Network Traffic Classification

Universal machine learning framework for network traffic classification. Supports multiple datasets, configurable ML models, and automated comparison of different model configurations.

Features

- **Multiple datasets support**: DDoS detection, Tor traffic detection, application classification
- **Three ML algorithms**: Random Forest, XGBoost, SVM
- **Flexible configuration**: Separate configs for datasets and model parameters
- **Batch processing**: Run multiple model configurations automatically
- **Automated visualizations**: Confusion matrices, feature importance, model comparison charts
- **Classification types**: Binary, multiclass, or both depending on dataset

Project Structure

```
.
├── main.py                 # Main entry point
├── classifiers.py          # ML model wrappers
├── data_utils.py           # Data loading and preprocessing
├── plots.py                # Visualization functions
├── requirements.txt        # Python dependencies
├── datasets/
│   └── datasets.json       # Dataset configurations
├── models/                 # Model configurations
│   ├── model_base.json       # Default parameters
│   ├── model_fast_test.json      # Quick testing
│   ├── model_high_estimators.json
│   ├── model_regularized.json
│   └── model_linear_svm.json
├── data/                   # CSV data files (not included)
└── results/                # Generated results and plots
```

Installation

```
pip install -r requirements.txt
```

Quick Start

```
# List available datasets
python main.py --list-datasets

# List available model configurations
python main.py --list-models

# Run analysis with all model configs
python main.py -d ddos

# Run with smaller dataset for testing
python main.py -d darknet_tor -s
```

Usage

Basic Commands

```
# Single model configuration
python main.py -d ddos -c base

# Multiple configurations
python main.py -d ddos -c base fast_test regularized

# Specific ML models only
python main.py -d ddos -m rf xgb

# Custom output directory
python main.py -d ddos -o results/experiment1

# Quiet mode (less output)
python main.py -d ddos -q
```

Command Line Arguments

Argument	Short	Description
`--dataset`	`-d`	Dataset to analyze
`--smaller`	`-s`	Use smaller dataset for quick testing
`--config`	`-c`	Specific model config(s) to use
`--models`	`-m`	ML models to use (rf, xgb, svm)
`--models-dir`		Directory with model configs (default: models/)
`--datasets-config`		Path to datasets config
`--output-dir`	`-o`	Output directory
`--list-datasets`	`-ld`	List available datasets
`--list-models`	`-lm`	List model configurations

Argument	Short	Description
`--quiet`	`-q`	Reduce output verbosity

Datasets

Dataset	Type	Description
`ddos`	binary + multiclass	DDoS attack detection (BENIGN vs ATTACK + attack types)
`darknet_tor`	multiclass only	Darknet traffic detection (Tor, Non-Tor, VPN, Non-VPN)
`darknet_app`	multiclass only	Application classification (AUDIO, VIDEO, CHAT, etc.)
`syscallsbinders`	multiclass only	Syscalls binders classification (malware analysis)

Results

Summary

All models were tested with 5 configurations: Baseline, Fast Test, High Estimators, Linear SVM Focus, and Regularized. Below are the best results achieved for each dataset.

Best Results Overview

Dataset	Best Model	Config	Type	Accuracy	F1-Score
DDoS (Binary)	XGBoost	High Estimators	Binary	**99.99%**	0.9999
DDoS (Multiclass)	XGBoost	Baseline	Multiclass	**92.70%**	0.9295
Darknet Tor	XGBoost	High Estimators	Multiclass	**98.50%**	0.9850
Darknet App	XGBoost	Baseline	Multiclass	**98.49%**	0.9845
Syscallsbinders	XGBoost	Baseline	Multiclass	**94.57%**	0.9456

DDoS Attack Detection

Binary classification (BENIGN vs ATTACK) and multiclass classification (attack type detection).

Binary Classification Results

Config	Random Forest	XGBoost	SVM
Baseline	99.98%	99.98%	99.87%
Fast Test	99.97%	99.95%	99.87%
High Estimators	99.98%	**99.99%**	99.87%
Regularized	99.96%	99.97%	99.83%
Linear SVM	99.98%	99.98%	99.88%

Multiclass Classification Results

Config	Random Forest	XGBoost	SVM
Baseline	89.40%	**92.70%**	86.99%
Fast Test	88.56%	92.58%	86.92%
High Estimators	89.38%	92.67%	86.99%
Regularized	89.27%	92.68%	86.77%
Linear SVM	89.40%	92.70%	87.95%

Visualizations □ Click to expand DDoS visualizations

Class Distribution:

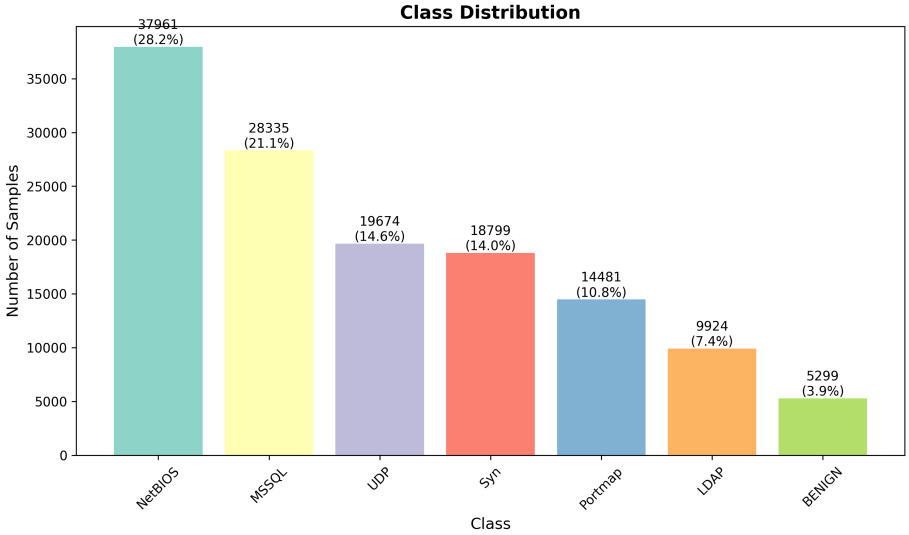


Figure 1: Class Distribution

Model Comparison:

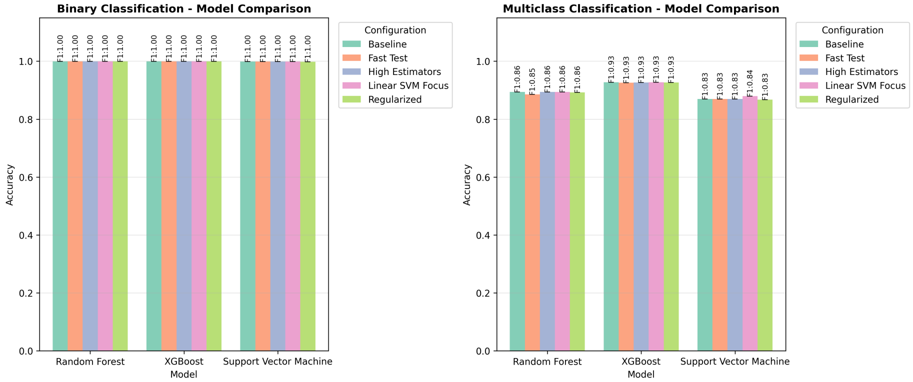


Figure 2: Model Comparison

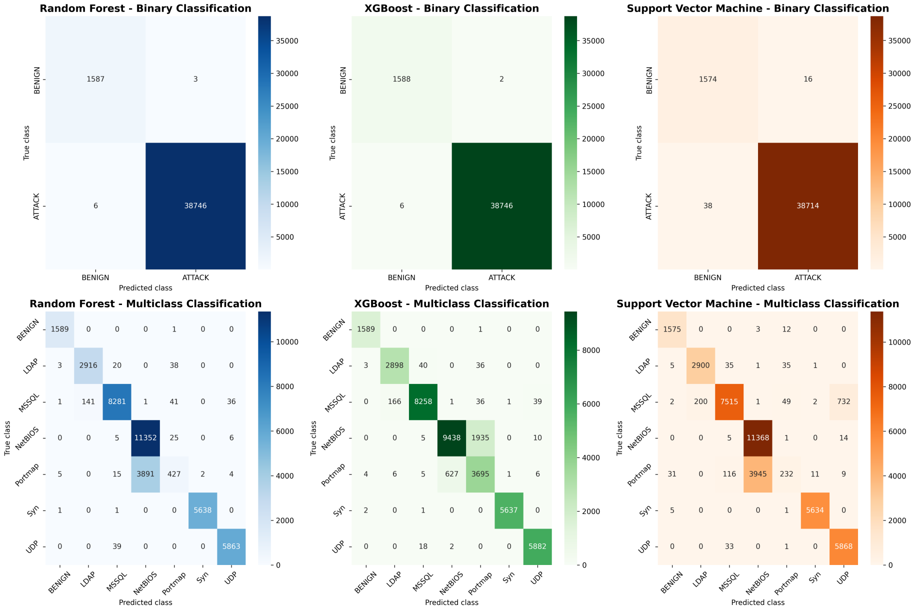


Figure 3: Confusion Matrices

Confusion Matrices (Baseline):

Feature Importance (Baseline):

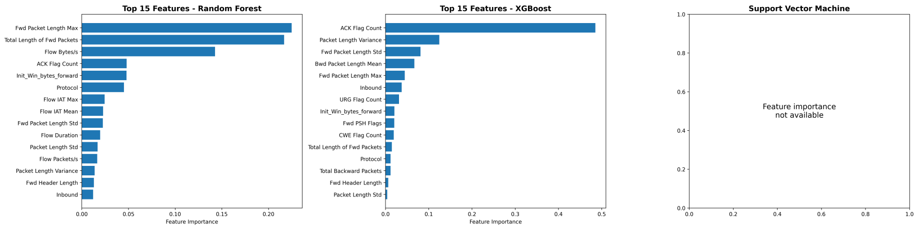


Figure 4: Feature Importance

Darknet Traffic Detection (Tor)

Multiclass classification: Tor, Non-Tor, VPN, Non-VPN traffic.

Results by Configuration

Config	Random Forest	XGBoost	SVM
Baseline	98.37%	98.49%	94.89%
Fast Test	97.67%	97.40%	94.89%
High Estimators	98.26%	**98.50%**	94.89%
Regularized	98.25%	98.31%	94.04%
Linear SVM	98.37%	98.49%	91.17%

Visualizations □ Click to expand Darknet Tor visualizations

Class Distribution:

Model Comparison:

Confusion Matrices (Baseline):

Feature Importance (Baseline):

Darknet Application Classification

Multiclass classification: AUDIO, VIDEO, CHAT, BROWSING, etc.

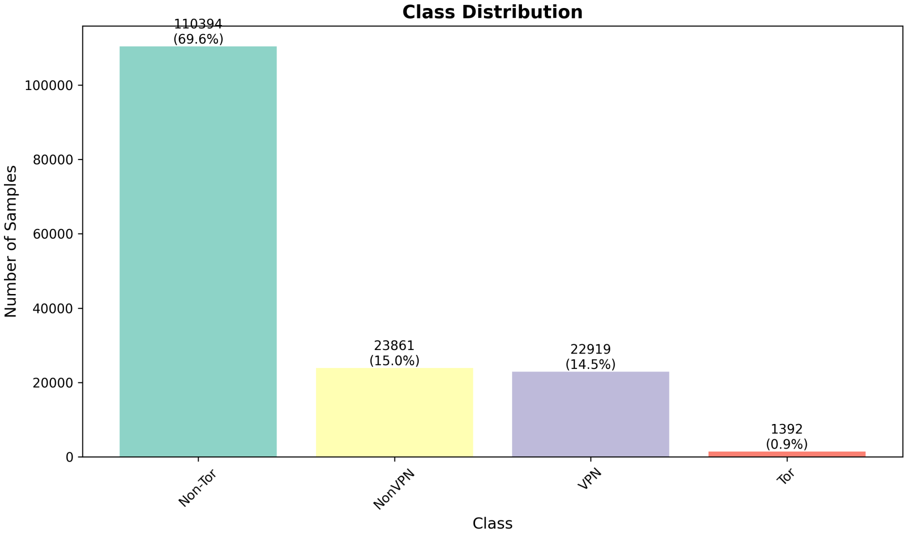


Figure 5: Class Distribution

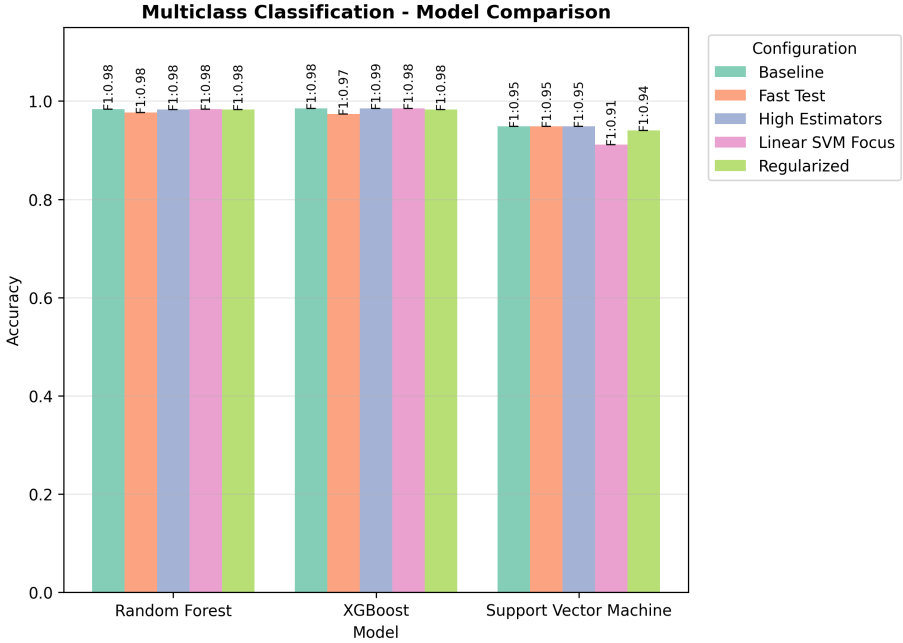


Figure 6: Model Comparison

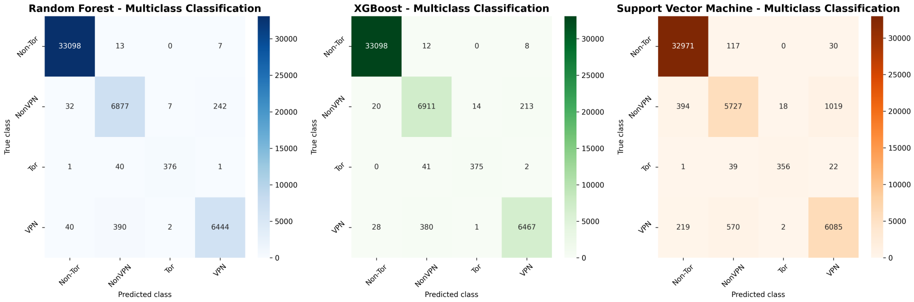


Figure 7: Confusion Matrices

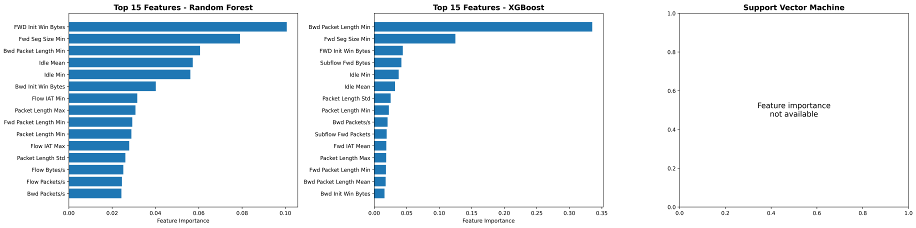


Figure 8: Feature Importance

Results by Configuration

Config	Random Forest	XGBoost	SVM
Baseline	98.43%	**98.49%**	95.96%
Fast Test	97.43%	98.15%	95.91%
High Estimators	98.40%	98.47%	95.96%
Regularized	97.96%	98.25%	95.77%
Linear SVM	98.43%	98.49%	94.46%

Visualizations □ Click to expand Darknet App visualizations

Class Distribution:

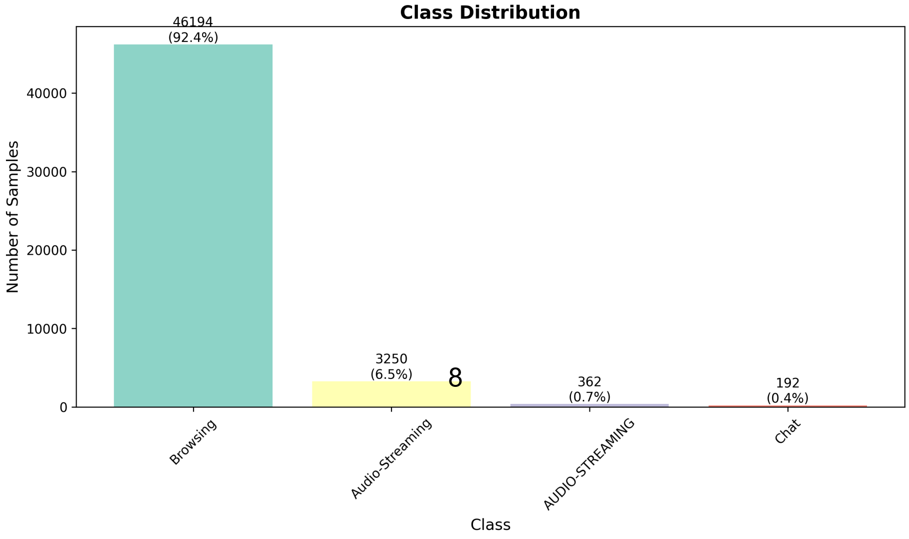


Figure 9: Class Distribution

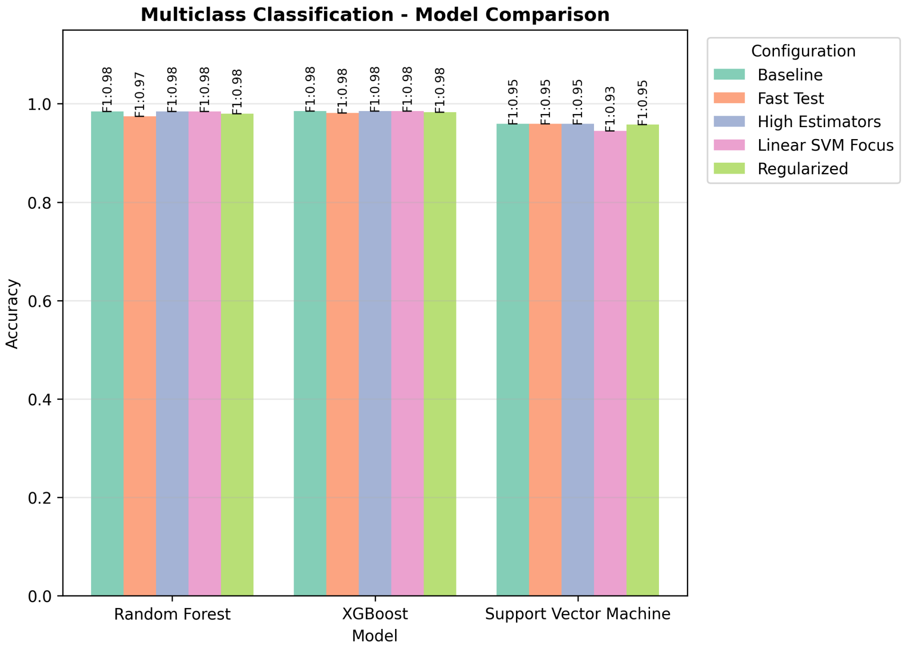
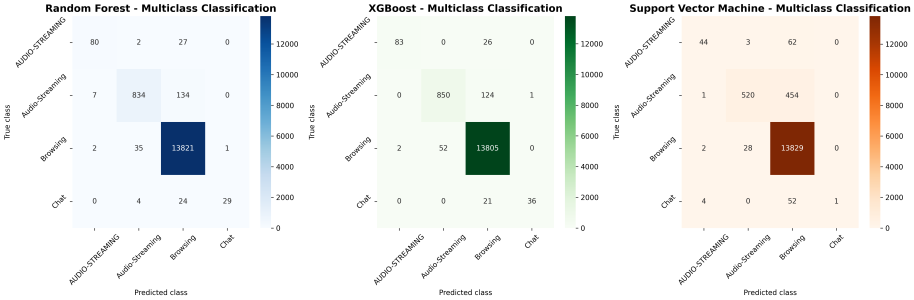


Figure 10: Model Comparison



Random Forest - Multiclass Classification

True class \ Predicted class	AUDIO-STREAMING	Audio-Streaming	Browsing	Chat
AUDIO-STREAMING	80	2	27	0
Audio-Streaming	7	834	134	0
Browsing	2	35	13821	1
Chat	0	4	24	29

XGBoost - Multiclass Classification

True class \ Predicted class	AUDIO-STREAMING	Audio-Streaming	Browsing	Chat
AUDIO-STREAMING	83	0	26	0
Audio-Streaming	0	850	124	1
Browsing	2	52	13805	0
Chat	0	0	21	36

Support Vector Machine - Multiclass Classification

True class \ Predicted class	AUDIO-STREAMING	Audio-Streaming	Browsing	Chat
AUDIO-STREAMING	44	3	62	0
Audio-Streaming	1	520	454	0
Browsing	2	28	13829	0
Chat	4	0	52	1

Figure 11: Confusion Matrices

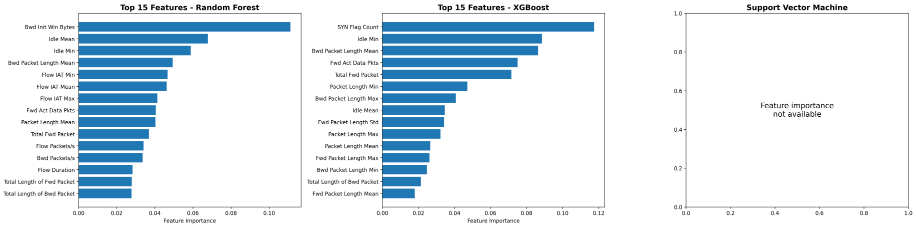


Figure 12: Feature Importance

Results by Configuration

Config	Random Forest	XGBoost	SVM
Baseline	94.51%	**94.57%**	78.16%
Fast Test	91.29%	92.70%	77.84%
High Estimators	94.08%	94.57%	78.16%
Regularized	93.05%	94.08%	76.32%
Linear SVM	94.51%	94.57%	86.52%

Visualizations □ Click to expand Syscallsbinders visualizations

Class Distribution:

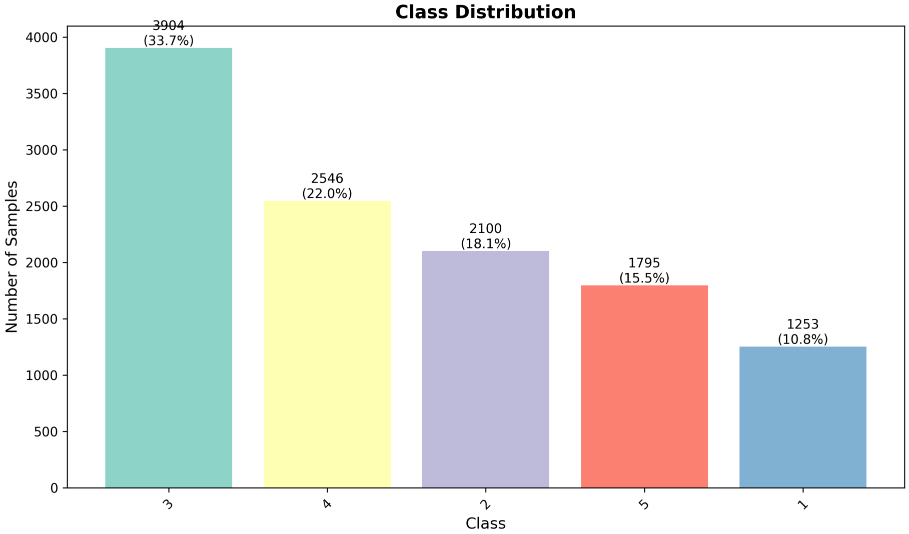


Figure 13: Class Distribution

Model Comparison:

Confusion Matrices (Baseline):

Feature Importance (Baseline):

Key Findings

1. **XGBoost consistently outperforms** other models across all datasets
2. **Tree-based models (RF, XGBoost)** achieve >94% accuracy on all tasks

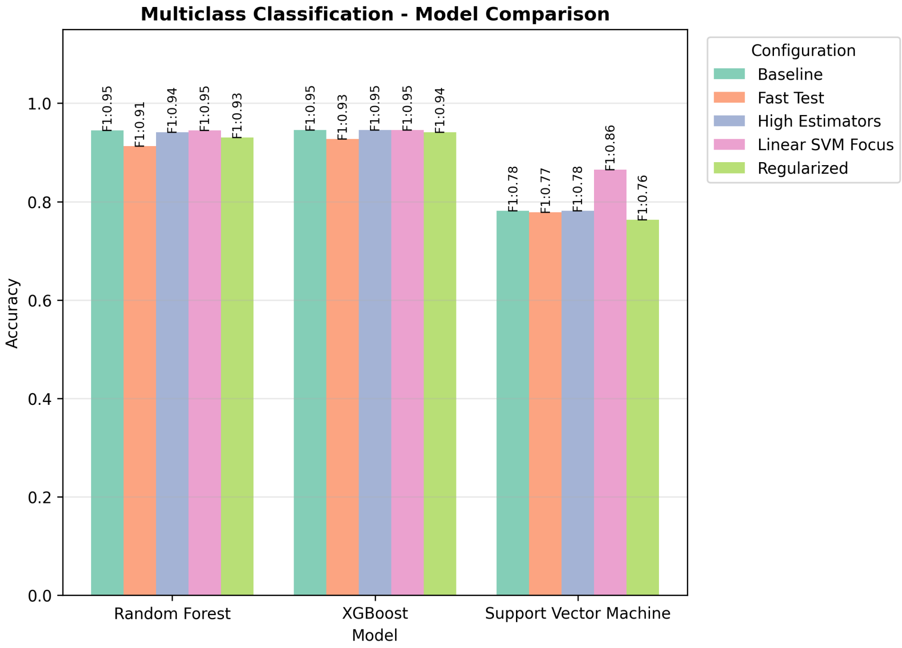


Figure 14: Model Comparison

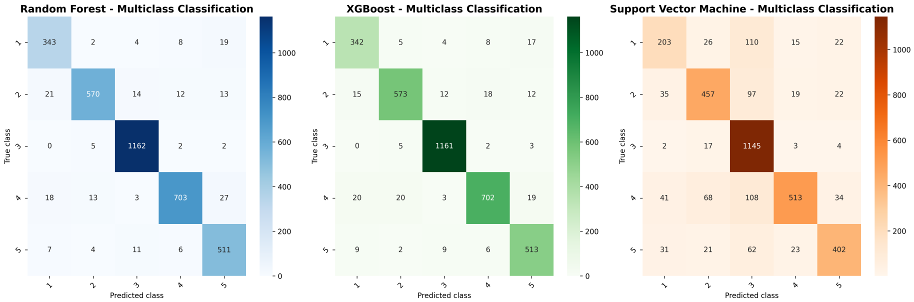


Figure 15: Confusion Matrices

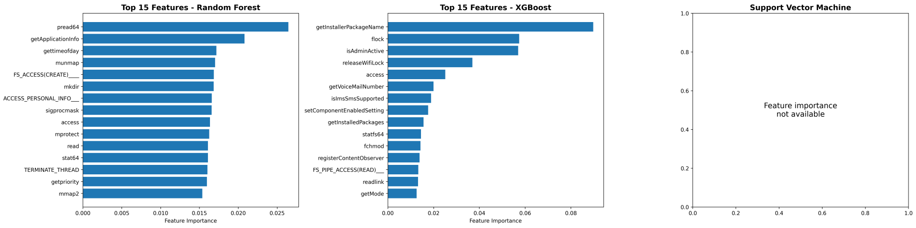


Figure 16: Feature Importance

3. **SVM performance varies** significantly depending on kernel choice (Linear vs RBF)
4. **DDoS binary classification** achieves near-perfect accuracy (99.99%)
5. **Network traffic classification** (Darknet) performs extremely well (~98.5%)

Adding New Datasets

Edit `datasets/datasets.json`:

```json
{
  "my_dataset": {
    "name": "My Custom Dataset",
    "files": ["data/mydata.csv"],
    "files_smaller": ["data/mydata_smaller.csv"],
    "label_column": "Label",
    "binary_positive_class": "NORMAL",
    "binary_labels": ["NORMAL", "ANOMALY"],
    "drop_columns": ["ID", "Timestamp"],
    "column_mapping": {},
    "binary_only": false,
    "multiclass_only": false
  }
}
```

Model Configurations

Each config in `models/` directory defines:

```json
{
  "name": "Configuration Name",
  "description": "What this config does",
  "preprocessing": {
    "variance_threshold": 0.0,
    "correlation_threshold": 0.95,
    "test_size": 0.3,
    "random_state": 42
  },
  "models": {
    "rf": { "n_estimators": 100, "max_depth": 20, ... },
    "xgb": { "n_estimators": 100, "max_depth": 10, ... },
    "svm": { "C": 1.0, "kernel": "rbf", ... }
  }
}
```

Available Configurations

Config	Description
`model_base.json`	Default balanced parameters
`model_fast_test.json`	Minimal params for quick testing
`model_high_estimators.json`	More trees for potentially better accuracy
`model_regularized.json`	Stronger regularization to prevent overfitting
`model_linear_svm.json`	Linear SVM kernel for high-dimensional data

Output Files

After running analysis, the following files are generated in `results/<dataset>/`:

File	Description
`all_results.csv`	Combined results from all configurations
`results_<config>.csv`	Results for specific configuration
`confusion_matrices_<config>.png`	Confusion matrix visualizations
`feature_importance_<config>.png`	Top 15 important features
`class_distribution.png`	Dataset class distribution
`model_comparison.png`	Comparison chart (when multiple configs)

Data Format

Expected CSV format with network flow features:

- Standard flow features (duration, packet counts, byte counts, etc.)
- Label column for classification target
- Supports CIC-IDS / CIC-DDoS dataset format

Example Workflow

```
# 1. Quick test with fast config
python main.py -d ddos -s -c fast_test

# 2. Full analysis with all configs
python main.py -d ddos

# 3. Compare specific configurations
python main.py -d ddos -c base regularized high_estimators

# 4. Run only tree-based models (faster than SVM)
python main.py -d ddos -m rf xgb
```

Requirements

- Python 3.8+
- pandas >= 2.0.0
- numpy >= 1.24.0
- scikit-learn >= 1.3.0
- xgboost >= 2.0.0
- matplotlib >= 3.7.0
- seaborn >= 0.12.0