G) networks are deemed a rapidly emerging technology with multiple applications and associated **cybersecurity challenges**, rendering **traffic categorization** a task of paramount importance in the network security sector, as well as the first stage in a network-based **intrusion detection system** (IDS).
- However, current detection systems, which work better when malware signatures are known in advance, are useless against **zero-day assaults** and **amorphous malware** and unable to deal with developing malware vectors or emerging network protocols, e.g. the **5G-related protocols**.

Goal

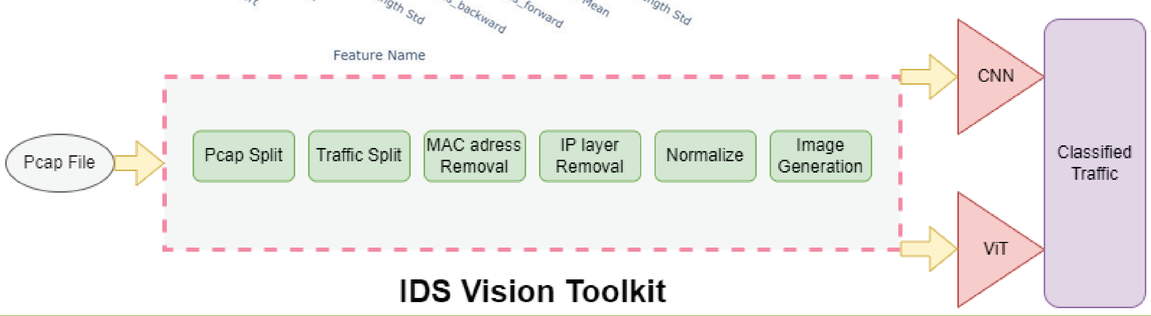
- Transformation of **raw traffic data** into grayscale **pictures** and employment of state-of-the-art image-based neural network models, namely **Vision Transformers** (ViT) and **Convolutional Neural Networks** (CNN) for an **IDS application properly tailored on 5G**.

Data Preprocessing



- CIC-Flow-Meter for the extraction of **80 statistical network traffic features**
- Clearance of redundant records
- Discard of extra features

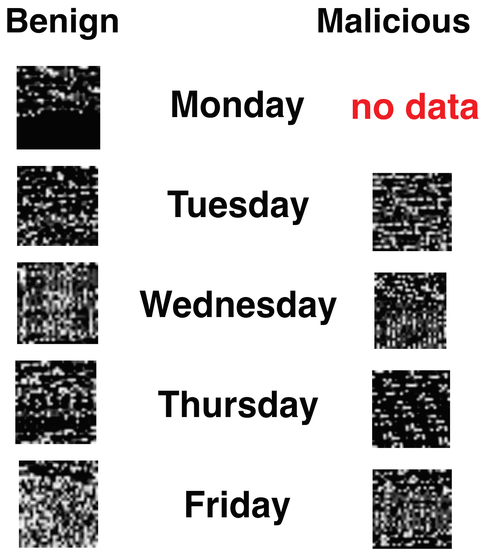
Comparison of **CIC-Flow-Meter** and **IDS Vision Toolkit** means informative comparison between **statistical** and **temporal data**



With **IDS Vision Toolkit**, raw traffic data (PCAP) is converted either png or jpg format

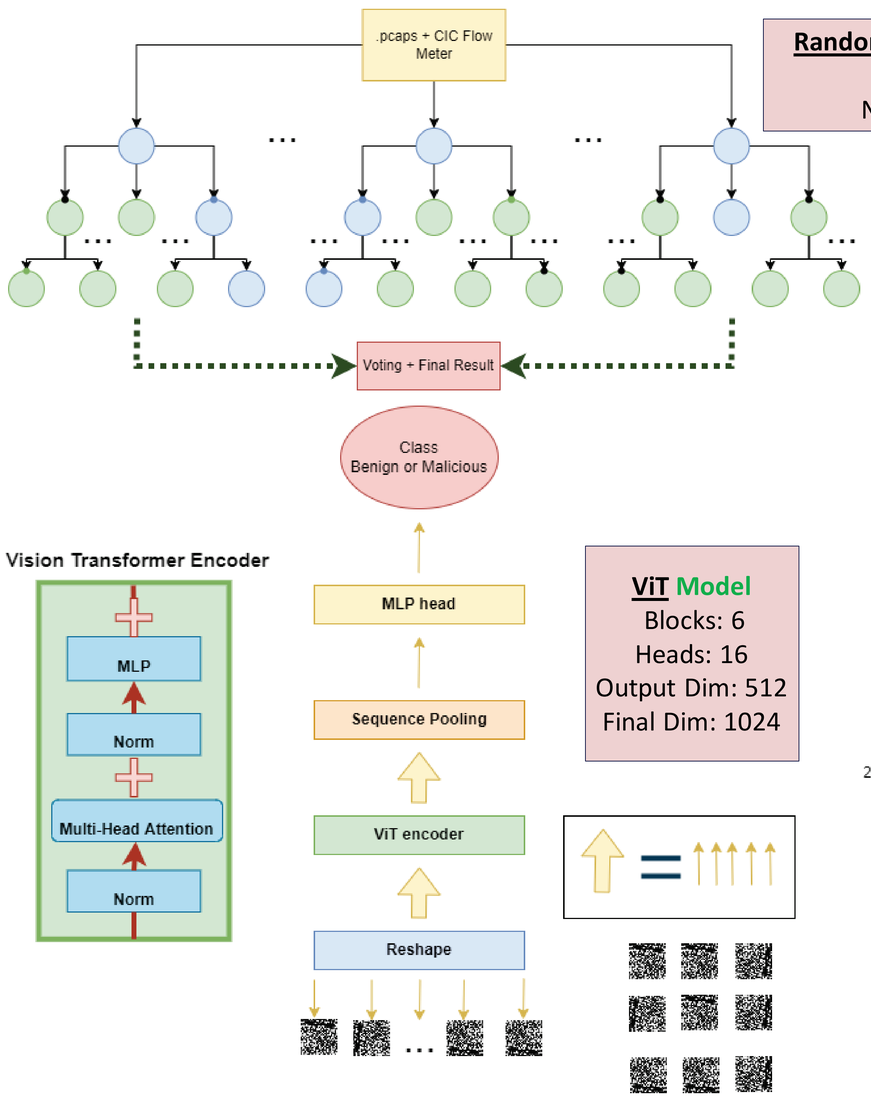
- **Step 1: Traffic Splitting**
- **Step 2: Traffic Clearing**
- **Step 3: Image Generation**

Data Visualization



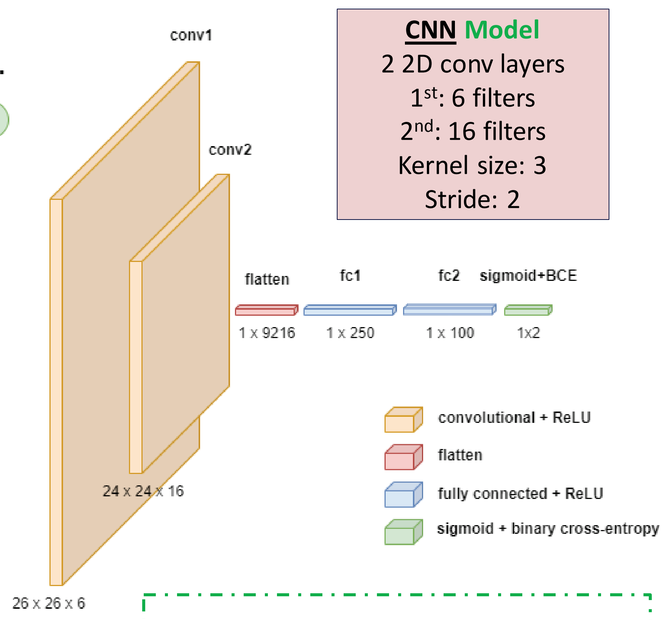
- **4,834,730** images, 4,046,667 benign and 788,053 malicious
- Each image represents a **flow**
- Each greyscale image is **28 × 28** bytes

Models' Architecture



Random Forest (RF) Model
Depth: 7
No. of trees: 78

ViT Model
Blocks: 6
Heads: 16
Output Dim: 512
Final Dim: 1024



CNN Model
2 2D conv layers
1st: 6 filters
2nd: 16 filters
Kernel size: 3
Stride: 2

To the best of our knowledge, **ViT** models **have not been examined** yet in terms of **cybersecurity** applications.

Experimental Results

CIC-Flow	RF	IDS Vision Toolkit	CNN	ViT
Accuracy	0,985	**Accuracy**	0,99	0,999
Precision	0,979	**Precision**	1	1
Recall	0,931	**Recall**	0,997	0,998
F1	0,954	**F1**	0,998	0,999

- **IDS-Vision** toolkit pre-processing method, leads to noticeable **better results** in comparison to the **CIC-Flow-Meter**
- **ViT** and **CNN**, achieved **almost the same** performance on the image dataset.

Conclusions

- The proposed preprocessing toolkit, named **IDS-Vision Toolkit**, extracts **images from PCAP files**, for classification of benign and malicious network traffic and it is a **promising tool for the employment of representation learning** as a technique for IDS purposes.
- The two experiments, in terms of different datasets (**statistical** and **tabular**) and ML algorithms exhibited promising results for the aforementioned classification task, achieving **accuracy higher than 98%**.
- The **image dataset** (tabular) as an input, led to **better results**, in comparison with the **tabular** dataset, paving the way for the opportunity to utilize **state-of-the-art models for image recognition tasks** for IDS purposes.
- **Future work** includes testing against **a larger and 5G-specific dataset** and on a **multi-label classification problem**, while the lossy pre-processing pipeline, could be addressed by creating a model that feeds flows and sessions into an **Auto-Encoder** without cropping the **packet payload** at all.

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CONTACT INFORMATION

Dr. Antonios Lalas, Centre for Research and Technologies Hellas, lalas@iti.gr