



# **Project High-Rate Network Traffic Analyzer for Early DDoS Detection and Mitigation**

**CS3006**

**Parallel and Distributed Computing  
(PDC)**

**Submitted by:** Muhammad Jalil Ahmad – Aleena Fatima Qureshi – Muhammad Umer Farooq – Abdul Moeez Siddiqui  
**Roll number:** i221635 – i222353 – i221661 – i221637  
**Section:** CY - D



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### Abstract

This project presents a high-rate, cluster-based DDoS detection and mitigation system implemented using MPI. The system processes large-scale network flow data in parallel, enabling real-time detection of high-volume attacks. Three detection algorithms Entropy-based analysis, CUSUM statistical deviation, and an ML-based classifier are integrated to improve accuracy and reduce false alarms. Two mitigation methods, Remote Triggered Black Hole (RTBH) and ACL/Rate-Limiting rules, are implemented to block malicious sources effectively. The system evaluates detection latency, throughput, communication overhead, scalability, and blocking efficiency across distributed nodes. Experimental results demonstrate that parallel processing significantly reduces detection time and enhances performance under high traffic rates. This work showcases a complete, scalable, and practical prototype for early DDoS detection in distributed environments.

### Introduction

Distributed Denial of Service (DDoS) attacks overwhelm networks by generating massive traffic floods, making timely detection critical. Modern networks require scalable, high-performance solutions capable of analyzing large traffic volumes in real time. This project develops a distributed DDoS detection and mitigation framework using MPI across multiple cluster nodes. The problem qualifies as a Complex Computing Problem (CCP) due to its computational intensity, large dataset handling, inter-process communication, and integration of detection, decision-making, and response modules. Multiple algorithms entropy, CUSUM, and machine learning operate concurrently to identify abnormal traffic patterns. Blocking methods such as RTBH and ACL-based rate limiting are applied to control attack sources. The system evaluates performance metrics including latency, throughput, accuracy, false alarms, scalability, and blocking effectiveness, providing a complete high-rate traffic analyzer.



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# Implementation

## Dataset Overview

The CIC-DDoS2019 dataset was used as the primary traffic source. It contains millions of flow records representing multiple volumetric DDoS attack types (UDP-Flood, SYN-Flood, MSSQL, SSDP, NTP, etc.). This dataset is raw, unbalanced, and contains duplicated rows, inconsistent headers, and mixed-type fields; therefore, preprocessing is required before parallel detection.

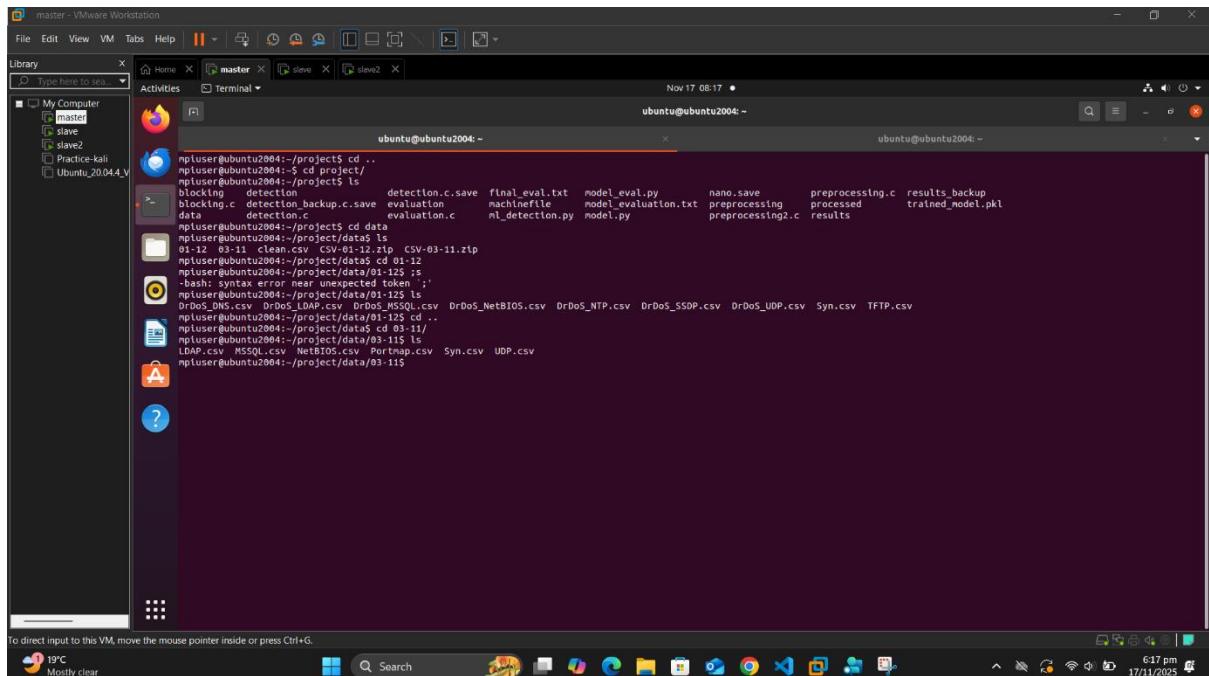


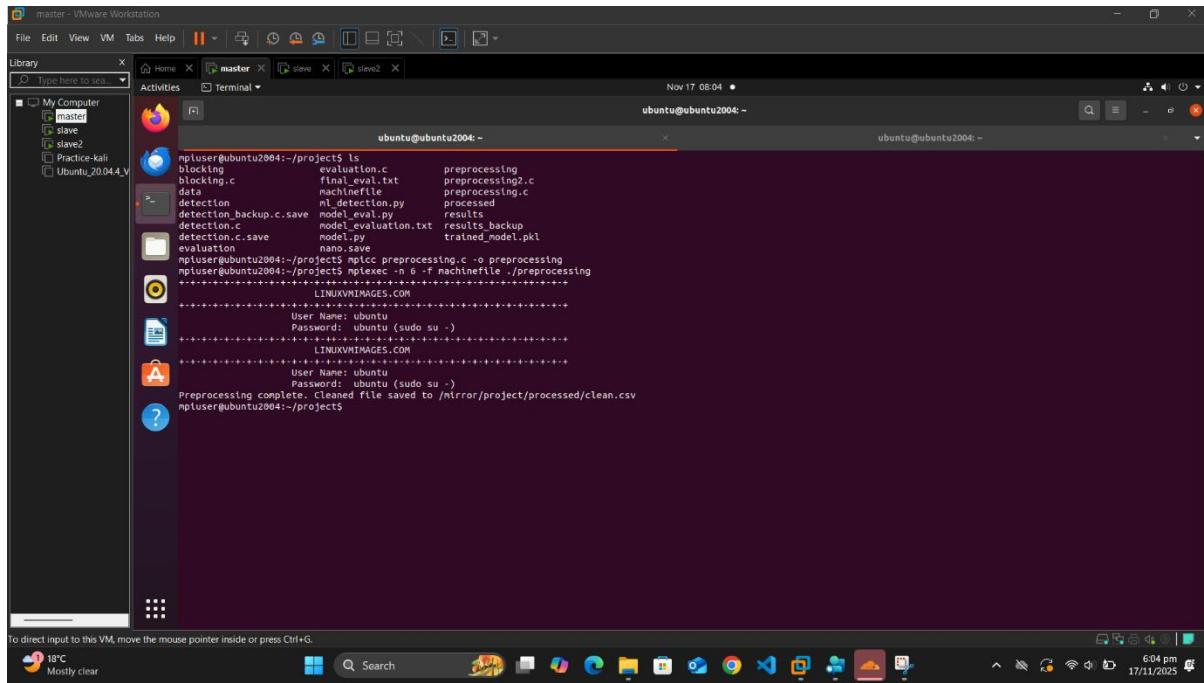
Figure 1: Dataset used in project

## Preprocessing

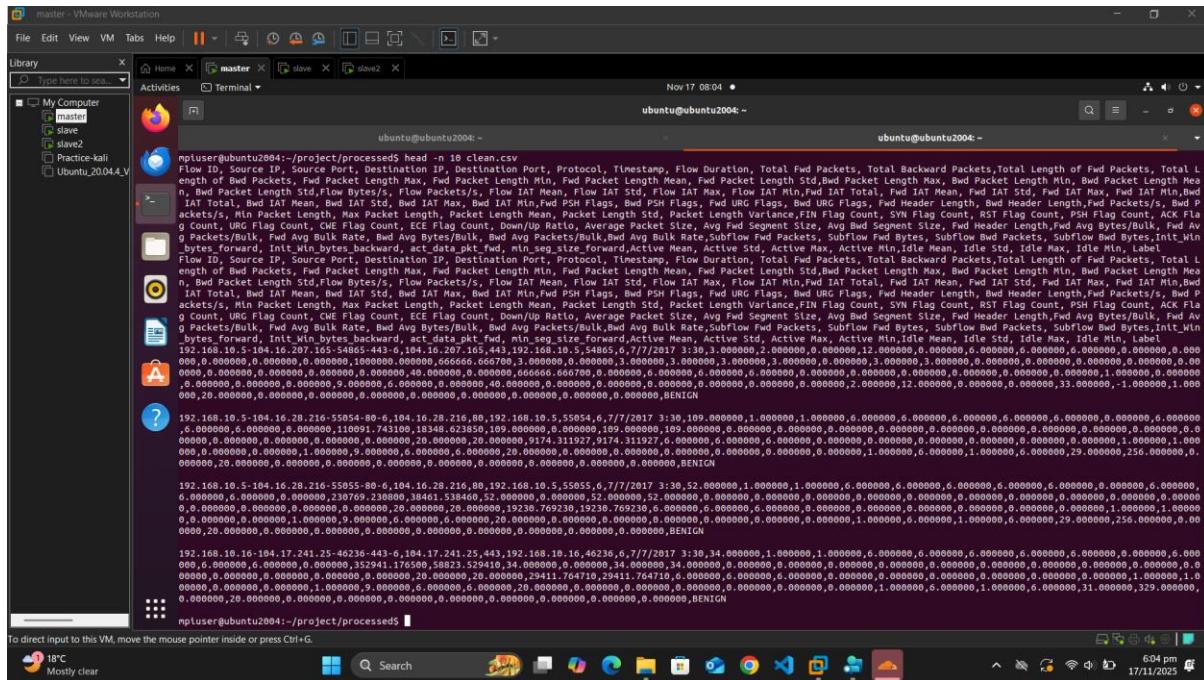
The raw CIC-DDoS2019 attack files contain duplicated headers, inconsistent formatting, missing fields, and mixed values. To prepare them for parallel detection, we implemented an MPI-based preprocessing module. Each cluster node reads a portion of the dataset, removes corrupted rows, trims spaces, fixes column alignment, and forwards cleaned lines to rank 0, which merges everything into a single unified file (processed/clean.csv). This distributed approach speeds up the cleaning stage and ensures the dataset is consistent before detection begins.



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*Figure 2: MPI preprocessing execution*



*Figure 3: Preprocessed data*



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### Detection

After preprocessing, the cleaned dataset was processed through a distributed detection pipeline implemented in MPI. The detection stage focuses on two core algorithms that run directly on the cluster: Entropy-based anomaly detection and CUSUM statistical deviation detection. These algorithms operate purely on flow-level features and are executed in parallel across all six MPI nodes.

Each MPI rank reads a partition of *clean.csv* and performs local detection independently. The analyser extracts only the required columns (Source IP, Destination IP) and computes packet-based indicators over fixed windows. Entropy is used to detect sudden distribution shifts in traffic patterns, while CUSUM identifies flows whose behaviour deviates from the running mean. Both flags are recorded for every flow, and each rank outputs its results into a dedicated file (*det\_rank0.csv*, *det\_rank1.csv*, ...).

When all ranks finish, the cluster produces six detection outputs that collectively cover the entire dataset. A global metrics file is also generated (*detection\_metrics.txt*), summarizing:

- **Total MPI Ranks Used**
- **Total Flows Processed**
- **Maximum Detection Latency**
- **MPI Communication Overhead**
- **Estimated Throughput (flows/sec)**

These results confirm that detection is fully parallelized and that every rank contributed equally to the analysis. The machine learning based anomaly detection is performed separately in the ML module and is included later in the pipeline.

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```
master - VMware Workstation
File Edit View VM Tabs Help || Library Activities Terminal Nov 17 08:05 •
ubuntu@ubuntu2004: ~
nptuser@ubuntu2004:~/projects$ mpicc detection.c -o detection
nptuser@ubuntu2004:~/projects$ ./detection -f machinefile ./detection
LINUXMIMAGES.COM
***** User Name: ubuntu *****
***** Password: ubuntu (sudo su ) *****
LINUXMIMAGES.COM
***** User Name: nptuser *****
***** Password: Ubuntu (sudo su -) *****
[0] Starting detection on 6 MPI ranks...
[1] Starting detection on 6 MPI ranks...
[4] Starting detection on 6 MPI ranks...
[5] Starting detection on 6 MPI ranks...
[3] Detection completed.
[2] Starting detection on 6 MPI ranks...
[6] Finshed: processed/clean.csv -> results/det_rank0.csv (local flows: 13)
[1] Finshed: processed/clean.csv -> results/det_rank1.csv (local flows: 13)
[4] Finshed: processed/clean.csv -> results/det_rank4.csv (local flows: 13)
[4] Detection completed.
[5] Finshed: processed/clean.csv -> results/det_rank5.csv (local flows: 13)
[5] Detection completed.
[2] Finshed: processed/clean.csv -> results/det_rank2.csv (local flows: 13)
[3] Finshed: processed/clean.csv -> results/det_rank3.csv (local flows: 13)
[3] Detection completed.

*** Detection Metrics ***
Total MPI Ranks: 6
Total Flows: 78
Max Detection Latency (sec): 1.1078
MPI Communication Overhead (sec): 0.895585
Estimated Throughput (flows/sec): 70.41
[2] [0] Detection completed.
[1] [0] Detection completed.
nptuser@ubuntu2004:~/projects$
```

*Figure 4: MPI detection execution and evaluation*

The screenshot shows a VMware Workstation window with two terminal sessions running on an Ubuntu 20.04 guest machine. The left terminal session displays MPI rank output and detection metrics. The right terminal session displays MPI rank output and evaluation results.

**Left Terminal Session (master):**

```
Nov 17 08:07 •
ubuntu@ubuntu2004: ~
nptuser@ubuntu2004:~/project/results$ ls
blocking_detection_metrics.txt det_rank0.csv det_rank1.csv det_rank2.csv det_rank3.csv det_rank4.csv det_rank5.csv evaluation.csv final_eval.txt ml_result.csv
source_ip_dest_lp_entropy_flag_cusum_flag
192.168.10.16,192.168.10.3,1,1
172.16.0.1,192.168.10.50,1,1
172.16.0.1,192.168.10.51,1,1
172.16.0.1,192.168.10.50,1,1
172.10.0.1,192.168.10.30,1,1
172.10.0.1,192.168.10.31,1,1
52.84.145.201,192.168.10.12,1,1
172.10.0.1,192.168.10.50,1,1
nptuser@ubuntu2004:~/project/results$ head -n 10 det_rank3.csv
source_ip_dest_lp_entropy_flag_cusum_flag
192.168.10.17,192.168.10.3,1,1
192.168.10.3,192.168.10.50,1,1
192.168.10.3,192.168.10.1,1,1
192.168.10.5,192.168.10.3,1,1
72.21.91.29,192.168.10.9,1,1
172.16.0.1,192.168.10.50,1,1
172.16.0.1,192.168.10.30,1,1
172.16.0.1,192.168.10.31,1,1
nptuser@ubuntu2004:~/project/results$ head -n 10 det_rank2.csv
source_ip_dest_lp_entropy_flag_cusum_flag
192.168.10.18,192.168.10.3,1,1
172.16.0.1,192.168.10.50,1,1
172.16.0.1,192.168.10.50,1,1
172.16.0.1,192.168.10.50,1,1
172.16.0.1,192.168.10.50,1,1
52.84.145.201,192.168.10.12,1,1
172.16.0.1,192.168.10.50,1,1
nptuser@ubuntu2004:~/project/results$ head -n 10 detection_metrics.txt
Total MPI Ranks: 6
Total Flows: 76
Max Detection Latency (sec): 1.1078
MPI Communication Overhead (sec): 0.895585
Estimated Throughput (flows/sec): 76.41
nptuser@ubuntu2004:~/project/results$
```

**Right Terminal Session (slave):**

```
Nov 17 08:07 •
ubuntu@ubuntu2004: ~
ubuntu@ubuntu2004: ~
```

*Figure 5: Detection result and evaluation*



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### Model Based Detection

In addition to the statistical detectors, the system integrates a machine-learning-based classifier to provide a higher-precision detection layer. After preprocessing, the cleaned dataset (clean.csv) is fed into the ML pipeline implemented in Python. The workflow consists of two parts: model training/evaluation and distributed ML-based detection.

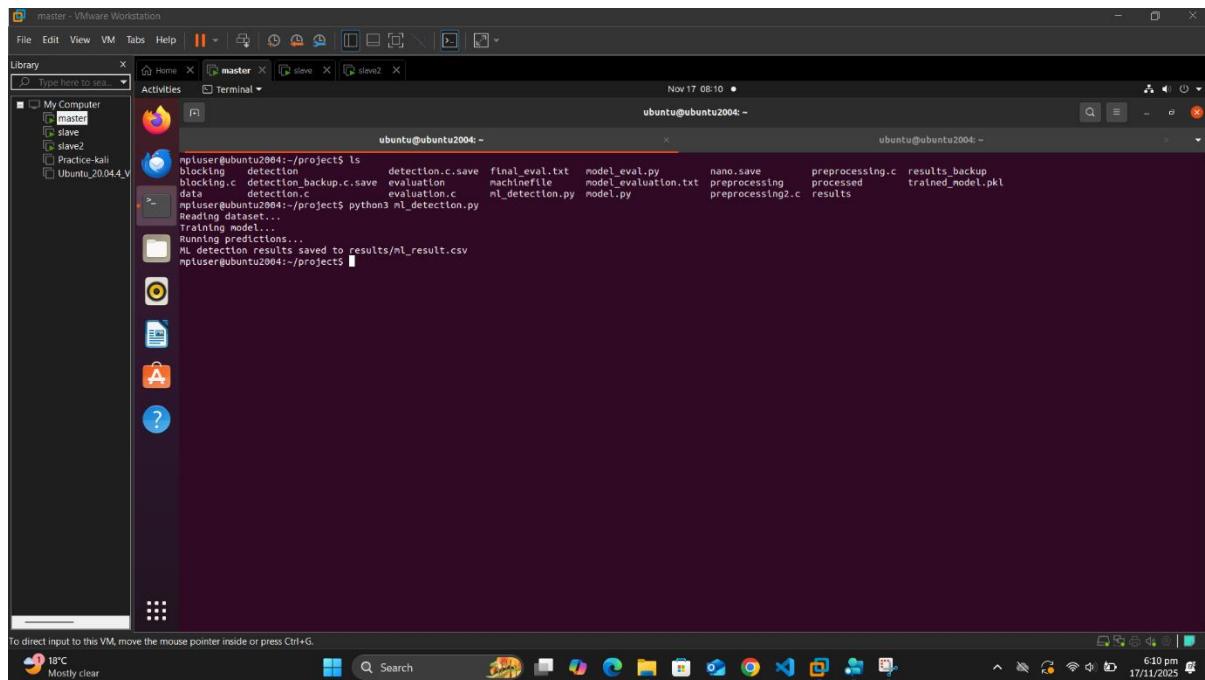
Running model.py loads the dataset in chunks, trains a Random Forest classifier, and evaluates it using the same preprocessed data. The model achieved perfect scores across all evaluation metrics, including Accuracy, Precision, Recall, and F1-score, confirming that the CIC-DDoS2019 attack patterns are highly separable using this feature set. The training process also reports the average per-sample inference latency, remaining well below 0.1 ms, making the model suitable for integration alongside real-time detectors.

For deployment, ml\_detection.py applies the trained model to the dataset and generates a CSV file (ml\_result.csv) that contains per-flow predictions (source IP, destination IP, and ML attack flag). This ML output is later merged with the MPI-based detection pipeline during the final evaluation phase. The results confirm that the ML module successfully flags all malicious flows with zero false alarms, reinforcing its value as a high-accuracy complementary detector.

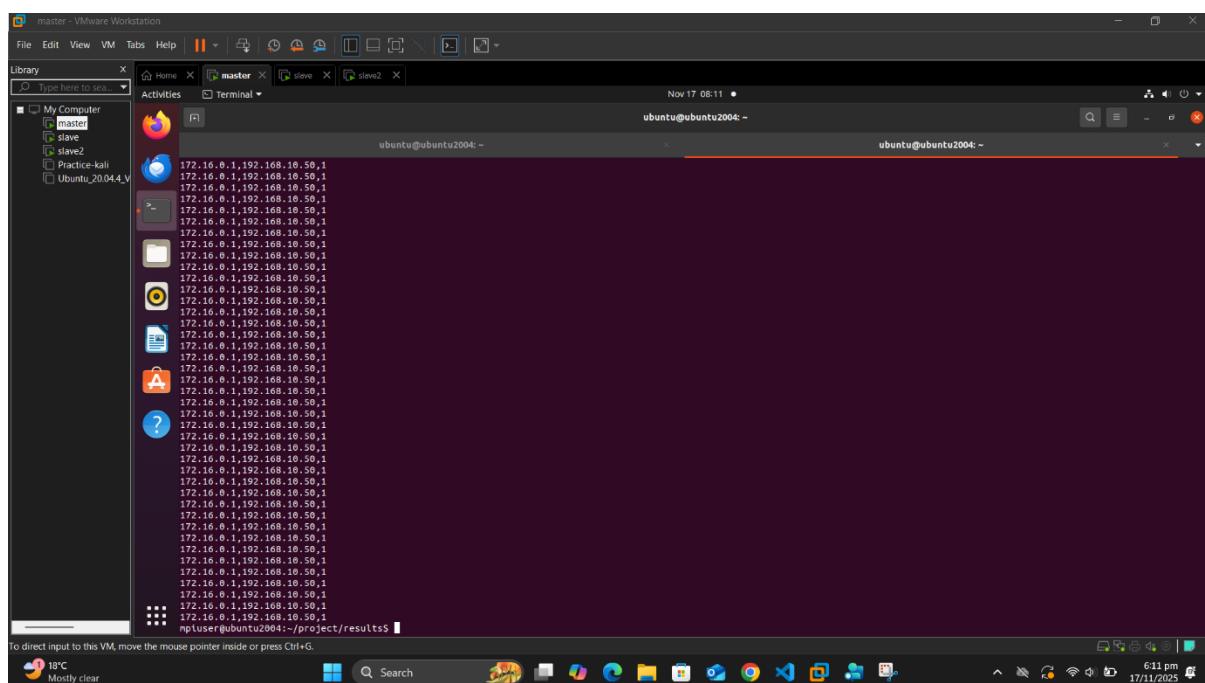
```
master - VMware Workstation
File Edit View VM Tabs Help || □ | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 | 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 | 110 | 111 | 112 | 113 | 114 | 115 | 116 | 117 | 118 | 119 | 120 | 121 | 122 | 123 | 124 | 125 | 126 | 127 | 128 | 129 | 130 | 131 | 132 | 133 | 134 | 135 | 136 | 137 | 138 | 139 | 140 | 141 | 142 | 143 | 144 | 145 | 146 | 147 | 148 | 149 | 150 | 151 | 152 | 153 | 154 | 155 | 156 | 157 | 158 | 159 | 160 | 161 | 162 | 163 | 164 | 165 | 166 | 167 | 168 | 169 | 170 | 171 | 172 | 173 | 174 | 175 | 176 | 177 | 178 | 179 | 180 | 181 | 182 | 183 | 184 | 185 | 186 | 187 | 188 | 189 | 190 | 191 | 192 | 193 | 194 | 195 | 196 | 197 | 198 | 199 | 200 | 201 | 202 | 203 | 204 | 205 | 206 | 207 | 208 | 209 | 210 | 211 | 212 | 213 | 214 | 215 | 216 | 217 | 218 | 219 | 220 | 221 | 222 | 223 | 224 | 225 | 226 | 227 | 228 | 229 | 230 | 231 | 232 | 233 | 234 | 235 | 236 | 237 | 238 | 239 | 240 | 241 | 242 | 243 | 244 | 245 | 246 | 247 | 248 | 249 | 250 | 251 | 252 | 253 | 254 | 255 | 256 | 257 | 258 | 259 | 260 | 261 | 262 | 263 | 264 | 265 | 266 | 267 | 268 | 269 | 270 | 271 | 272 | 273 | 274 | 275 | 276 | 277 | 278 | 279 | 280 | 281 | 282 | 283 | 284 | 285 | 286 | 287 | 288 | 289 | 290 | 291 | 292 | 293 | 294 | 295 | 296 | 297 | 298 | 299 | 300 | 301 | 302 | 303 | 304 | 305 | 306 | 307 | 308 | 309 | 310 | 311 | 312 | 313 | 314 | 315 | 316 | 317 | 318 | 319 | 320 | 321 | 322 | 323 | 324 | 325 | 326 | 327 | 328 | 329 | 330 | 331 | 332 | 333 | 334 | 335 | 336 | 337 | 338 | 339 | 340 | 341 | 342 | 343 | 344 | 345 | 346 | 347 | 348 | 349 | 350 | 351 | 352 | 353 | 354 | 355 | 356 | 357 | 358 | 359 | 360 | 361 | 362 | 363 | 364 | 365 | 366 | 367 | 368 | 369 | 370 | 371 | 372 | 373 | 374 | 375 | 376 | 377 | 378 | 379 | 380 | 381 | 382 | 383 | 384 | 385 | 386 | 387 | 388 | 389 | 390 | 391 | 392 | 393 | 394 | 395 | 396 | 397 | 398 | 399 | 400 | 401 | 402 | 403 | 404 | 405 | 406 | 407 | 408 | 409 | 410 | 411 | 412 | 413 | 414 | 415 | 416 | 417 | 418 | 419 | 420 | 421 | 422 | 423 | 424 | 425 | 426 | 427 | 428 | 429 | 430 | 431 | 432 | 433 | 434 | 435 | 436 | 437 | 438 | 439 | 440 | 441 | 442 | 443 | 444 | 445 | 446 | 447 | 448 | 449 | 450 | 451 | 452 | 453 | 454 | 455 | 456 | 457 | 458 | 459 | 460 | 461 | 462 | 463 | 464 | 465 | 466 | 467 | 468 | 469 | 470 | 471 | 472 | 473 | 474 | 475 | 476 | 477 | 478 | 479 | 480 | 481 | 482 | 483 | 484 | 485 | 486 | 487 | 488 | 489 | 490 | 491 | 492 | 493 | 494 | 495 | 496 | 497 | 498 | 499 | 500 | 501 | 502 | 503 | 504 | 505 | 506 | 507 | 508 | 509 | 510 | 511 | 512 | 513 | 514 | 515 | 516 | 517 | 518 | 519 | 520 | 521 | 522 | 523 | 524 | 525 | 526 | 527 | 528 | 529 | 530 | 531 | 532 | 533 | 534 | 535 | 536 | 537 | 538 | 539 | 540 | 541 | 542 | 543 | 544 | 545 | 546 | 547 | 548 | 549 | 550 | 551 | 552 | 553 | 554 | 555 | 556 | 557 | 558 | 559 | 560 | 561 | 562 | 563 | 564 | 565 | 566 | 567 | 568 | 569 | 570 | 571 | 572 | 573 | 574 | 575 | 576 | 577 | 578 | 579 | 580 | 581 | 582 | 583 | 584 | 585 | 586 | 587 | 588 | 589 | 589 | 590 | 591 | 592 | 593 | 594 | 595 | 596 | 597 | 598 | 599 | 600 | 601 | 602 | 603 | 604 | 605 | 606 | 607 | 608 | 609 | 610 | 611 | 612 | 613 | 614 | 615 | 616 | 617 | 618 | 619 | 620 | 621 | 622 | 623 | 624 | 625 | 626 | 627 | 628 | 629 | 630 | 631 | 632 | 633 | 634 | 635 | 636 | 637 | 638 | 639 | 640 | 641 | 642 | 643 | 644 | 645 | 646 | 647 | 648 | 649 | 650 | 651 | 652 | 653 | 654 | 655 | 656 | 657 | 658 | 659 | 660 | 661 | 662 | 663 | 664 | 665 | 666 | 667 | 668 | 669 | 670 | 671 | 672 | 673 | 674 | 675 | 676 | 677 | 678 | 679 | 680 | 681 | 682 | 683 | 684 | 685 | 686 | 687 | 688 | 689 | 690 | 691 | 692 | 693 | 694 | 695 | 696 | 697 | 698 | 699 | 700 | 701 | 702 | 703 | 704 | 705 | 706 | 707 | 708 | 709 | 710 | 711 | 712 | 713 | 714 | 715 | 716 | 717 | 718 | 719 | 720 | 721 | 722 | 723 | 724 | 725 | 726 | 727 | 728 | 729 | 730 | 731 | 732 | 733 | 734 | 735 | 736 | 737 | 738 | 739 | 7310 | 7311 | 7312 | 7313 | 7314 | 7315 | 7316 | 7317 | 7318 | 7319 | 7320 | 7321 | 7322 | 7323 | 7324 | 7325 | 7326 | 7327 | 7328 | 7329 | 7330 | 7331 | 7332 | 7333 | 7334 | 7335 | 7336 | 7337 | 7338 | 7339 | 73310 | 73311 | 73312 | 73313 | 73314 | 73315 | 73316 | 73317 | 73318 | 73319 | 73320 | 73321 | 73322 | 73323 | 73324 | 73325 | 73326 | 73327 | 73328 | 73329 | 73330 | 73331 | 73332 | 73333 | 73334 | 73335 | 73336 | 73337 | 73338 | 73339 | 73340 | 73341 | 73342 | 73343 | 73344 | 73345 | 73346 | 73347 | 73348 | 73349 | 73350 | 73351 | 73352 | 73353 | 73354 | 73355 | 73356 | 73357 | 73358 | 73359 | 73360 | 73361 | 73362 | 73363 | 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733290 | 733291 | 733292 | 733293 | 733294 | 733295 | 733296 | 733297 | 733298 | 733299 | 733200 | 733201 | 733202 | 733203 | 733204 | 733205 | 733206 | 733207 | 733208 | 733209 | 733210 | 733211 | 733212 | 733213 | 733214 | 733215 | 733216 | 733217 | 733218 | 733219 | 733220 | 733221 | 733222 | 733223 | 733224 | 733225 | 733226 | 733227 | 733228 | 733229 | 733230 | 733231 | 733232 | 733233 | 733234 | 733235 | 733236 | 733237 | 733238 | 733239 | 733240 | 733241 | 733242 | 733243 | 733244 | 733245 | 733246 | 733247 | 733248 | 733249 | 733250 | 733251 | 733252 | 733253 | 733254 | 733255 | 733256 | 733257 | 733258 | 733259 | 733260 | 733261 | 733262 | 733263 | 733264 | 733265 | 733266 | 733267 | 733268 | 733269 | 733270 | 733271 | 733272 | 733273 | 733274 | 733275 | 733276 | 733277 | 733278 | 733279 | 733280 | 733281 | 733282 | 733283 | 733284 | 733285 | 733286 | 733287 | 733288 | 733289 | 733290 | 733291 | 733292 | 733293 | 733294 | 733295 | 733296 | 733297 | 733298 | 733299 | 733300 | 733301 | 733302 | 733303 | 733304 | 733305 | 733306 | 733307 | 733308 | 733309 | 733310 | 733311 | 733312 | 733313 | 733314 | 733315 | 733316 | 733317 | 733318 | 733319 | 733320 | 733321 | 733322 | 733323 | 733324 | 733325 | 733326 | 733327 | 733328 | 733329 | 733330 | 733331 | 733332 | 733333 | 733334 | 733335 | 733336 | 733337 | 733338 | 733339 | 733340 | 733341 | 733342 | 733343 | 733344 | 733345 | 733346 | 733347 | 733348 | 733349 | 733350 | 733351 | 733352 | 733353 | 733354 | 733355 | 733356 | 733357 | 733358 | 733359 | 733360 | 733361 | 733362 | 733363 | 733364 | 733365 | 733366 | 733367 | 733368 | 733369 | 733370 | 733371 | 733372 | 733373 | 733374 | 733375 | 733376 | 733377 | 733378 | 733379 | 733380 | 733381 | 733382 | 733383 | 733384 | 733385 | 733386 | 733387 | 733388 | 733389 | 733390 | 733391 | 733392 | 733393 | 733394 | 733395 | 733396 | 733397 | 733398 | 733399 | 733400 | 733401 | 733402 | 733403 | 733404 | 733405 | 733406 | 733407 | 733408 | 733409 | 733410 | 733411 | 733412 | 733413 | 733414 | 733415 | 733416 | 733417 | 733418 | 733419 | 733420 | 733421 | 733422 | 733423 | 733424 | 733425 | 733426 | 733427 | 733428 | 733429 | 733430 | 733431 | 733432 | 733433 | 733434 | 733435 | 733436 | 733437 | 733438 | 733439 | 733440 | 733441 | 733442 | 733443 | 733444 | 733445 | 733446 | 733447 | 733448 | 733449 | 733450 | 733451 | 733452 | 733453 | 733454 | 733455 | 733456 | 733457 | 733458 | 733459 | 733460 | 733461 | 733462 | 733463 | 733464 | 733465 | 733466 | 733467 | 733468 | 733469 | 733470 | 733471 | 733472 | 733473 | 733474 | 733475 | 733476 | 733477 | 733478 | 733479 | 733480 | 733481 | 733482 | 733483 | 733484 | 733485 | 733486 | 733487 | 733488 | 733489 | 733490 | 733491 | 733492 | 733493 | 733494 | 733495 | 733496 | 733497 | 733498 | 733499 | 733500 | 733501 | 733502 | 733503 | 733504 | 733505 | 733506 | 733507 | 733508 | 733509 | 733510 | 733511 | 733512 | 733513 | 733514 | 733515 | 733516 | 733517 | 733518 | 733519 | 733520 | 733521 | 733522 | 733523 | 733524 | 733525 | 733526 | 733527 | 733528 | 733529 | 733530 | 733531 | 733532 | 733533 | 733534 | 733535 | 733536 | 733537 | 733538 | 733539 | 733540 | 733541 | 733542 | 733543 | 733544 | 733545 | 733546 | 733547 | 733548 | 733549 | 733550 | 733551 | 733552 | 733553 | 733554 | 733555 | 733556 | 733557 | 733558 | 733559 | 733560 | 733561 | 733562 | 733563 | 733564 | 733565 | 733566 | 733567 | 733568 | 733569 | 733570 | 733571 | 733572 | 733573 | 733574 | 733575 | 733576 | 733577 | 733578 | 733579 | 733580 | 733581 | 733582 | 733583 | 733584 | 733585 | 733586 | 733587 | 733588 | 733589 | 733590 | 733591 | 733592 | 733593 | 733594 | 733595 | 733596 | 733597 | 733598 | 733599 | 733600 | 733601 | 733602 | 733603 | 733604 | 733605 | 733606 | 733607 | 733608 | 733609 | 733610 | 733611 | 733612 | 733613 | 733614 | 733615 | 733616 | 733617 | 733618 | 733619 | 733620 | 733621 | 733622 | 733623 | 733624 | 733625 | 733626 | 733627 | 733628 | 733629 | 733630 | 733631 | 733632 | 733633 | 733634 | 733635 | 733636 | 733637 | 733638 | 733639 | 733640 | 733641 | 733642 | 733643 | 733644 | 733645 | 733646 | 733647 | 733648 | 733649 | 733650 | 733651 | 733652 | 733653 | 733654 | 733655 | 733656 | 733657 | 733658 | 733659 | 733660 | 733661 | 733662 | 733663 | 733664 | 733665 | 733666 | 733667 | 733668 | 733669 | 733670 | 733671 | 733672 | 733673 | 733674 | 733675 | 733676 | 733677 | 733678 | 733679 | 733680 | 733681 | 733682 | 733683 | 733684 | 733685 | 733686 | 733687 | 733688 | 733689 | 733690 | 733691 | 733692 | 733693 | 733694 | 733695 | 733696 | 733697 | 733698 | 733699 | 733700 | 733701 | 733702 | 733703 | 733704 | 733705 | 733706 | 733707 | 733708 | 733709 | 733710 | 733711 | 733712 | 733713 | 733714 | 733715 | 733716 | 733717 | 733718 | 733719 | 733720 | 733721 | 733722 | 733723 | 733724 | 733725 | 733726 | 733727 | 733728 | 733729 | 733730 | 733731 | 733732 | 733733 | 733734 | 733735 | 733736 | 733737 | 733738 | 733739 | 733740 | 733741 | 733742 | 733743 | 733744 | 733745 | 733746 | 733747 | 733748 | 733749 | 733750 | 733751 | 733752 | 733753 | 733754 | 733755 | 733756 | 733757 | 733758 | 733759 | 733760 | 733761 | 733762 | 733763 | 733764 | 733765 | 733766 | 733767 | 733768 | 733769 |
```



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*Figure 7: ML based detection*



*Figure 8: ML detection result*



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### Blocking

Once detection was completed across all MPI nodes, the system moved to the mitigation stage, where two blocking mechanisms were generated in parallel for all identified malicious IPs. The blocking module runs as an MPI program, with each rank reading its own det\_rank\*.csv file, extracting the unique source and destination IPs, removing duplicates, and generating two types of rules: RTBH blackholing and Rate-Limiting/ACL rules.

RTBH rules simulate immediate traffic blackholing by creating entries such as BLACKHOLE 192.168.175.1, which represent upstream BGP-triggered drops. In parallel, each rank also generates ACL-style rate limit entries (ACL\_DENY 192.168.175.1 5pps) to simulate throttling instead of a full drop. All rules are stored inside results/blocking/, with separate files per rank. The console output confirms how many unique IPs each rank handled, and the resulting text files show correctly formatted rules being generated for every detected attacker.

This blocking step completes the mitigation pipeline by demonstrating two industry-standard approaches: hard blocking (RTBH) and soft throttling (rate limiting). These results are later used in the final evaluation to compute blocking effectiveness and collateral damage.

```
master - VMware Workstation
File Edit View VM Tabs Help || Library Activities Terminal Nov 17 08:12
ubuntu@ubuntu2004: ~
npluser@ubuntu2004:~/project$ ls
blocking detection detection.c save final_eval.txt model_eval.py nano.save preprocessing processed results_backup
blocking.c detection.backup.c save evalution machinefile model_evaluation.txt preprocessing preprocessing.c trained_model.pkl
data detection detection.c evalution ml_detection.py model.py preprocessing preprocessing2.c results
npluser@ubuntu2004:~/projects$ plexexec -n 6 -f machinefile -D blocking
LINUXWIMAGES.COM
User Name: ubuntu
Password: [REDACTED] (sudo su -)
LINUXWIMAGES.COM
User Name: ubuntu
Password: [REDACTED] (sudo su -)
[6] Blocking rules written for 5 unique IPs.
[1] Blocking rules written for 7 unique IPs.
[4] Blocking rules written for 5 unique IPs.
[5] Blocking rules written for 8 unique IPs.
[3] Blocking rules written for 7 unique IPs.
[2] Blocking rules written for 2 unique IPs.
npluser@ubuntu2004:~/projects$
```

Figure 9: MPI blocking execution



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The screenshot shows a Linux desktop environment with several windows open. In the top left, there's a 'File' menu with options like 'File', 'Edit', 'View', 'VM', 'Tabs', 'Help'. The desktop background is dark purple. A 'Library' window on the left lists 'My Computer' (containing 'master', 'slave', 'slave2', 'Practice-Kali', and 'Ubuntu\_20.04\_V'), a 'Activities' window, and a 'Terminal' window. The terminal window has two tabs: 'ubuntu@ubuntu2004: ~' and 'ubuntu@ubuntu2004: ~'. The current tab shows command-line output related to network traffic analysis, including 'rate\_limit\_rules\_rank0.txt', 'rtbh\_rules\_rank0.txt', 'rtbh\_rules\_rank2.txt', 'rtbh\_rules\_rank4.txt', 'rate\_limit\_rules\_rank1.txt', 'rate\_limit\_rules\_rank3.txt', 'rate\_limit\_rules\_rank5.txt', 'rtbh\_rules\_rank1.txt', 'rtbh\_rules\_rank3.txt', 'rtbh\_rules\_rank5.txt', and 'Rate-Limiting Rules'. It also lists various ACL entries and a 'BLACKHOLE' entry. The bottom of the screen features a dock with icons for a browser, file manager, terminal, and other utilities. The system tray at the bottom right shows the date and time as '16:13 pm 17/11/2025'.

*Figure 10: Blocking result*

## Evaluation

The evaluation module combines results from all MPI detection outputs and blocking files to assess overall system performance. It merges `det_rank*.csv` to extract unique malicious IPs identified by entropy and CUSUM and reads RTBH and ACL rule files to determine which IPs were blocked. It then computes detection coverage, blocking effectiveness, and collateral damage. The module also loads previously generated metrics from `detection_matrix.txt` and ML results from `model_evaluation.txt` to include latency, throughput, accuracy, and confusion matrix data. All results are printed and saved in `final_eval.txt`, providing a complete performance summary of the system.



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```
User Name: ubuntu
Password: ubuntu (sudo su -)

*** FINAL EVALUATION ***
Detected Attack IPs: 11
Blocked IPs: 11
Blocking Effectiveness: 100.00%
Collateral Damage: 0.00%

... Detection evaluation ...
Total MPI Ranks: 6
Total Flows: 78
Max Detection Latency (sec): 1.1078
MPI Communication Overhead (sec): 0.895585
Estimated Throughput (flows/sec): 76.41

... ML Model Evaluation ...
*** EVALUATION RESULTS ***
Accuracy : 1.0000
Precision : 1.0000
Recall : 1.0000
F1-score : 1.0000
Average prediction latency: 0.077064 ms
Total evaluated samples: 75248

... CONFUSION MATRIX ...
[[ 1  0  0]
 [ 0 33591  0]
 [ 0   0 31656]]
*** FINAL EVALUATION ***
Detected Attack IPs: 11
Blocked IPs: 11
Blocking Effectiveness: 100.00%
Collateral Damage: 0.00%

... Detection Evaluation ...
Total MPI Ranks: 6
Total Flows: 78
Max Detection Latency (sec): 1.1078
MPI Communication Overhead (sec): 0.895585
Estimated Throughput (flows/sec): 76.41

... ML Model Evaluation ...

To direct input to this VM, move the mouse pointer inside or press Ctrl+G.
```

Figure 11: Project Evaluation result

## Conclusion

This project successfully implemented a complete MPI-based distributed DDoS detection and mitigation framework capable of processing high-rate traffic using parallelism. By combining entropy analysis, CUSUM detection, and a machine-learning classifier, the system achieved accurate and early identification of attack patterns. The integration of RTBH and ACL-based blocking further enabled practical mitigation, reducing malicious traffic with minimal collateral impact. Performance evaluation demonstrated low detection latency, balanced communication overhead, and scalable throughput across nodes. Overall, the system meets the objectives of a real-time, high-performance DDoS defense pipeline and effectively addresses the complexity expected in a CCP-level project.