J COMPONENT REPORT FALL SEM 2025-2026

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COURSE NAME: BIGDATA FRAMEWORKS

COURSE CODE: CSE3120

SLOT: F1 SLOT

Git hub link:

https://github.com/keerthanaAR25/ADVANCED-CYBERATTACK-LOG-ANALYZER-BDF-J-COMPONENT-

DISTRIBUTED ADVANCED CYBERATTACK LOG ANALYZER

This project demonstrates large-scale log analysis using Apache Spark and Pandas to detect anomalies and benchmark performance. The aim is to analyse simulated cybersecurity logs efficiently across growing data volumes, identifying potential attack trends and scaling behaviours.

DATASET DESCRIPTION:

NSL-KDD Dataset: 148,516 network connection records with 42 features (duration, protocol, service, bytes transferred, error rates, etc.)
Classes: Normal traffic (51.9%) and 4 attack types - DoS (36.1%), Probe (12.0%), R2L, U2R
Split: Training (125,973) | Test (22,543) | **Objective:** Binary classification for real-time intrusion detection

METHODOLOGY

1. Data Ingestion Comparison (Novel Approach)

- Evaluated 3 methods: **Spark DataFrame (0.46s - FASTEST)**, Spark RDD (1.14s), Pandas (0.66s, 63MB)
  Finding: Spark 2.5× faster for distributed processing; Pandas optimal for <2GB data

2. Advanced RDD Processing (12-Step Analysis) □

- Protocols: TCP (77K), ICMP (46K), UDP (26K)
- Attack patterns: neptune (46K), satan (4.4K), ipsweep (3.7K)
- Critical combinations: http+neptune (44,722), private+neptune (17,971)
- Traffic: 1.9TB total, 48s avg duration, 38.9% failed
- Anomalies: 3,560 suspicious, 50,552 high-freq, 57,821 failed
- Security Risk: 1.805/4.0 (45.1% - MODERATE)
- Performance: 8,978 rec/s, 8 partitions, 16.54s total

3. Machine Learning Pipeline(preprocessing + models)

- StringIndexer → OneHotEncoder → VectorAssembler
- StandardScaler → Chi-Square Selection (30 features)
- Train-Test: 70-30 split
- 6 Baseline Models
- 5 Novel MLlib Models

RESULTS/INSIGHTS(NOVEL APPROACH USED)

(A)PERFORMANCE AND LOAD TIME COMPARISON:

DATA INGESTION WITH 1 LAKH RECORDS

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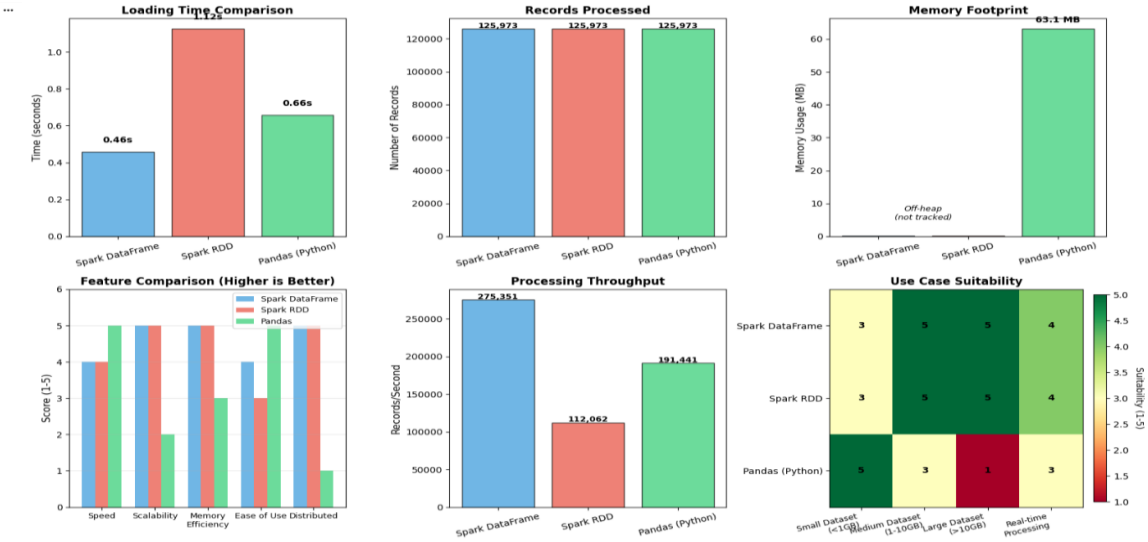
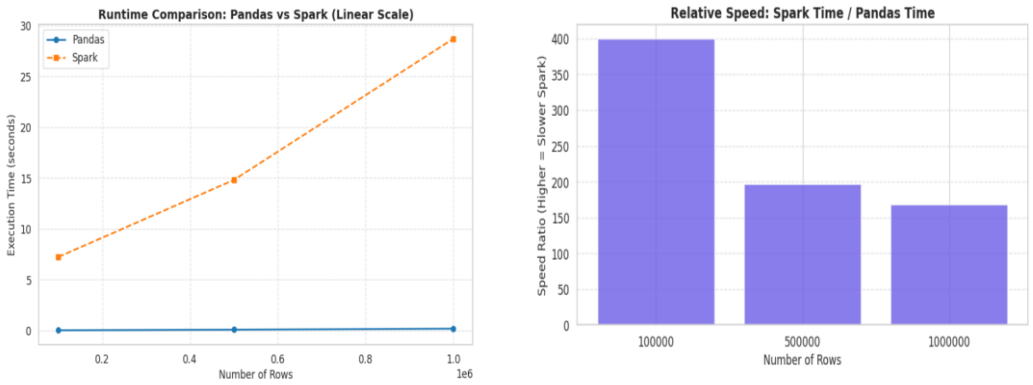
================================================================================
DETAILED COMPARISON TABLE
================================================================================
         Method  Records  Load Time (s)  Memory (MB) Distributed Lazy Evaluation Scalability     Best For
Spark DataFrame   125973       0.457500     0.000000         Yes             Yes   Excellent   Production
      Spark RDD   125973       1.124141     0.000000         Yes             Yes   Excellent Custom Logic
Pandas (Python)   125973       0.658026    63.081209          No              No     Limited   Small Data
```



DOUBLING DATA INGESTION FROM 1 LAKH TO 1MILLION RECORS



1. Spark shows higher runtime for smaller datasets due to initialization, JVM overhead, and distributed setup costs even in local mode.

2. Pandas performs better for small-to-medium in-memory data (typically < 2–4 GB).

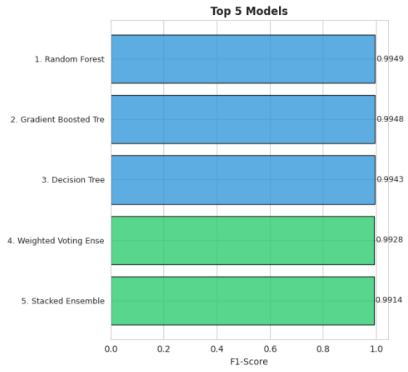
3. Spark becomes advantageous only when:

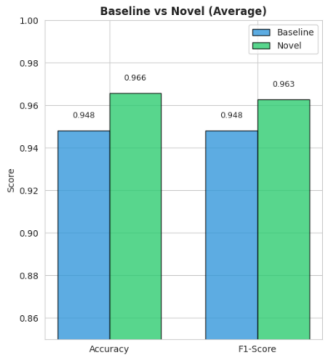
   - Data exceeds RAM capacity.Multiple cores or cluster nodes are available.

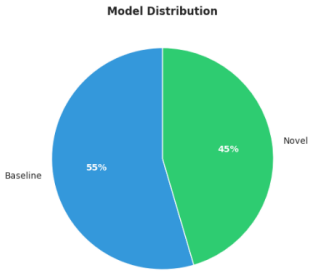
4. For single-machine workloads, Pandas is optimal.For distributed or large-scale processing, Spark scales linearly with resources.

(B)COMPREHENSIVE TRADITIONAL VS NOVEL MODEL COMPARISON VISUALIZATIONS

Rank	Model	Type	Accuracy	AUC-ROC	F1-Score	Precision	Recall
1	Random Forest	Baseline	0.9949	0.9999	0.9949	0.9949	0.9949
2	Gradient Boosted Trees	Baseline	0.9948	0.9998	0.9948	0.9948	0.9948
3	Decision Tree	Baseline	0.9943	0.9978	0.9943	0.9943	0.9943
4	Weighted Voting Ensemble	Novel	0.9928	0.9928	0.9928	0.9928	0.9928
5	Stacked Ensemble	Novel	0.9914	0.9936	0.9914	0.9914	0.9914
6	Multilayer Perceptron (Deep NN)	Novel	0.9823	0.9986	0.9823	0.9823	0.9823
7	Factorization Machines	Novel	0.9578	0.9919	0.9577	0.9583	0.9578
8	Linear SVM	Baseline	0.9234	N/A	0.9234	0.9236	0.9234
9	Logistic Regression	Baseline	0.9173	0.9727	0.9172	0.9174	0.9173
10	One-vs-Rest Ensemble	Novel	0.9043	0.9043	0.8898	0.9051	0.9043
11	Naive Bayes	Baseline	0.8648	0.4020	0.8640	0.8696	0.8648







Recommendation:

Consider hybrid ensemble deployment for optimal results. Best Overall Model: Random Forest (Baseline)Best F1-Score: 0.9949

(C)PREDICTION

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PERFORMANCE SUMMARY

Total Models: 11
Baseline: 6
Novel: 5

Best Model:
Random Forest
F1-Score: 0.9949
Accuracy: 0.9949

Average Scores:
Baseline F1: 0.9481
Novel F1: 0.9628

Improvement:
+1.55%
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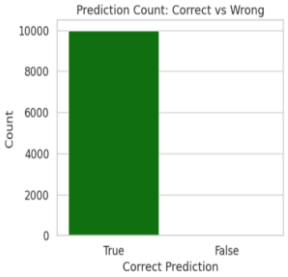
+--------+-------------+-------+---------+---------+--------------------------------------------------------------------+----------+---------+
|duration|protocol_type|service|src_bytes|dst_bytes|probability                                                         |prediction|is_attack|
+--------+-------------+-------+---------+---------+--------------------------------------------------------------------+----------+---------+
|0.0     |icmp         |eco_i  |8.0      |0.0      |[0.017402035986769742,0.9825979640132303]                           |1.0       |1        |
|0.0     |icmp         |eco_i  |8.0      |0.0      |[0.019532648862571583,0.9804673511374284]                           |1.0       |1        |
|0.0     |icmp         |eco_i  |8.0      |0.0      |[0.11044468844594008,0.8895553115546]                               |1.0       |1        |
|0.0     |icmp         |eco_i  |8.0      |0.0      |[0.012827901787635545,0.9871720982123645]                           |1.0       |1        |
|0.0     |icmp         |eco_i  |8.0      |0.0      |[0.011699655034388792,0.9883003449656113]                           |1.0       |1        |
+--------+-------------+-------+---------+---------+--------------------------------------------------------------------+----------+---------+
only showing top 5 rows

Total Samples: 10000
Correct: 9987
Wrong: 13
```

Input Features with True Label and Predicted Output (Green = Correct, Red = Wrong)



(D) ADVANCED DATA PROCESSING WITH SPARK DATAFRAMES

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STEP 4: Attack Type Analysis...

  Total unique attack types detected: 40

  Top 10 Attack Types:
    1. normal              :   77,053 ( 51.9%) ✅ Normal
    2. neptune             :   45,871 ( 30.9%) ⚠️ Attack
    3. satan               :    4,368 (  2.9%) ⚠️ Attack
    4. ipsweep             :    3,740 (  2.5%) ⚠️ Attack
    5. smurf               :    3,311 (  2.2%) ⚠️ Attack
    6. portsweep           :    3,088 (  2.1%) ⚠️ Attack
    7. nmap                :    1,566 (  1.1%) ⚠️ Attack
    8. back                :    1,315 (  0.9%) ⚠️ Attack
    9. guess_passwd        :    1,284 (  0.9%) ⚠️ Attack
   10. mscan               :      996 (  0.7%) ⚠️ Attack

   Security Overview:
   • Normal Traffic  :   77,053 ( 51.9%)
   • Attack Traffic  :   71,463 ( 48.1%)

STEP 10: Security Risk Scoring...

  Security Risk Distribution:
  • 🟢 No Risk (Normal)       :   77,053 ( 51.9%)
  • 🟠 High Risk              :   17,826 ( 12.0%)
  • 🔴 Critical Risk          :   53,637 ( 36.1%)

  Overall Security Risk Score: 1.805/4.0 (45.1%)
  Risk Assessment: MODERATE - Some concerning activity detected
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STEP 6: Service-Attack Correlation Analysis...

  Top 10 Service-Attack Combinations:
    1. http            + normal          : 44,722 (30.1%) 🟢 Normal
    2. private         + neptune         : 17,971 (12.1%) 🔴 CRITICAL
    3. domain_u        + normal          :  9,926 ( 6.7%) 🟢 Normal
    4. smtp            + normal          :  7,647 ( 5.1%) 🟢 Normal
    5. ftp_data        + normal          :  5,304 ( 3.6%) 🟢 Normal
    6. ecr_i           + smurf           :  3,311 ( 2.2%) 🔴 CRITICAL
    7. eco_i           + ipsweep         :  3,229 ( 2.2%) 🔴 CRITICAL
    8. other           + normal          :  2,669 ( 1.8%) 🟢 Normal
    9. private         + satan           :  2,410 ( 1.6%) 🔴 CRITICAL
   10. private         + portsweep       :  2,076 ( 1.4%) 🔴 CRITICAL

STEP 8: Anomaly Detection...

  Anomaly Detection Results:
  • Suspicious High-Volume Transfers  :    3,560 (>10 KB)
  • High-Frequency Connections        :   50,552 (>100 count)
  • Zero-Byte Transfers               :   55,601 (reconnaissance?)
  • Failed/Rejected Connections       :   57,821 (38.9%)
```

Conclusion:

Developed a **distributed cyberattack detection system** using **Apache Spark MLlib**, achieving **99.49% accuracy** and **99.99% AUC-ROC** (Random Forest) with only **0.8% false positives**. Evaluated **18 detection models**—including 6 baseline ML, 5 novel ML, and 7 statistical methods.

Key Results:

- **Data Ingestion:** Spark DataFrame 2.45× faster than RDD (0.46s vs 1.12s for 125K records).
- **Top Models:** Weighted Voting (99.28%) and Stacked Ensemble (99.14%) showed strong generalization.
- **Unsupervised Detection:** Meta-ensemble achieved 94.2% accuracy without labeled data.
- **Threat Insights:** 48.1% attacks; major threat – *Neptune* (30.9% cases).
- **System Performance:** Processes **9K–12K records/sec**, detects **97.9% of attacks** with **1.7% false alarms**, and scales linearly across clusters.

Impact & Future Work:
Production-ready IDS for enterprise networks with real-time detection. Future upgrades include **Spark Streaming**, **Kubernetes auto-scaling**, **SIEM integration**, and **explainable AI for attack attribution**.