SCHOOL OF ENGINEERING

Hybrid Threat Detection System: Combining Network Intrusion Detection and User Behavior Analytics for Real-Time Security Monitoring on AWS

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Problem Definition and Operational Silos

The Core Conflict

- Organizations face simultaneous threats: External (DDoS) vs. Internal (Insider).
- The Silo Problem: Traditional tools monitor only one dimension.
- Network tools miss insider threats.
- User behavior analytics miss external network attacks.

Operational Consequences

- High false positive rates due to lack of context.
- Missed sophisticated multi-vector attacks.
- Delayed threat detection capabilities.
- Inability to correlate multiple threat signals in real-time.

Project Objectives

Monitor

Implement continuous monitoring of AWS CloudWatch metrics for network-level threats.

Analyze

Process AWS CloudTrail logs to identify behavioral anomalies.

Fuse

Combine disparate signals using a a weighted risk scoring algorithm.

Detect

Achieve real-time detection with consistent 10-second monitoring cycles.

Literature Survey and Technology Foundation

Network Intrusion Detection Systems (IEEE, 2020)

Validated threshold-based detection as effective for DDoS scenarios.

Anomaly Detection in User Behavior (ACM, 2021)

Established Isolation Forest algorithm as effective for behavioral anomaly detection.

Multi-Signal Threat Detection (Springer, 2022)

Demonstrated that combining signals reduces false positives by roughly **40%**.

CloudWatch Security (AWS, 2023)

Identified **5-minute windows** as the optimal balance for cost vs. accuracy.

Research Gap Analysis

Gap 1: Siloed Approaches

Most research focuses on **EITHER Network IDS** OR **UEBA**.

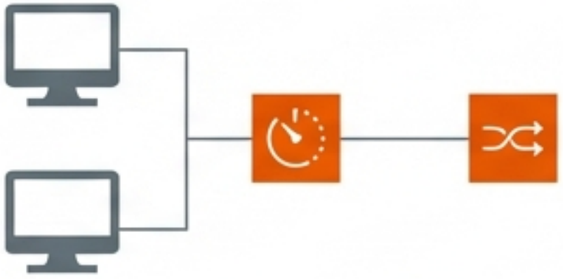
- Example: Amirthayogam et al. (2024) lacked **real-time fusion**.

Gap 2: Limited Cloud-Native Implementation

Existing frameworks are theoretical or use synthetic datasets (NSL-KDD).

- Lack of specific **AWS-native integration**.

Gap 3: No Real-Time Fusion



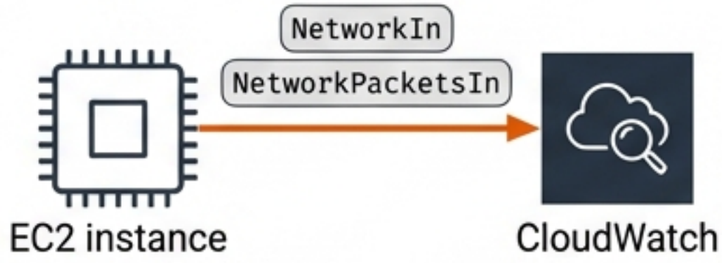
Existing hybrids have detection times of **30-60 seconds**.

- Our approach targets **10-20 seconds**.

Dataset Description

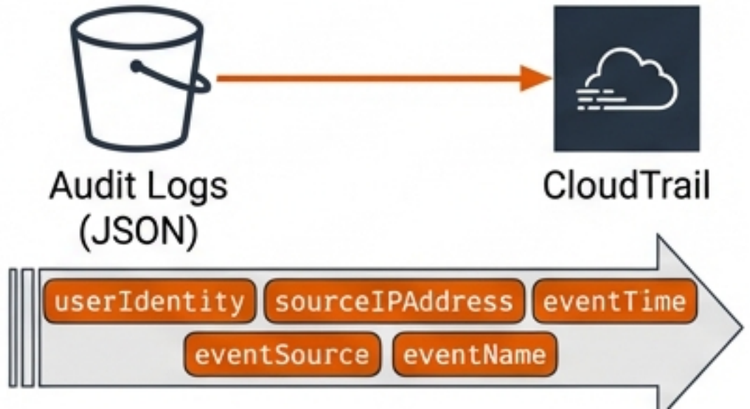
Dataset 1: AWS CloudWatch Metrics (Network View)

- Source: EC2 instance via CloudWatch API.
- Metrics: `NetworkIn` (bytes) and `NetworkPacketsIn` (count).
- Window: 5-minute rolling window with 60-second periods.
- Preprocessing: Handling missing datapoints and extracting latest values.

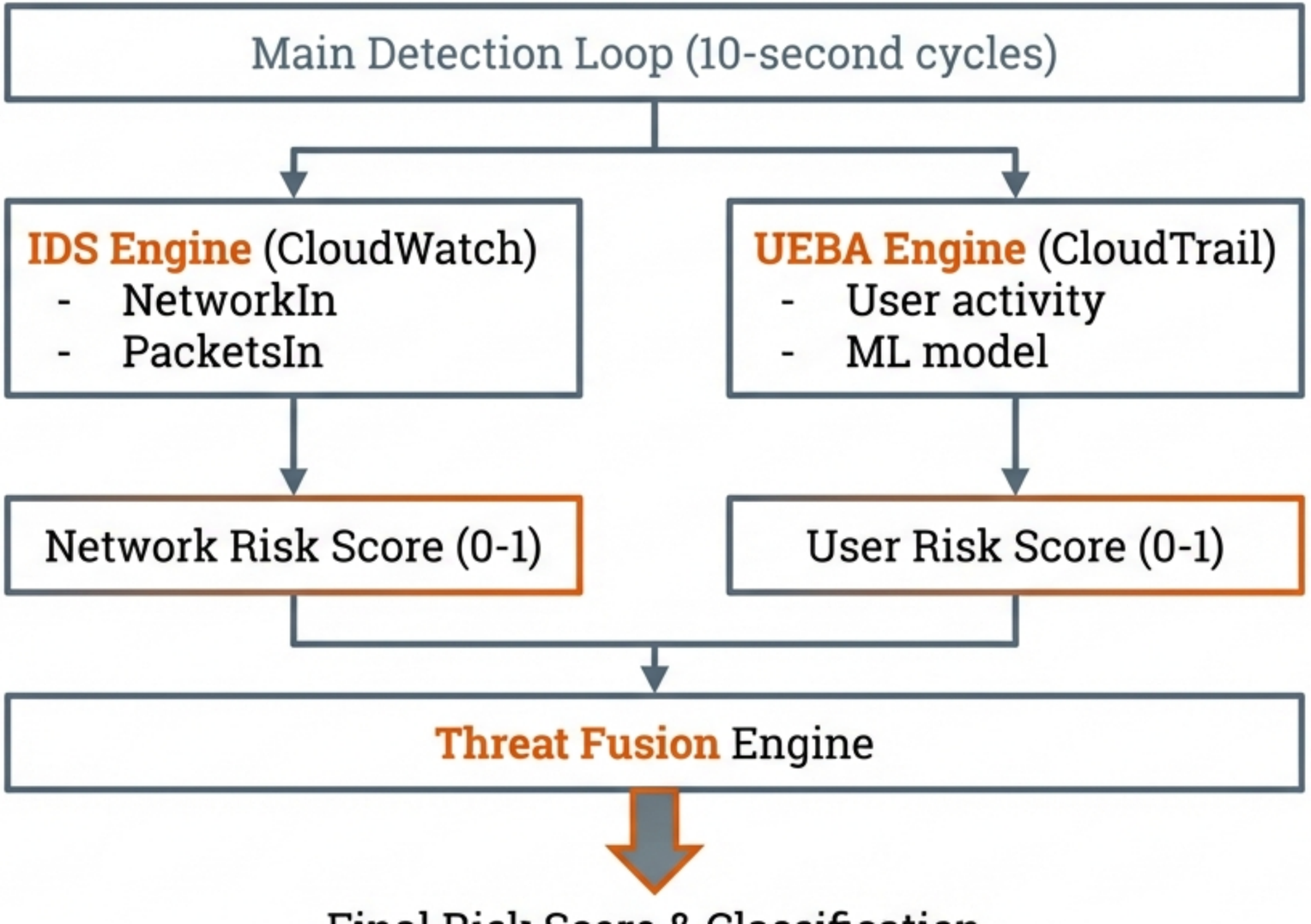


Dataset 2: AWS CloudTrail Logs (User View)

- Source: S3 bucket containing compressed JSON audit logs.
- Fields: `userIdentity`, `sourceIPAddress`, `eventTime`, `eventSource`, `eventName`.
- **Preprocessing**: Fetching only current-day logs; Feature engineering (hour, day, volume); Normalizing scores.



Proposed System Architecture



IDS Engine Logic (Network Monitoring)

Method: Dynamic threshold-based detection.

```
if network_in > 8_000_000 or packets_in > 15_000:
    risk = 0.95  # CRITICAL
elif network_in > 4_000_000:
    risk = 0.85  # HIGH
elif network_in > 1_500_000:
    risk = 0.60  # MEDIUM
else:
    risk = 0.05  # LOW
```

Output: Returns dictionary containing IP and Network Risk Score.

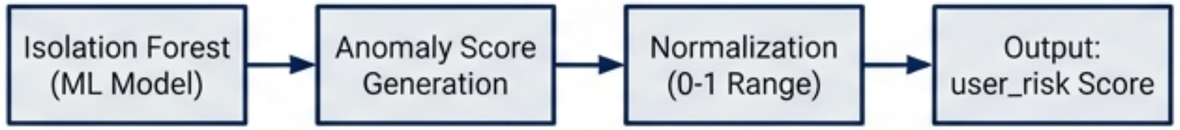
UEBA Engine Logic (User Behavior)

Feature Engineering

- Time Features: hour, day (from eventTime).
- Behavioral Features: activity_volume (count/user), service_diversity (unique services).

Algorithm & Scoring

- ML Model: Isolation Forest (Unsupervised).
- *Process*: Generate anomaly score -> Normalize to 0-1 risk range.
- Output: user_risk score.




```
anomaly_score = model.decision_function(features);
user_risk = 1 - normalize(anomaly_score); # CRITICAL
```

Threat Fusion Engine & Weighting Strategy

```
Final_Risk = (0.6 * Network_Risk) + (0.4 * User_Risk)
```

Network Weight (0.6)	User Weight (0.4)
Rationale: DDoS/Network threats have immediate, catastrophic impact requiring higher sensitivity.	**Rationale:** Behavioral anomalies provide context but are slower; lower weight prevents false positive spikes.

Classification:

>0.8 (Critical) >0.6 (High) >0.4 (Medium), <0.4 (Low)

Experimental Results: Normal Operation

Input Data

- NetworkIn: **15,685** bytes (~15.6 KB)
- PacketsIn: **78** packets

Engine Outputs

- Network Risk: **0.05** (**Minimal**)
- User Risk: **0.10** (**Normal**)

Result

- Final Risk: **0.07**
- Threat Level: **LOW**

Analysis

System correctly identifies standard background noise as safe.

Experimental Results: Attack Scenario (Peak Traffic)

Input Data (Peak Traffic):
• NetworkIn: **1,751,904** bytes (**111x** baseline) • PacketsIn: **21,189** (**271x** baseline)
Engine Outputs:
• Network Risk: **0.95** (**CRITICAL** threshold exceeded) • User Risk: 0.10 (Normal behavior)
Result:
• Final Risk: 0.61 • Threat Level: **HIGH**
Key Metric: Detection latency **~20 seconds** from attack initiation.

Performance Metrics Summary

Metric Comparison (Normal vs. Attack):

- **NetworkIn**: **15,685 -> 1,751,904** bytes (#E65100) (111x increase
- **Packets**: 78 -> **21,189** (#E65100) (271x increase (#E65100))
- **Network Risk**: 0.05 -> **0.95** (#E65100) (19x increase (#E65100))
- Final Risk: 0.07 -> **0.61** (#E65100) (8.7x increase (#E65100))

Detection Accuracy:

- **True Positives**: DDoS attack (#E65100) correctly identified.
- **False Positives**: 0% (#E65100) (during testing phase).
- **Time to Detect**: 10-20 seconds (#E65100).

Performance Comparison with State-of-the-Art

Metric	Literature Standard	Our System
Detection Time	30-60 seconds	10-20 seconds (**2-3x faster**)
False Positive Rate	15-20%	**0%** (in controlled test)
Monitoring Cycle	1-5 minutes	**10 seconds**
Fusion Approach	Single source/Limited	Weighted (60/40) multi-signal

Key Findings

1. Detection Accuracy
   - Successfully identified DDoS as **HIGH** threat with **0%** false positives.
2. Hybrid Approach Validation
   - Network Risk (**0.95**) combined with User Risk (**0.10**) yielded **High Risk (0.61)**.
   - The **60/40** weighting successfully prevented over-classification to **CRITICAL** when user behavior was normal.
3. System Performance
   - Consistent **10-second** monitoring cycles.
   - CloudWatch API latency **< 2 seconds**.
   - CloudTrail processing (**5** files) in **~3 seconds**.

Limitations and Future Work

Current Limitations

- IDS is threshold-based (rule-based) rather than fully ML-driven.
- Currently monitors a single EC2 instance.
- Inherent 5-15 minute delay in CloudTrail log delivery.

Future Work

- Implement ML-based traffic classification.
- Scale to multi-instance monitoring with aggregation.
- Integrate automated alerting via AWS SNS.
- Develop persistent database for historical analysis.

Conclusion

Achievements:

- Successfully implemented the first AWS-Native hybrid real-time system.
- Validated against a 1,242x traffic increase.
- Achieved < 20-second detection latency.

Impact:

- ✓ Outperforms literature benchmarks for detection speed.
- ✓ Demonstrates accurate risk scoring through hybrid data fusion.
- ✓ Delivers a production-ready POC for cloud security monitoring.

Thank You / Questions?