

SCHOOL OF  
COMPUTING  
CHENNAI

# Computer Science Engineering - Cyber Security

- Topic:** Zero Trust Security for Web Applications in Microservice-Based Environments
- Domain:** Cybersecurity – DevOps
- Members:** Dinesh Kumar.N (ch.en.u4cys21014)  
V. Jayaraj (ch.en.u4cys21026)
- Supervisor:** Dr. S. Udhayakumar  
CSE- Cybersecurity



# Problem Identification

- Traditional authentication and authorization mechanisms often rely on perimeter-based security, which fails to protect against internal threats and lateral movement within containerized environments.
- Increasing use of cloud services and remote work has expanded the attack surface, making it difficult to secure data and applications effectively.
- The complexity and scale of managing permissions and access controls in containerized and microservices architectures expose vulnerabilities.

# Problem Statement

- The current reliance on perimeter-based security fails to provide the necessary protection for data and applications in the context of expanding cloud services and remote work, necessitating a shift to a Zero Trust Architecture.
- Zero Trust Architecture addresses these gaps by enforcing strict identity verification, continuous monitoring, and least-privilege access, significantly enhancing security in dynamic and distributed container deployments.



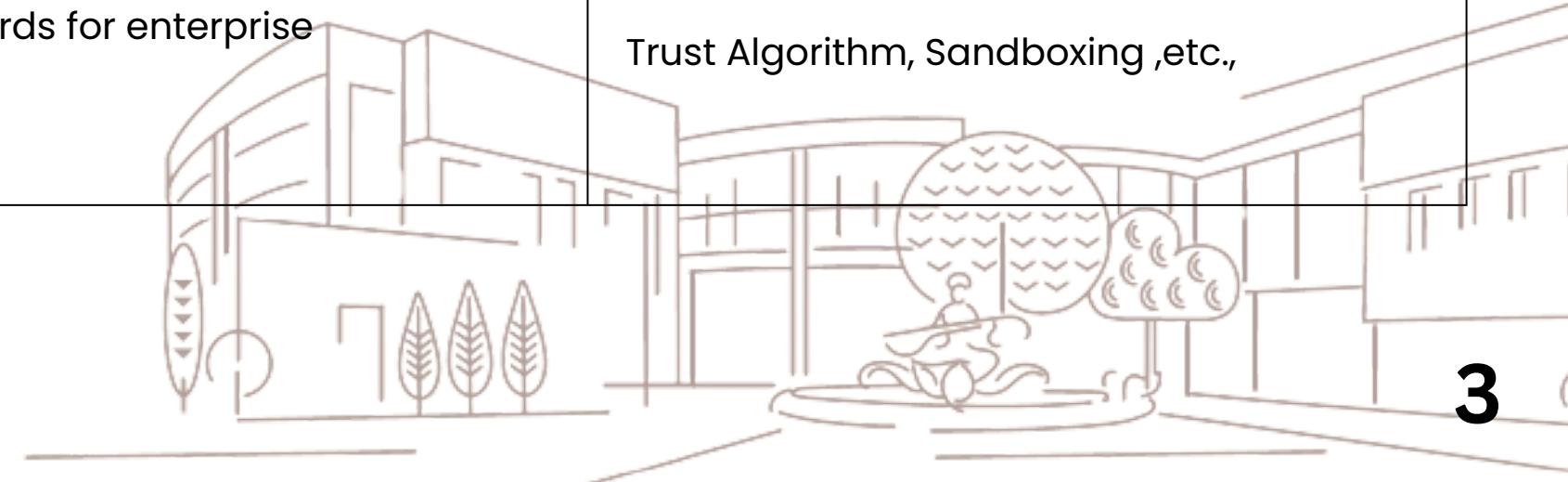
# Literature Review

S.NO	Title and Author	Objective	Algorithms/Techniques
1	<b>Building A Zero Trust Architecture Using Kubernetes</b> Daniel D'Silva; Dayanand D. Ambawade, published in IEEE: 2021 I2CT	Use containers to build a Zero Trust Architecture providing authentication with Least Privilege	Attribute based access control, JSON Web Token
2)	<b>Establishing a Zero Trust Strategy in Cloud Computing Environment</b> Saima Mehraj; M. Tariq Banday, published in IEEE: 2020 ICCCI	Propose a Zero Trust strategy to enhance trust establishment between customers and cloud service providers	Multi Factor Authentication, Mapping Data Flow, Microsegmentation
3)	<b>Authentication and authorization orchestrator for microservice-based software architectures</b> A. Bánáti1 , E. Kail1 , K. Karóczkai1 and M. Kozlovszky1 MIPRO 2018	Investigating the different types of authentication and authorization methods in order to implement our solution for a healthcare application.	OAuth2, SSO, JWT and OpenID
4)	<b>Securing a Cloud-Native C2 Architecture Using SSO and JWT</b> Ryan Melton, 2021 IEEE Aerospace Conference	To implement Zero Trust Architecture on Command and Control application named COSMOS in kubernetes cluster	Istio (mTLS), JWT, KeyCloak, SSO
5)	<b>Zero Trust Architecture</b> Scott Rose Oliver Borchert Stu Mitchell Sean Connelly NIST Special Publication 800-207	Define Zero Trust Architecture standards for enterprise organizations	Trust Algorithm, Sandboxing ,etc.,

Zero Trust Security for Web Applications in Microservice-Based Environments

N. Dinesh Kumar

V. Jayaraj



# Project Significance

- Implementing Zero Trust Architecture (ZTA) in containerized environments is crucial for enhancing security.
- By implementing least-privilege access and continuous monitoring, organizations can better protect their sensitive data and applications from evolving threats.
- Containers are inherently ephemeral and dynamic, making traditional perimeter-based security ineffective.
- ZTA benefits organizations, DevOps teams, and IT security professionals by improving security posture, ensuring regulatory compliance, and enabling efficient, secure deployments, thus promoting safer and more resilient infrastructure.

## Tech Stack Used

**Frontend:** React js -- TailwindCSS -- Redux

**Big Data:** Apache Spark -- PySpark -- mlib

**Backend:** Python -- flask -- Node js

**DevOps:**

- Docker
- Kubernetes – AWS EKS
- Helm Chart
- Git

**Database:** MongoDB /AWS DynamoDB

**ZTA Features:** JWT -- mTLS -- Falco -- R8

**Android App:** React Native -- Java



# Objective

- Design and implement a Zero Trust Architecture that enforces strict identity verification and continuous monitoring, ensuring that every access request within containerized environments is authenticated and authorized.
- Develop mechanisms for least-privilege access, ensuring that users and applications have only the permissions necessary for their tasks, minimizing the risk of unauthorized actions.
- Integrate advanced security measures that protect against internal and external threats, ensuring a robust and resilient security posture in dynamic containerized environments.

# Scope

To Evaluate current security.

Develop a Zero Trust framework for containers, integrate continuous identity verification and access controls.

Develop a POC for ZTA in web and android applications, conduct testing, provide documentation.

**Github Repo:** <https://github.com/Dinesh-4320/Zero-Trust-Project>



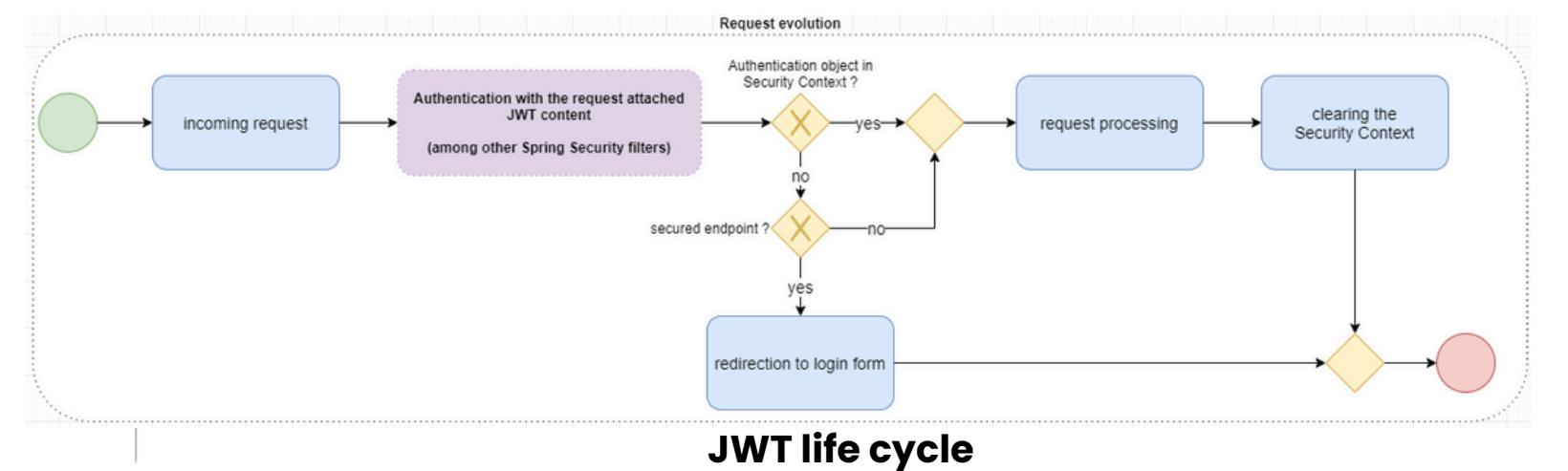
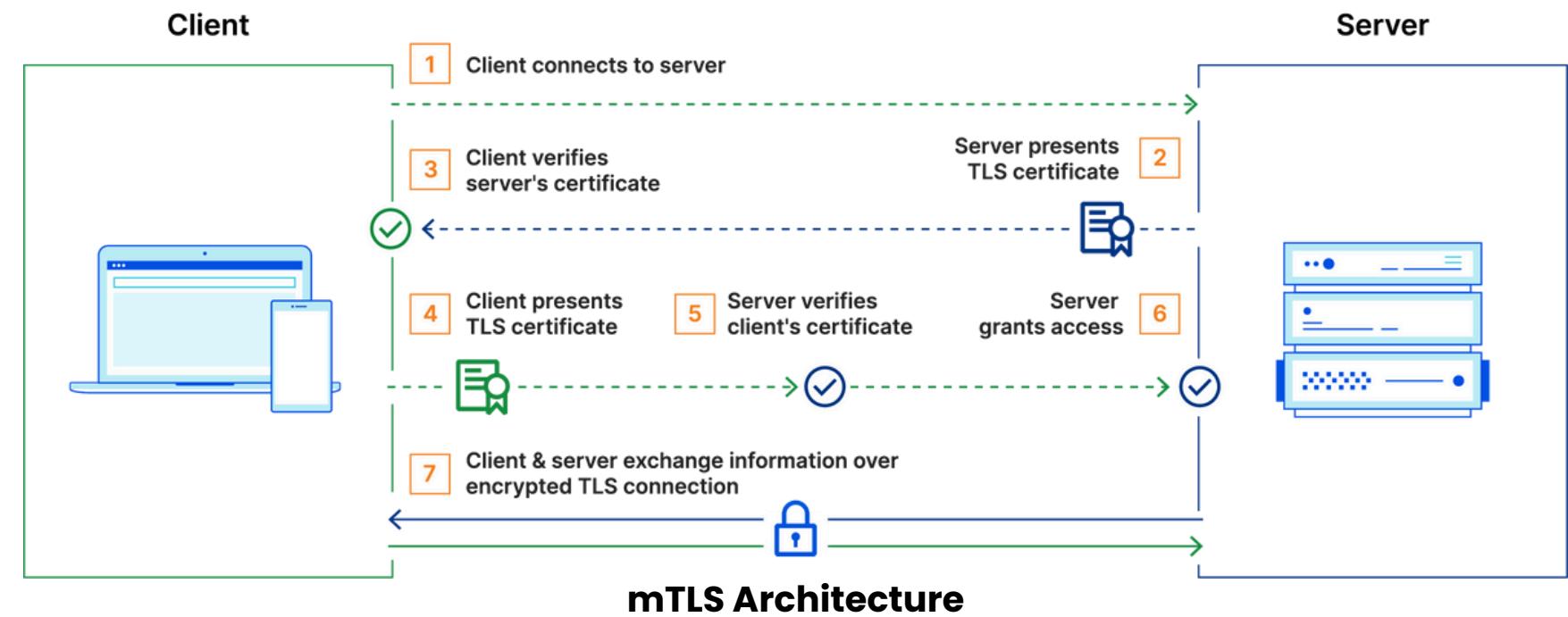
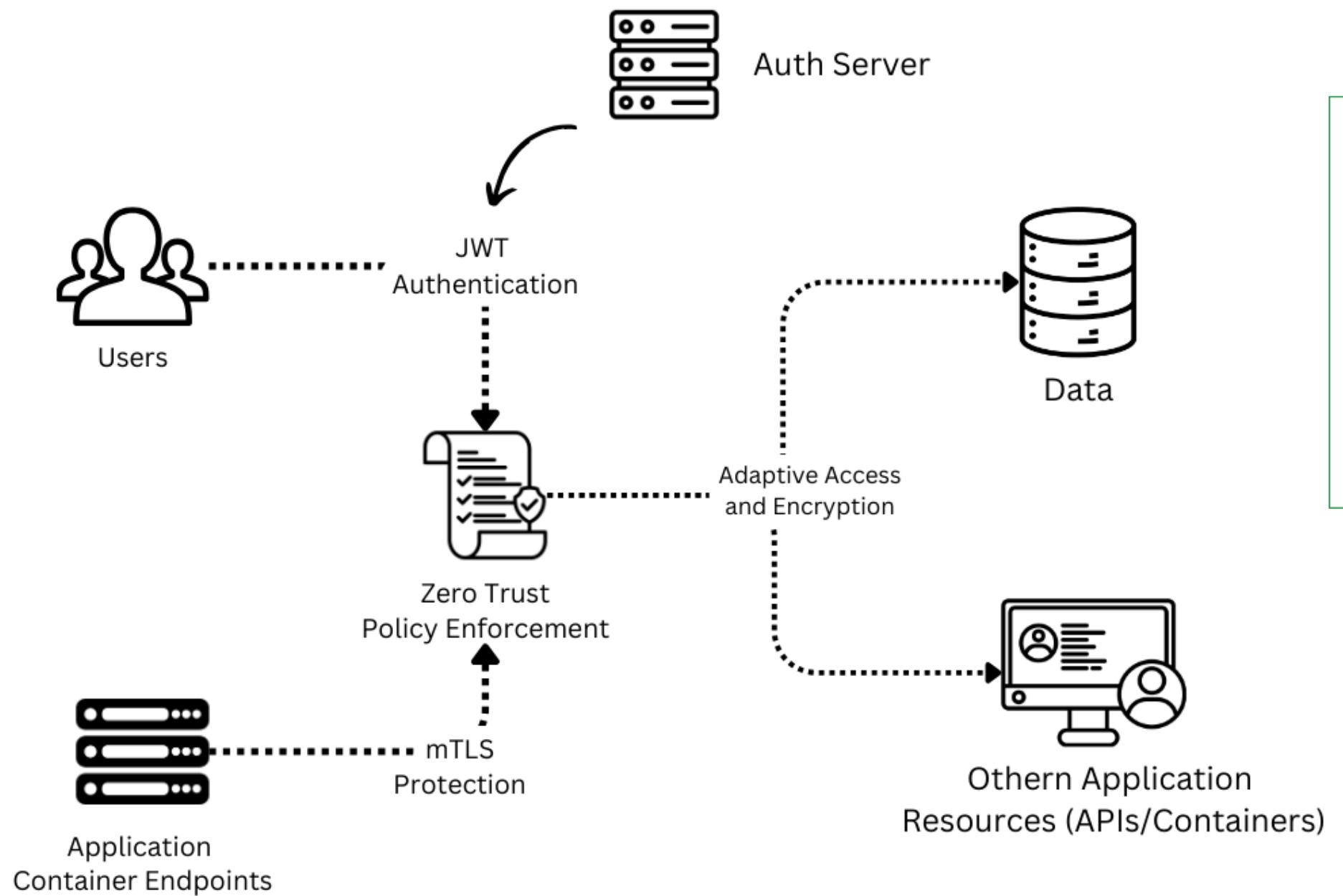
Zero Trust Security for Web Applications in Microservice-Based Environments

N. Dinesh Kumar

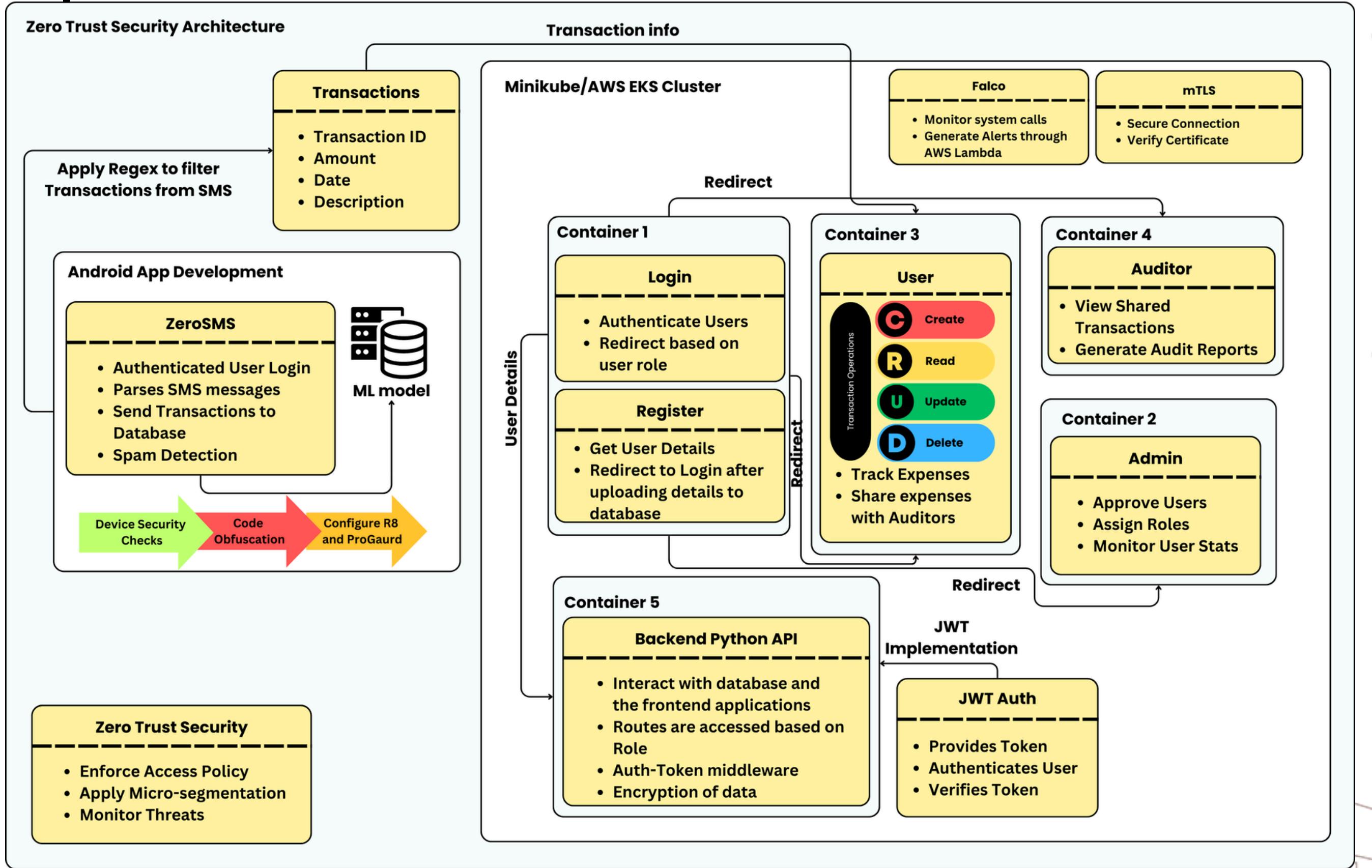
V. Jayaraj



# General ZTA Diagram



# Implementation

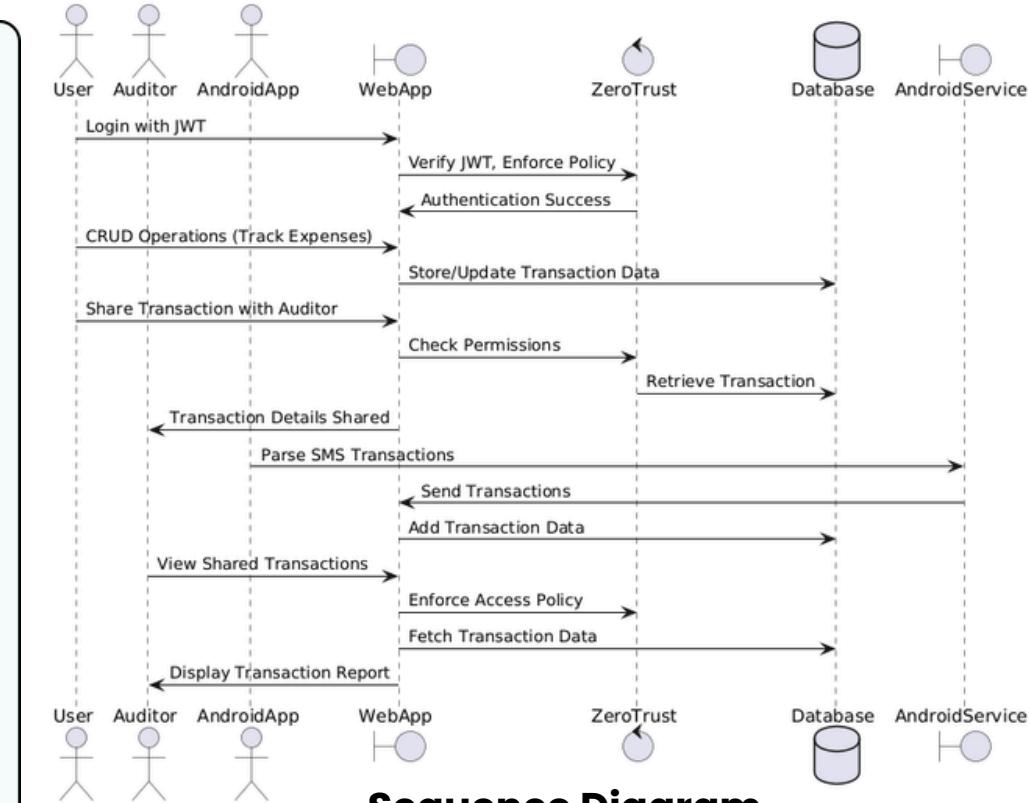


Web and Android Application Architecture Diagram

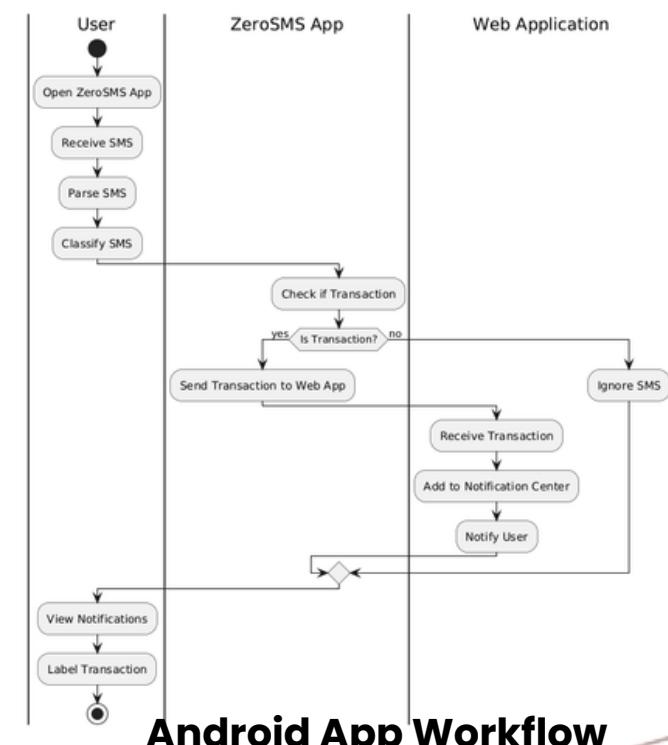
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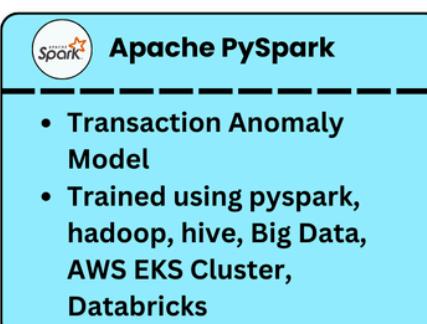


Sequence Diagram

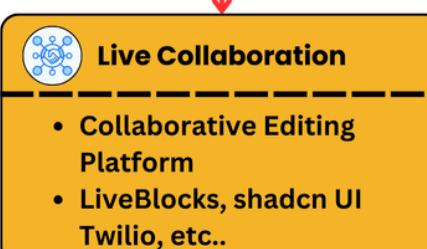


Android App Workflow

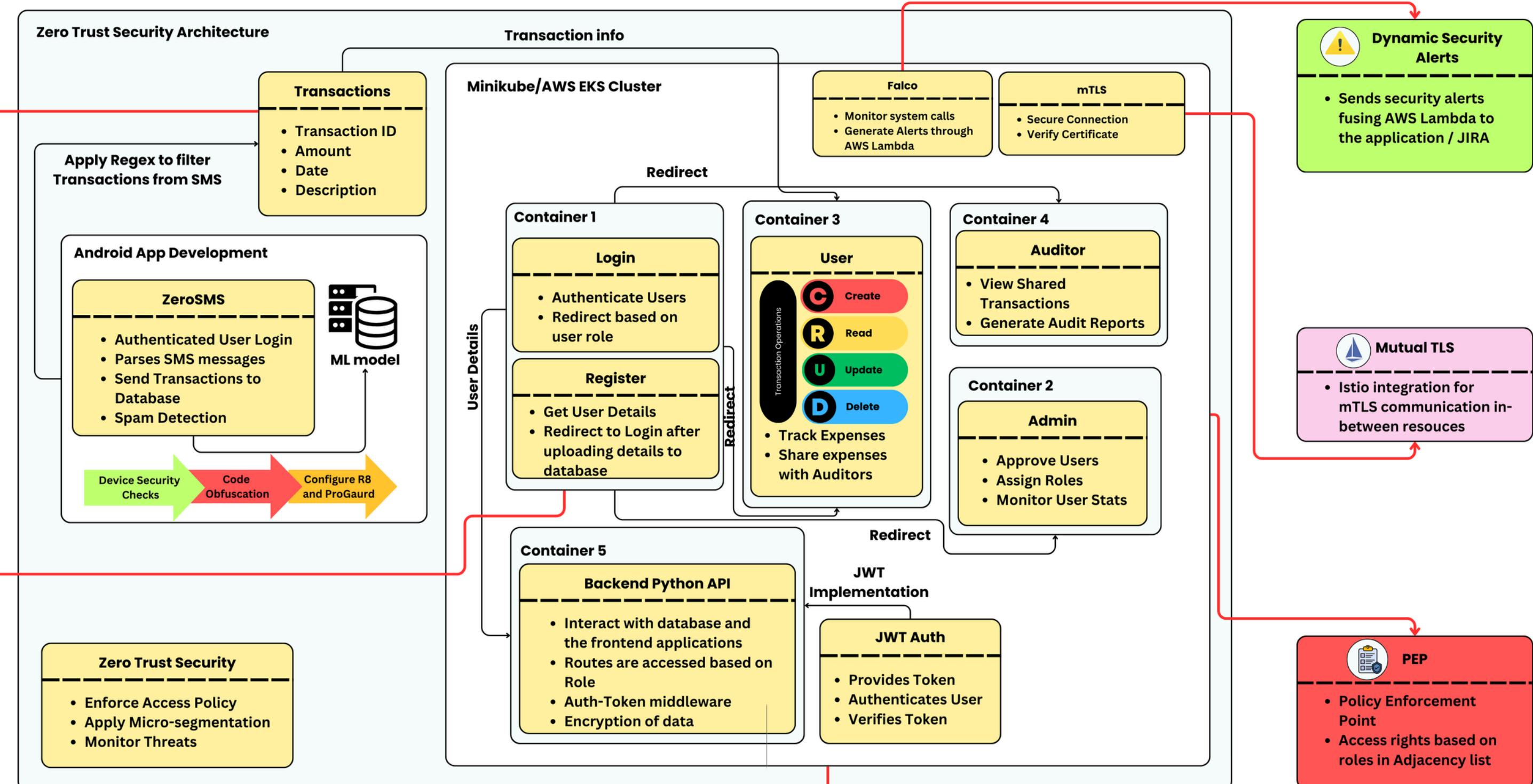
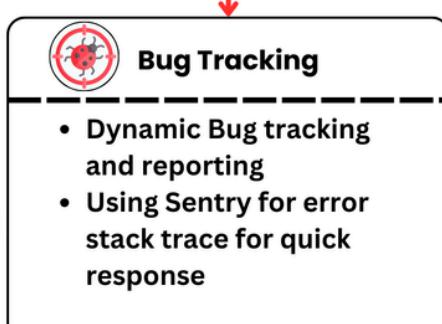
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STAMFORD, Conn., July 5, 2023

# Gartner Survey Finds 79% of Corporate Strategists See AI and Analytics as Critical to Their Success Over the Next Two Years

Strategists Believe More Strategic Planning and Execution Activities Could Be Automated

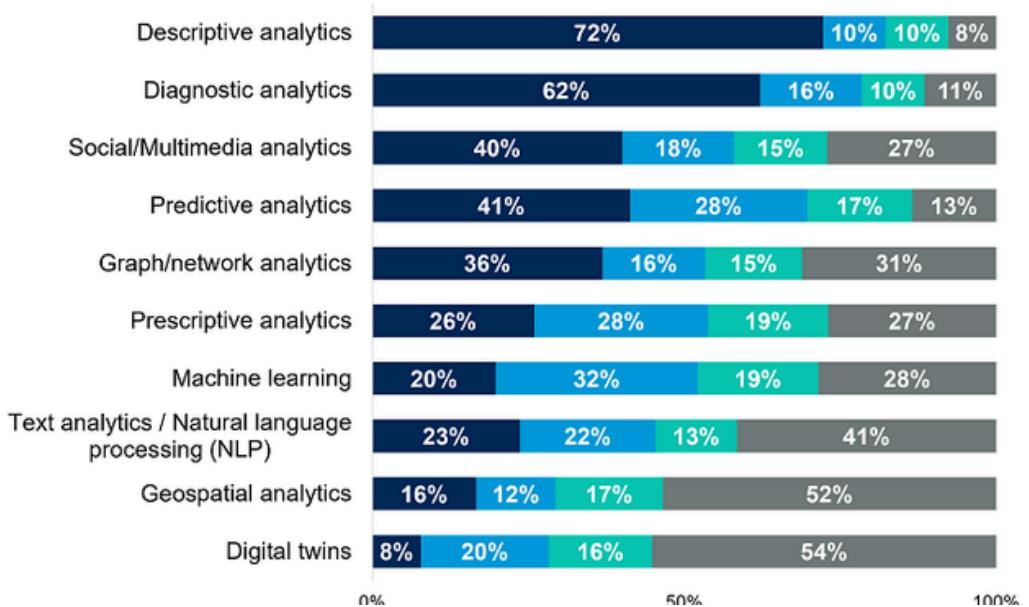
## Hype Cycle for Artificial Intelligence, 2023



gartner.com

Source: Gartner  
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Gartner



Gartner Director Analyst Afraz Jaffri. "Early adoption of these innovations will lead to significant competitive advantage and ease the problems associated with utilizing AI models within business processes."

### WE LIVE PROGRESS

## AI in the workplace: The good, the bad, and the algorithmic

While AI can liberate us from tedious tasks and even eliminate human error, it's crucial to remember its weaknesses and the unique capabilities that humans bring to the table



Imogen Byers

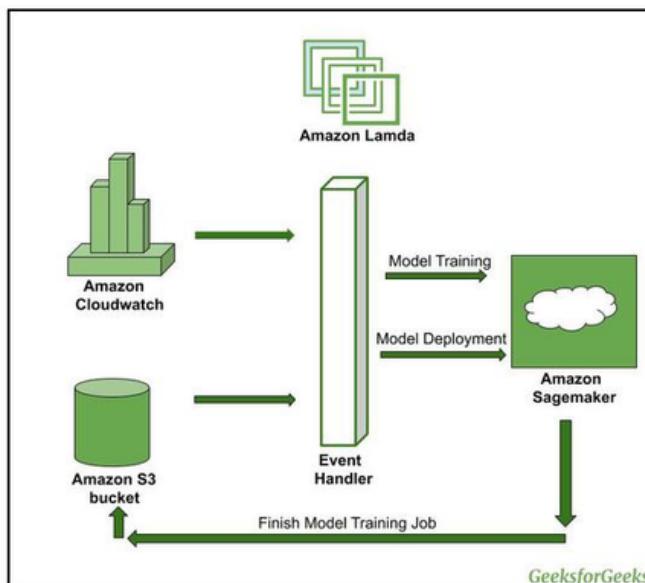
The most effective approach to cybersecurity is not to rely solely on AI or humans but to use the strengths of both. This could mean using AI to handle large-scale data analysis and processing while relying on human expertise for decision-making, strategic planning, and communications. AI should be used as a tool to aid and enhance your workforce, not replace it.

# Cloud Provider

# Service

# Key Features

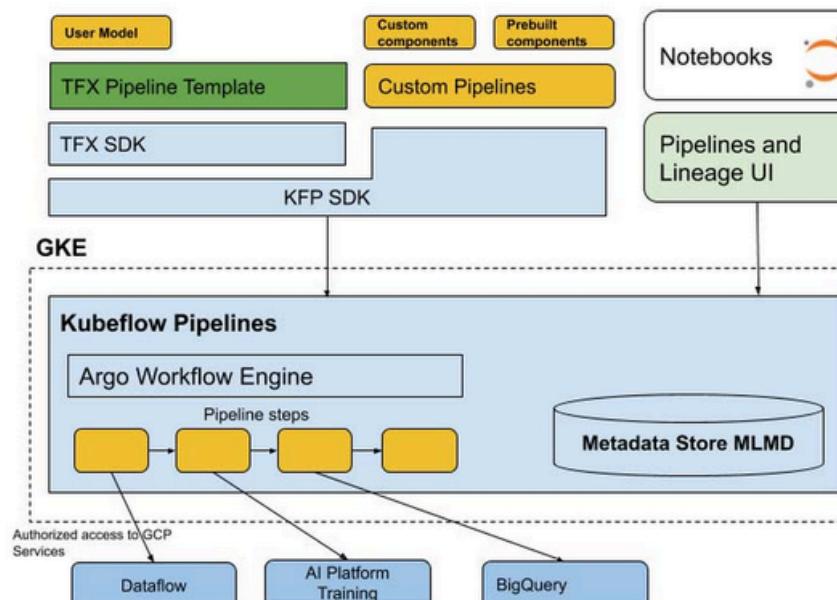
# Advantages



## SageMaker

- End-to-end machine learning platform
- Build, train, and deploy models in a distributed manner
- Supports algorithms like XGBoost
- Pre-built models for common use cases
- Auto-scaling and resource provisioning

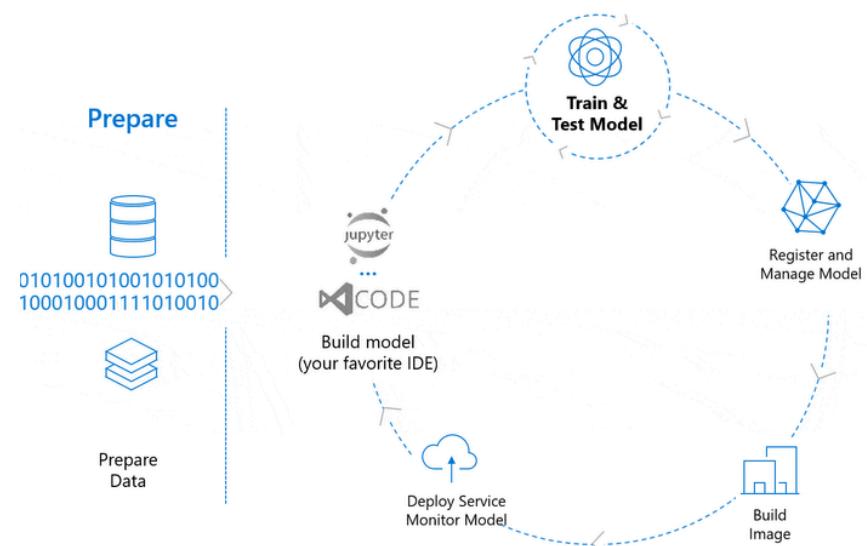
- Comprehensive ML capabilities
- Automatic scaling
- Widely used algorithms support



## Vertex AI Platform

- Custom model training
- Hyperparameter tuning
- TensorFlow integration for global prediction serving
- Seamless integration with Google's cloud infrastructure

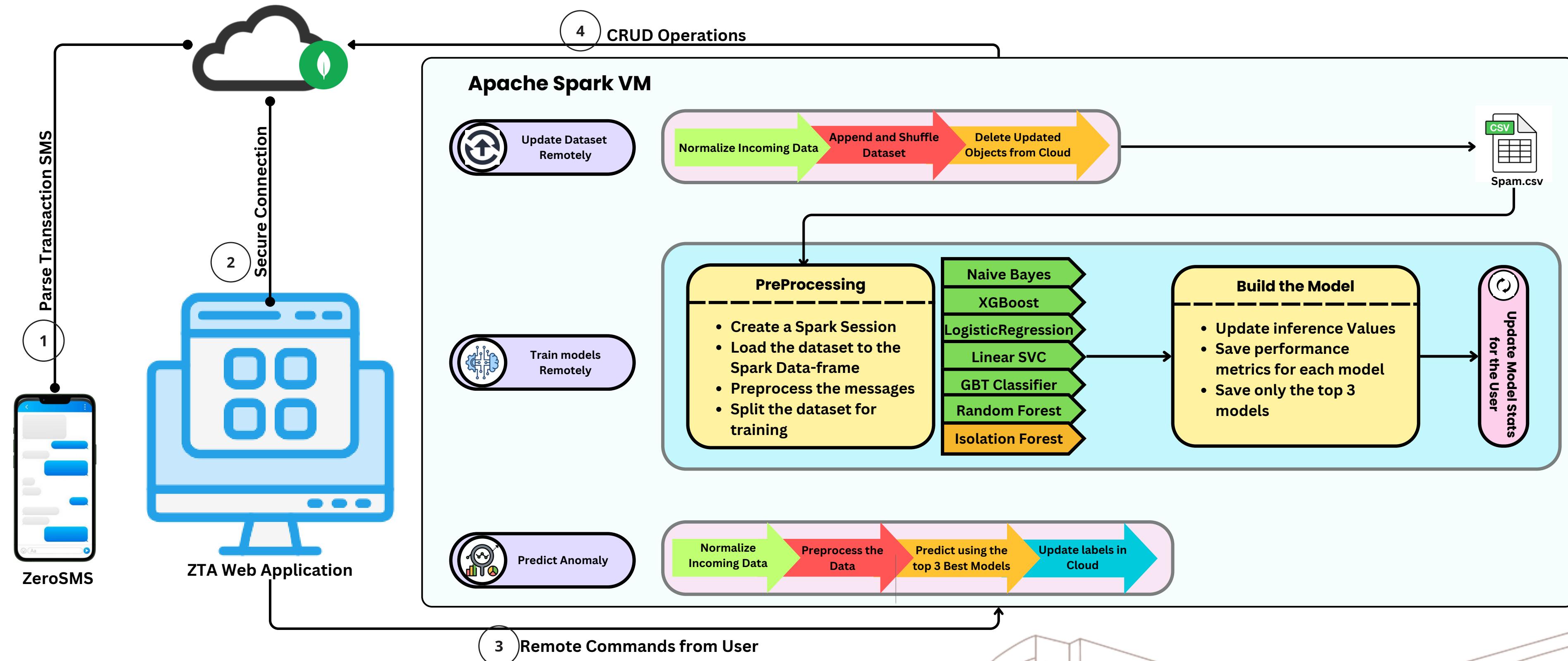
- Advanced TensorFlow support
- Flexible training options
- Efficient hyperparameter tuning



## Azure Machine Learning

- Simplified pipelines for data ingestion, model training, deployment, and monitoring
- Integration with Jupyter Notebooks and Microsoft Power BI

- Ease of use
- Strong integration with Microsoft ecosystem
- Productivity-focused tools



# ZERO TRUST SECURITY FOR WEB APPLICATIONS IN MICROSERVICE-BASED ENVIRONMENTS

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MENTOR: Dr. S. Udhaya Kumar

Tools and Technologies: AWS EKS, Kubernetes, Docker, Falco, React js, React Native, Android Studio, R8, ProGaurd, Apache Spark, Big Data



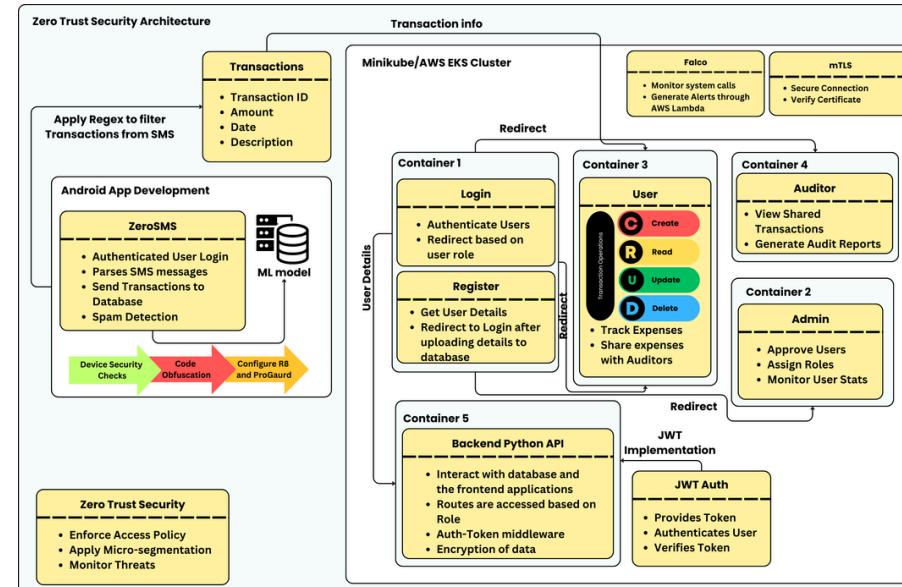
<https://github.com/Dinesh-4320/Zero-Trust-Project>

## INTRODUCTION AND OBJECTIVE

In today's digital landscape, traditional security models fall short against modern cyber threats. As organizations move to cloud-native architectures, the attack surface grows, increasing vulnerability. The Zero Trust Security Model addresses these risks by enforcing continuous authentication, strict access control, and encryption. This project aims to implement a secure web application using Zero Trust principles, focusing on identity verification with JWT and mTLS, adaptive access control, encrypted communication, and real-time threat detection.

## ALGORITHM TO IMPLEMENT ZTA

- Authenticate User
  - a. Validate Credentials
  - b. Assign Role
- Enforce Least Privilege
  - a. If authorized, grant minimal access
  - b. Else, deny access
- Request Access to Resource
  - a. Verify Token and Permissions
  - b. Log Access if valid, else deny
- Secure Containers
  - a. Initialize and Secure Kubernetes
  - b. Deploy Containers with mTLS
- Monitor and Detect Threats
  - a. Audit Activity
  - b. Detect Anomalies
- Encrypt Data at Rest and In Transit
- Implement Real-Time Threat Response
  - a. AI/ML for proactive threat detection
  - b. Automate incident response for detected anomalies



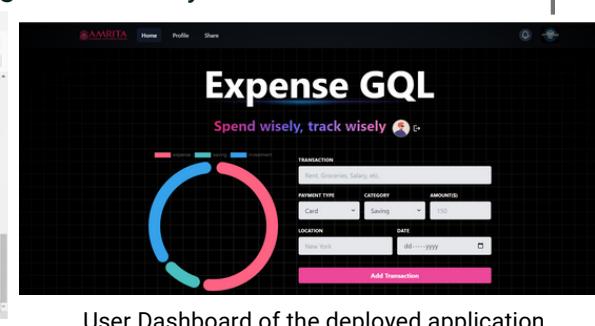
## METHODOLOGY

The system integrates a mobile Android app, web application, and security module following Zero Trust principles. The Android app parses SMS data for transaction information, while the web application handles user management, transactions, and applies security policies.

Security protocols include:

- JWT Authentication for secure user sessions.
- mTLS for encrypted communication between services.
- Policy Enforcement Point (PEP) for real-time access control.
- Falco for real-time threat monitoring via system calls.

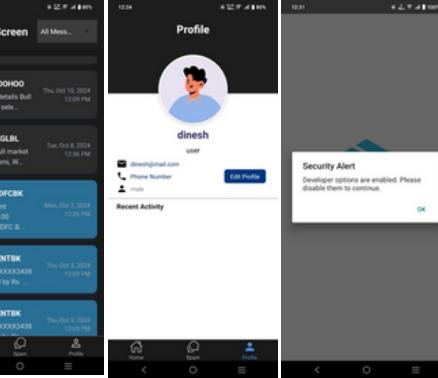
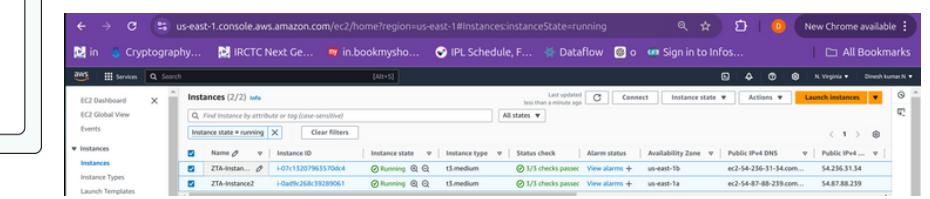
Roles like Admin, Auditor, and User are defined to manage access and operations securely. Additional measures, such as code obfuscation and detection of rooted devices, further strengthen security.



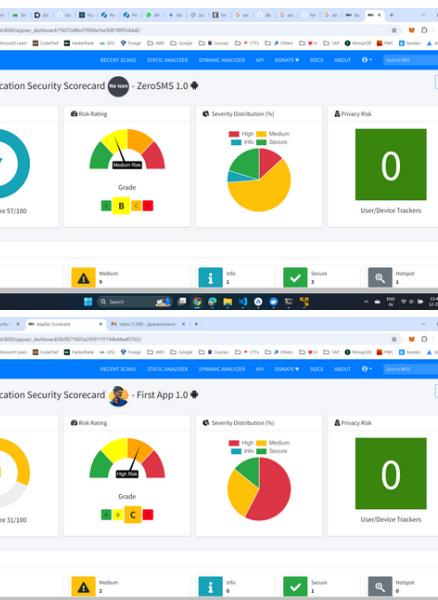
User Dashboard of the deployed application

## RESULT ANALYSIS

The web application is designed to efficiently manage personal and business financial transactions by enabling users to manually input and track their expenses, savings, and investments in an organized manner. In addition to manual entry, the app offers seamless synchronization of transactions through SMS parsing using the integrated ZeroSMS app, ensuring that users can automatically log financial activities received via text messages. To help users better understand their financial status, the application provides detailed visual insights through interactive charts and graphs, allowing for easier monitoring of spending patterns, savings growth, and investment performance. The app also supports role-based access control (RBAC), granting specific permissions to administrators and auditors for oversight and management purposes, ensuring that users with different roles have appropriate access levels based on their responsibilities. Built on a robust Zero Trust security framework, the application ensures that all access points are secure, utilizing JWT (JSON Web Token) authentication to verify the identity of each user, reducing the risk of unauthorized access.



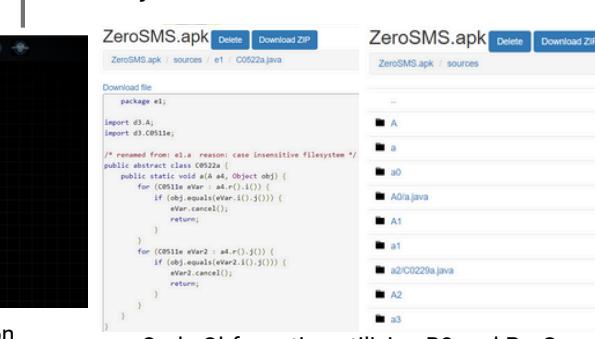
Root | Developer Options | Debugging detection using "JailMonkey" Library



ZeroSMS - Security score that is 83.87% higher than that of the standard APK in MobSF Scan

## CONCLUSION

This project implemented the Zero Trust strategy to enhance the security of containerized environments through a proof of concept (PoC) that included a secure web app, Python API, and Android application. Key measures such as JWT authentication, continuous monitoring, mTLS, and RBAC were integrated to demonstrate effective Zero Trust principles. Future enhancements could focus on applying machine learning for anomaly detection, automating security audits, and integrating security into CI/CD pipelines. Additionally, training developers in Zero Trust practices and conducting real-world deployments will further improve security in containerized environments.



Code Obfuscation utilizing R8 and ProGuard

## References

- [1] O. E. Imokhai, T. E. Emmanuel, A. A. Joshua, E. S. Emakhu, and S. Adebiyi, "Zero Trust Architecture: Trend and Impact on Information Security," International Journal of Emerging Technology and Advanced Engineering, vol. 12, no. 7, pp. 87–92, July 2022.
- [2] S. Rose, O. Borchert, S. Mitchell, and S. Connelly, NIST Special Publication 800-207 Zero Trust Architecture. Gaithersburg, MD: National Institute of Standards and Technology (NIST), 2020.
- [3] Y. He, D. Huang, L. Chen, Y. Ni, and X. Ma, "A Survey on Zero Trust Architecture: Challenges and Future Trends," Wireless Communications and Mobile Computing, vol. 2022, Article ID 6476274, 13 pages, 2022. DOI: <https://doi.org/10.1155/2022/6476274>.
- [4] A. Mustyala and S. Tatineni, "Advanced Security Mechanisms in Kubernetes: Isolation and Access Control Strategies," ESP Journal of Engineering & Technology Advancements, vol. 1, no. 2, pp. 45–52, 2021.
- [5] B. Pranoto, "Threat Mitigation in Containerized Environments," Applied Research in Artificial Intelligence and Cloud Computing, vol. 6, no. 8, pp. 142–151, 2023.
- [6] S. Bagheri, H. Kermabon-Bobinnec, S. Majumdar, Y. Jarraya, L. Wang, and M. Pourzandi, "Warping the Defence Timeline: Non-disruptive Proactive Attack Mitigation for Kubernetes Clusters," in Proc. IEEE International Conference on Communications (ICC 2023), Rome, Italy, 28 May – 01 June, 2023, pp. 567–574.
- [7] D. D'Silva and D. D. Ambawade, "Building a Zero Trust Architecture Using Kubernetes," in Proc. 2021 6th International Conference for Convergence in Technology (I2CT), Pune, India, Apr. 2021, pp. 1–5.
- [8] P. Varalakshmi, B. Guhan, P. V. Siva, T. Dhanush, and K. Saktheeswaran, "Improvising JSON Web Token Authentication in SDN," in Proc. 2022 International Conference on Communication, Computing and Internet of Things (IC3IoT), Mar. 2022. DOI: [10.1109/IC3IOT53935.2022.9767873](https://doi.org/10.1109/IC3IOT53935.2022.9767873).



# Thank You!



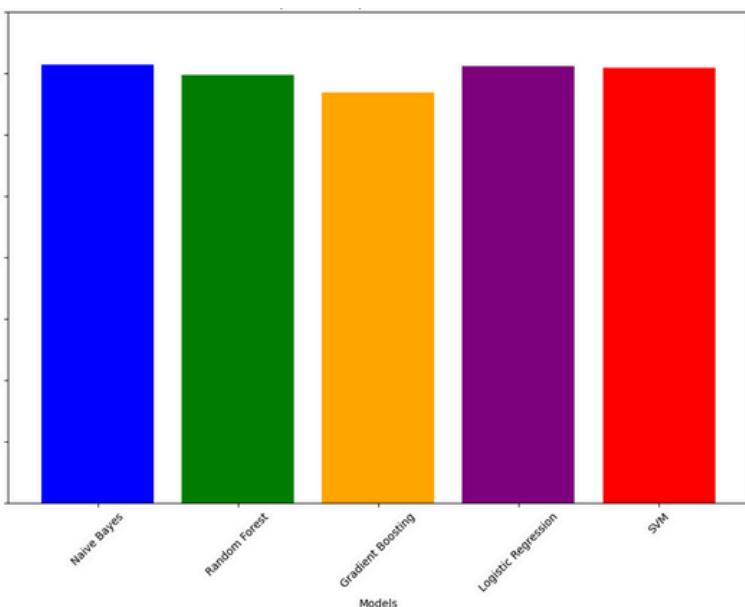


# Results and Analysis

The web application, deployed on an EKS cluster with node groups, ensures scalability, fault tolerance, and seamless service communication for a smooth user experience. The user dashboard supports secure CRUD operations, while data sharing with auditors provides selective access. Auditors have read-only access to transactions, and the admin dashboard allows dynamic role assignment and access control.

Security is enhanced using AWS Lambda and Falco, which monitor the cluster for anomalies and trigger real-time alerts for threat detection. Session logs offer a comprehensive audit trail, tracking user activities and ensuring compliance with Zero Trust principles by continuously monitoring user actions.

Naive Bayes was the best model with an F1 score of 0.918 and accuracy of 0.978, showing a strong balance of precision and recall. SVM had the highest precision (1.0) and ROC AUC score (0.984), while Logistic Regression also performed well with an F1 score of 0.909. Random Forest and Gradient Boosting had slightly lower F1 scores but maintained high accuracy across all models.



```
disciklean@disciklean: ~
Context: arn:aws:eks:us-east-1:926767960185:cluster/ZTA-Cluster <|> all <> Attach <|> Logs Previ
Cluster: arn:aws:eks:us-east-1:926767960185:cluster/ZTA-Cluster <|> default <> Delete <|> Logs Prev
User: arn:aws:eks:us-east-1:926767960185:cluster/ZTA-Cluster <> Describe <|> Port-Forwa
K9s Rev: v0.31.1 ⚡v0.32.5 <> Edit <|> Sanitize
K8s Rev: v1.31.0-eks-a737599 <> Help <|> Shell
CPU: n/a <> Kill <|> Show Node
MEM: n/a

disciklean@disciklean: ~/Desktop/DigitalBackOffice/dataflow-infra
```

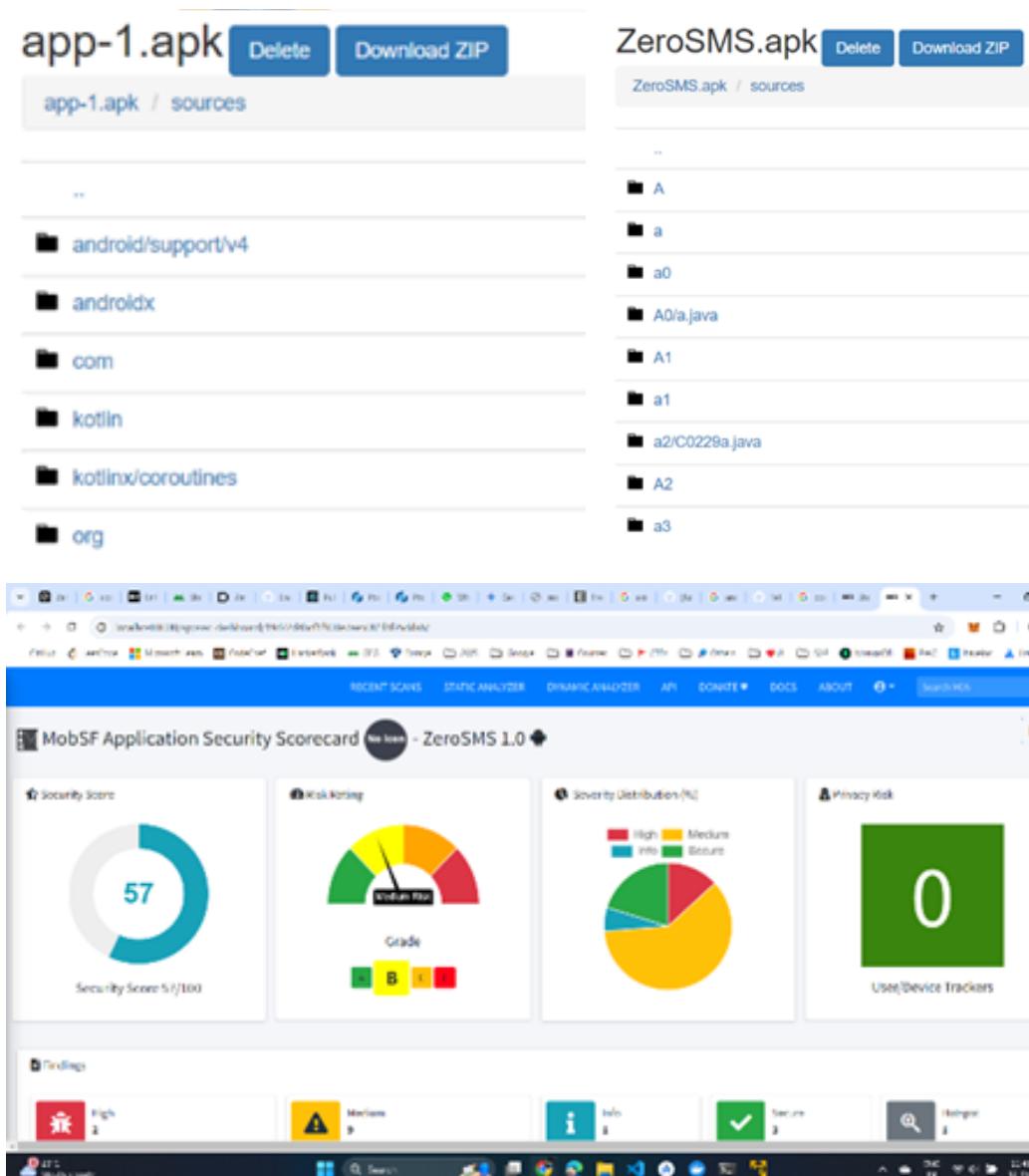
NAMESPACE\POD	NAME	PF	READY	STATUS	RESTARTS	IP	NODE	AGE
cert-manager	cert-manager-5b594dcc49-wb69q	●	1/1	Running	0	10.0.1.198	ip-10-0-1-138.ec2.internal	14m
cert-manager	cert-manager-cainjector-6dbfdd6cd-lh9hz	●	1/1	Running	0	10.0.2.239	ip-10-0-2-223.ec2.internal	15m
cert-manager	cert-manager-webhook-778c658fc-dpmwk	●	1/1	Running	0	10.0.2.21	ip-10-0-2-223.ec2.internal	14m
falco	falco-falcosidekick-66cc764f87-89dxh	●	1/1	Running	0	10.0.2.187	ip-10-0-2-223.ec2.internal	62s
falco	falco-k8s-metacollector-b49d9d954-n6rkw	●	1/1	Running	0	10.0.1.40	ip-10-0-1-138.ec2.internal	62s
falco	falco-vb6g	●	2/2	Running	0	10.0.1.79	ip-10-0-1-138.ec2.internal	62s
kube-system	aws-node-7zjsw	●	2/2	Running	0	10.0.1.28	ip-10-0-1-138.ec2.internal	62s
kube-system	coredns-789f8477df-bmt95	●	2/2	Running	0	10.0.1.223	ip-10-0-2-223.ec2.internal	4h7m
kube-system	coredns-789f8477df-vzb1q	●	1/1	Running	0	10.0.1.138	ip-10-0-1-138.ec2.internal	4h7m
kube-system	kube-proxy-8zr76	●	1/1	Running	0	10.0.2.223	ip-10-0-2-223.ec2.internal	4h7m
kube-system	kube-proxy-fphgd	●	1/1	Running	0	10.0.1.138	ip-10-0-1-138.ec2.internal	4h7m
nginx-ingress	nginx-ingress-controller-66d477f4f4-xvw2c	●	1/1	Running	0	10.0.1.291	ip-10-0-1-138.ec2.internal	64m
zta	admin-6d4bf565f-cm57d	●	1/1	Running	0	10.0.2.147	ip-10-0-2-223.ec2.internal	26m
zta	auditor-5d75759d55-xxcnr	●	1/1	Running	0	10.0.2.162	ip-10-0-2-223.ec2.internal	26m
zta	backend-6f59899f75-hnsjd	●	1/1	Running	0	10.0.1.235	ip-10-0-1-138.ec2.internal	26m
zta	public-784dbd5d96-j88bb	●	1/1	Running	0	10.0.2.12	ip-10-0-2-223.ec2.internal	26m
zta	user-9764bcd6b-74dsk	●	1/1	Running	0	10.0.1.157	ip-10-0-1-138.ec2.internal	26m

```
CloudWatch > Live Tail
Live Tail info
Highlight up to 5 terms (Not case sensitive)
Filter Actions Clear Cancel Start
0 events/sec, 100% displayed 00:04:14 View in columns Log stream
Timestamp (Local) Message
2024-10-15T10:09:23.287+05:30 START RequestId: d5c36fb5-3907-4008-8622-22411a044e Version: $LATEST
2024-10-15T10:09:23.288+05:30 Received Alert: {"hostname": "falco-mz7ch", "output": "04:39:19.606688616: Notice A shell was spawned in a container with an attached terminal (evt.typeee..}
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2024-10-15T10:09:23.289+05:30 REPORT RequestId: d5c36f55-39bf-400a-8622-2245411a044e Duration: 1.57 ms Billed Duration: 2 ms Memory Size: 128 MB Max Memory Used: 32 MB
2024-10-15T10:09:23.723+05:30 START RequestId: 47537d73-0002-493d-a935-11fb56ff72b6b Version: $LATEST
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2024-10
```

# Results and Analysis

To prepare for production release, the app leverages the JailMonkey library to detect rooting and unsafe environments, while utilizing R8 and ProGuard tools for code optimization and obfuscation to enhance performance and security. The APK is securely signed with a private key from a trusted keystore, ensuring authorized distribution.

The below figures compares and tests ZeroSMS APK against standard APKs. Due to R8 and ProGuard obfuscation, reverse engineering ZeroSMS is significantly more challenging. A MobSF scan shows ZeroSMS achieving a security score of 57 (Grade B), 83.87% higher than a standard APK, which scored 31 (Grade C). ZeroSMS has SMS permissions and allows "http" traffic for backend connectivity, impacting its security score.



```
package com.example.firstapp;

import android.os.Bundle;
import android.view.View;
import android.widget.Button;
import android.widget.EditText;
import android.widget.TextView;
import androidx.appcompat.app.AppCompatActivity;

public class MainActivity extends AppCompatActivity {
    Button add;
    TextView display;
    Button reset;
    Button sub;
    EditText x;
    EditText y;

    /* access modifiers changed from: protected */
    public void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_main);
        this.x = (EditText) findViewById(R.id.et1);
        this.y = (EditText) findViewById(R.id.et2);
        this.add = (Button) findViewById(R.id.b1);
        this.sub = (Button) findViewById(R.id.b2);
        this.reset = (Button) findViewById(R.id.b3);
        this.display = (TextView) findViewById(R.id.td);
        this.add.setOnClickListener(new View.OnClickListener() {
            public void onClick(View v) {
                MainActivity.this.display.setText(Integer.toString(Integer.parseInt(this.x.getText().toString()) + Integer.parseInt(this.y.getText().toString())));
            }
        });
        this.sub.setOnClickListener(new View.OnClickListener() {
            public void onClick(View v) {
                MainActivity.this.display.setText(Integer.toString(Integer.parseInt(this.x.getText().toString()) - Integer.parseInt(this.y.getText().toString())));
            }
        });
        this.reset.setOnClickListener(new View.OnClickListener() {
            public void onClick(View v) {
                MainActivity.this.display.setText("0");
            }
        });
    }
}
```

```
RECENT SCANS STATIC ANALYZER DYNAMIC ANALYZER API DONATE DOCS ABOUT SEARCH

MobSF Application Security Scorecard - ZeroSMS 1.0

Security Score 57/100
Risk Rating Grade B
Severity Distribution (%) High: 0%, Medium: 57%, Info: 43%, Secure: 0%
User/Device Trackers 0

Findings: High 2, Medium 9, Info 8, Secure 2, Negative 0

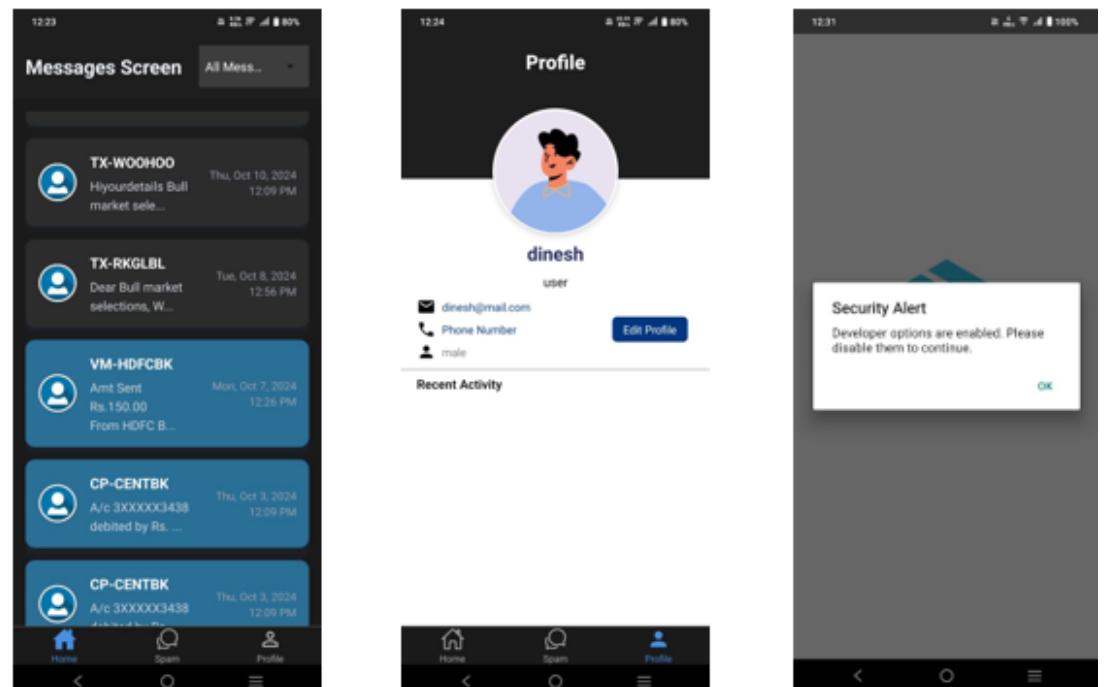
RECENT SCANS STATIC ANALYZER DYNAMIC ANALYZER API DONATE DOCS ABOUT SEARCH

MobSF Application Security Scorecard - First App 1.0

Security Score 31/100
Risk Rating Grade C
Severity Distribution (%) High: 31%, Medium: 31%, Info: 38%, Secure: 0%
User/Device Trackers 0

Findings: High 4, Medium 2, Info 8, Secure 2, Negative 0
```

```
signingConfigs {
    debug {
        storeFile file('debug.keystore')
        storePassword 'android'
        keyAlias 'androiddebugkey'
        keyPassword 'android'
    }
    release {
        if (project.hasProperty('MYAPP_UPLOAD_STORE_FILE')) {
            storeFile file(MYAPP_UPLOAD_STORE_FILE)
            storePassword MYAPP_UPLOAD_STORE_PASSWORD
            keyAlias MYAPP_UPLOAD_KEY_ALIAS
            keyPassword MYAPP_UPLOAD_KEY_PASSWORD
        }
    }
}
buildTypes {
    debug {
        signingConfig signingConfigs.debug
    }
    release {
        // Caution! In production, you need to generate your own keystore file.
        // see https://reactnative.dev/docs/signed-apk-android.
        signingConfig signingConfigs.release
        debuggable false
        shrinkResources true
        minifyEnabled true
        proguardFiles getDefaultProguardFile("proguard-android.txt"), "proguard-rules.pro"
    }
}
```



## Conclusion and Future Work

This project demonstrated the application of Zero Trust principles to enhance security in containerized environments through a proof of concept (PoC) that included a secure web application, Python API, and Android app. Key strategies such as JWT authentication, continuous monitoring, root detection, mTLS within containers, and Role-Based Access Control (RBAC) were implemented. The outcomes emphasize the importance of trust verification at every layer and proactive monitoring to significantly mitigate security risks in modern containerized systems.

Future efforts can focus on integrating advanced threat detection using machine learning to identify anomalies in containerized applications. Automating security audits and incorporating continuous vulnerability scanning in CI/CD pipelines will strengthen ongoing security assessments. Additionally, providing Zero Trust training for developers will promote a security-first mindset. Real-world deployments of these solutions in varied organizational settings would offer insights into improving security measures and adapting strategies to evolving cyber threats.

