Binary Classification of Internet Traffic

Identifying Distributed Denial of Service Attacks

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INTRODUCTION

- **Distributed Denial of Service (DDOS)** is a common attack method for Internet service disruption.
- **Multiple attack methods can result in DDOS**: broad detection and mitigation ability is a must to minimize vulnerability.
- **Attacks are often concurrent with legitimate traffic**: goal of mitigation is to filter malicious traffic while allowing benign traffic to pass without significant obstruction.
- Data set for building logistic regression contains 7,616,509 observations and 85 variables, including a Label variable for Benign vs DDOS traffic. 17% of observations are from DDOS attacks.

METHODS

- **Examine data set** to gather comprehensive information on variable properties. Eliminate variables that cannot be used due to poor or lacking information. Identify and impute missing or erroneous data if possible.
  - ~50000 observations had values NA, infinity, or implausibly negative for certain variables due to lack of precision and accuracy in time-related information. Values were recalculated to restore information.
- **Cluster variables** to identify variables of greatest interest.
- **Discretize variables and calculate odds of benign vs ddos traffic for each bin** to extract additional information and trends from selected variables. Natural log of odds also calculated for each bin.
- **Eliminate non-significant variables** from selection for logistic model.
- **Create logistic regression model** using selected variables. Model is trained on 80% of the data set.
- **Refine logistic regression model** to eliminate redundancy and select for highly significant variables.

RESULTS

- Logistic regression model with 17 selected variables has 99.9% concordant pair rate (C=0.999). Model predicts a lower probability of possible DDOS traffic for benign cases than actual DDOS attacks in most observations.
- Maximal KS statistic of .954
- Model can be simplified depending on needs and resources. C=.995 with as few as 4 variables.
  - Initial measurements only: C=.965 with 3 variables, with marginal gains for additional initial statistics.
- Sensitivity and specificity are maximized with probability threshold of 0.188.
  - 17 variable model correctly identifies 98.7% of benign traffic and 98.2% of DDOS traffic.

Table 1. Concordance Statistics for Selected Models

Number of Variables	Concordance
17	0.999
12	0.998
4	0.995
3 (initial statistics)	0.965

Figure 1. KS Chart for Benign vs DDOS Classification

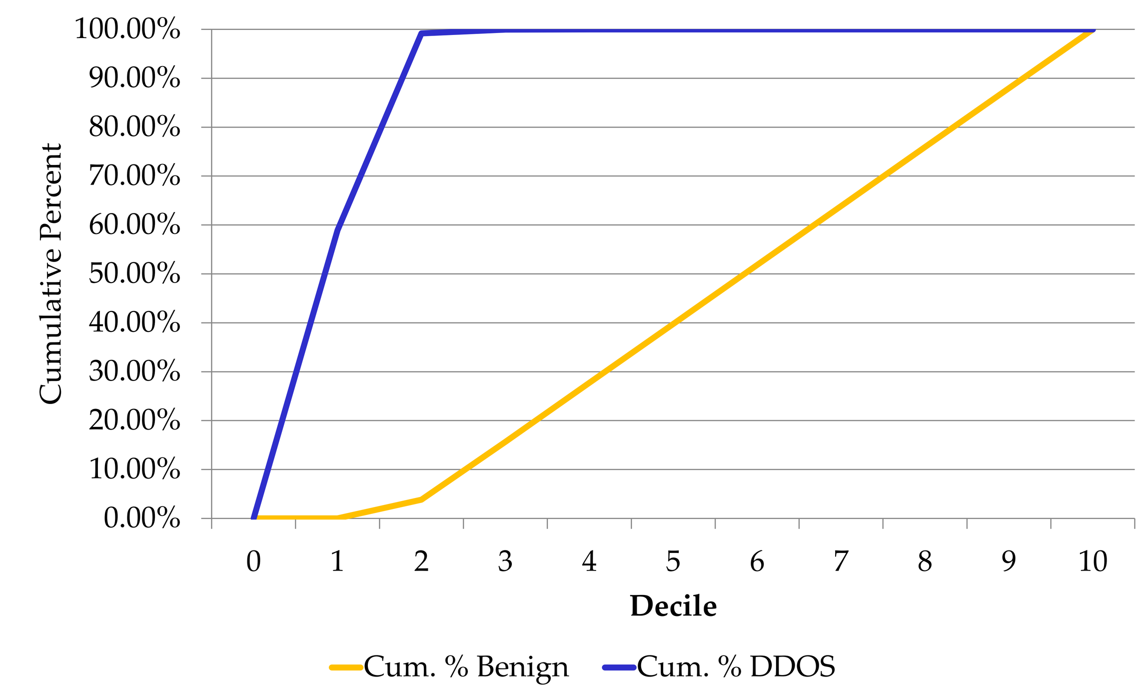


Table 2. Confusion Matrix for Logistic Regression Model with 17 Variables

Label	Prediction		
Frequency Percent	Benign	DDOS	Total
Benign	1248228	16168	1264396
	81.94	1.06	83.00
DDOS	4410	254495	258905
	0.29	16.71	17.00
Total	1252638	270663	1523301
	82.23	17.77	100.00

Figure 2. ROC Curve for Logistic Regression Model

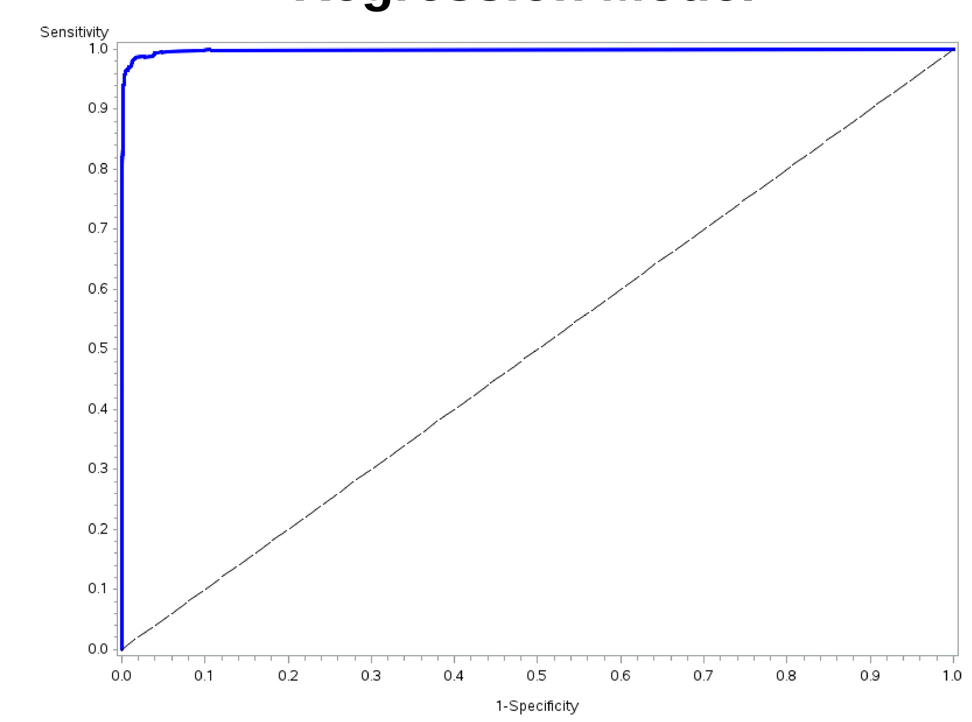


Figure 3. Gain Chart for Benign vs DDOS Classification

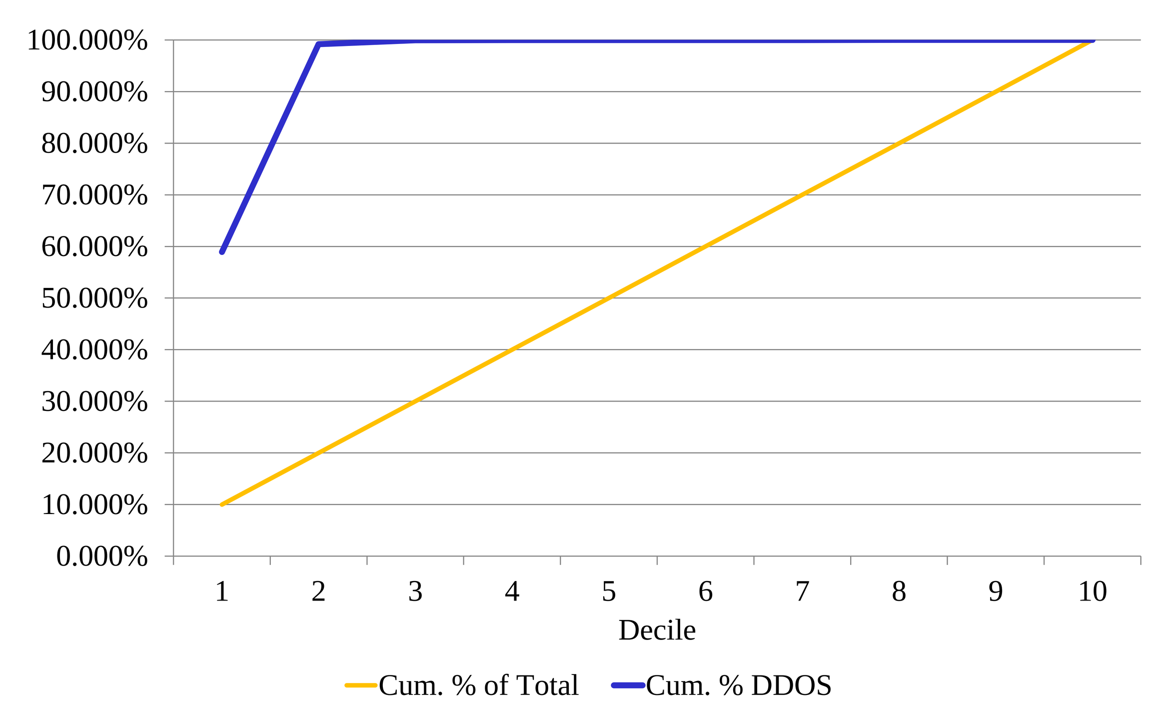
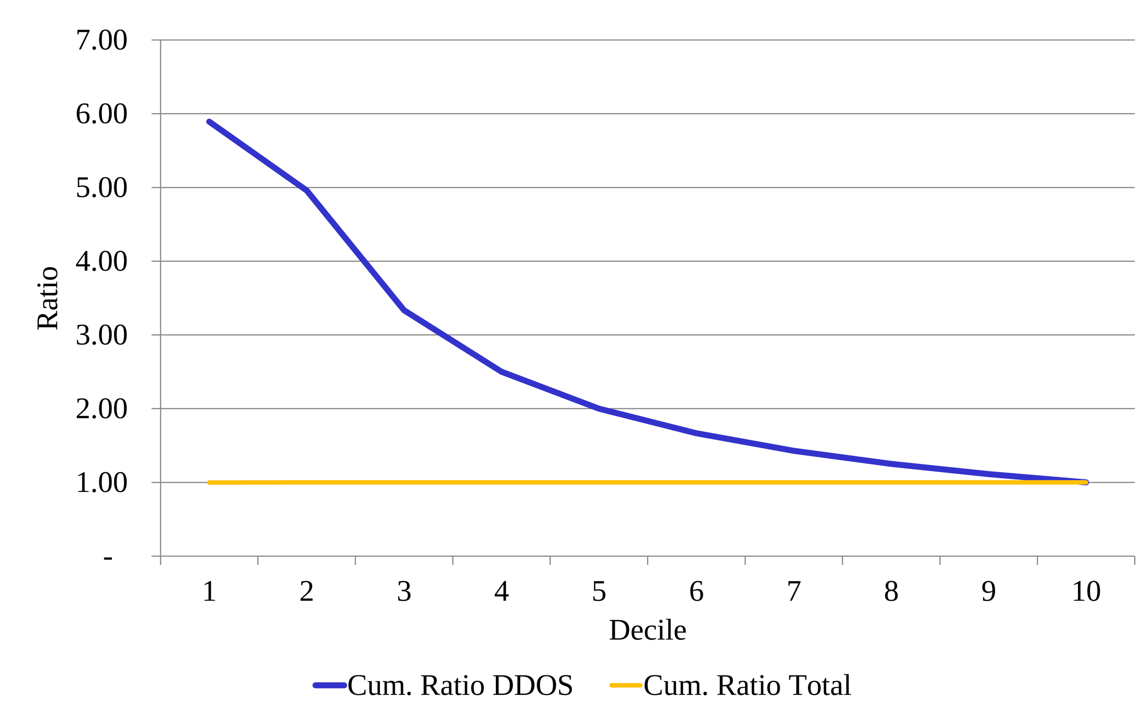


Figure 4. Lift Chart for Benign vs DDOS Classification



DISCUSSION

- **The selected logistic regression model has very high accuracy in classifying benign vs DDOS traffic.**
  - High separation between benign and DDOS traffic.
  - High success rate despite several variations in attack vectors and methods.
  - Effective as a first line of defense in filtering malicious traffic.
  - Content delivery and DDOS mitigation services have strong records in detecting attacks.
- **Predictive success in data set does not guarantee similar level of success moving forward.**
  - Traffic patterns, attack methods, and security practices can evolve rapidly.
  - Model likely to benefit from periodic re-evaluation.
  - Unknown success rate against novel attack vectors of the same general class.
- **Limitations & Improvements**
  - No analysis of trends by time or location (IP address)
  - Lack of precision on some variables
  - Possible errors from traffic logging software used

SAS CODE

```
%IMPV5 (DSN=class.test, VARS=&varlist, EXCLUDE=Label,
PCTREM=1,MSTD=);

PROC SQL;
        SELECT NAME INTO: VARNAME SEPARATED BY ' '
        FROM DICTIONARY.COLUMNS
        WHERE UPCASE(LIBNAME)="DDOS" AND
UPCASE(MEMNAME)="DDOS" AND NAME NOT IN("Label");
QUIT;
PROC VARCLUS DATA=import OUTTREE=tree MAXCLUSTERS=71;
        VAR &varname;
RUN;

PROC GLMSELECT DATA=ddos.disc2;
        MODEL label=&mvar / DETAILS=all SELECTION=lasso
STATS=all;
RUN;

PROC LOGISTIC DATA=train DESC OUTEST=betas
        OUTMODEL=scoringdata;
        MODEL label=&mvarsn /SELECTION=BACKWARD
        CTABLE pprob=(0.16 to 0.21 by 0.001)
        LACKFIT RISKLIMITS;
        OUTPUT OUT=output p=predicted;
        SCORE DATA=valid OUT=ddos.score;
RUN;
```

ACKNOWLEDGEMENTS

Iman Sharafaldin, Arash Habibi Lashkari, and Ali A. Ghorbani, “Toward Generating a New Intrusion Detection Dataset and Intrusion Traffic Characterization”, 4th International Conference on Information Systems Security and Privacy (ICISSP), Portugal, January 2018

M Devendra Prasad, Prasanta Babu V, and C Amarnath. “Machine Learning DDoS Detection Using Stochastic Gradient Boosting”. JCSE International Journal of Computer Sciences and Engineering, Vol 7, Issue 4, April 2019

Data retrieved from https://www.kaggle.com/datasets/devendra416/ddos-datasets 2 April 2022.