ITU-MiniTwit – DevOps Monitoring & CI/CD Report

MSc Group N — Spring 2025 Jesse Noah Lang - jnol@itu.dk Ivaylo Valeri Nikolov - ivni@itu.dk

---

1. System's Perspective

1.1 Architecture Overview

The ITU-MiniTwit platform is **fully hosted on DigitalOcean** and embraces a containerised micro-service pattern managed via Docker Compose. Two dedicated droplets implement a **classic split-brain topology**:

Droplet	Public IP	Role	Main containers
app-prod-01	`161.35.71.145`	User-facing application	`nginx`, `minitwit-blue`, `minitwit-green`, `simulator-api`
mon-prod-01	`68.183.210.76`	Observability stack	`prometheus`, `grafana`, `elasticsearch`, `kibana`, `filebeat`, `alertmanager`, `node-exporter`, `cadvisor`

A **blue-green strategy** is enforced at the container layer: two identical backend containers run in parallel; a `/etc/nginx/conf.d/upstream.conf` symlink determines which revision receives live traffic. State is isolated in a named Docker volume holding **SQLite** (WAL + shared-cache mode). Structured JSON logs are mounted into `/var/lib/minitwit/logs`; `filebeat.yml` harvests and ships lines over the VPC to Elasticsearch.

1.1.1 Component Diagram (PlantUML)

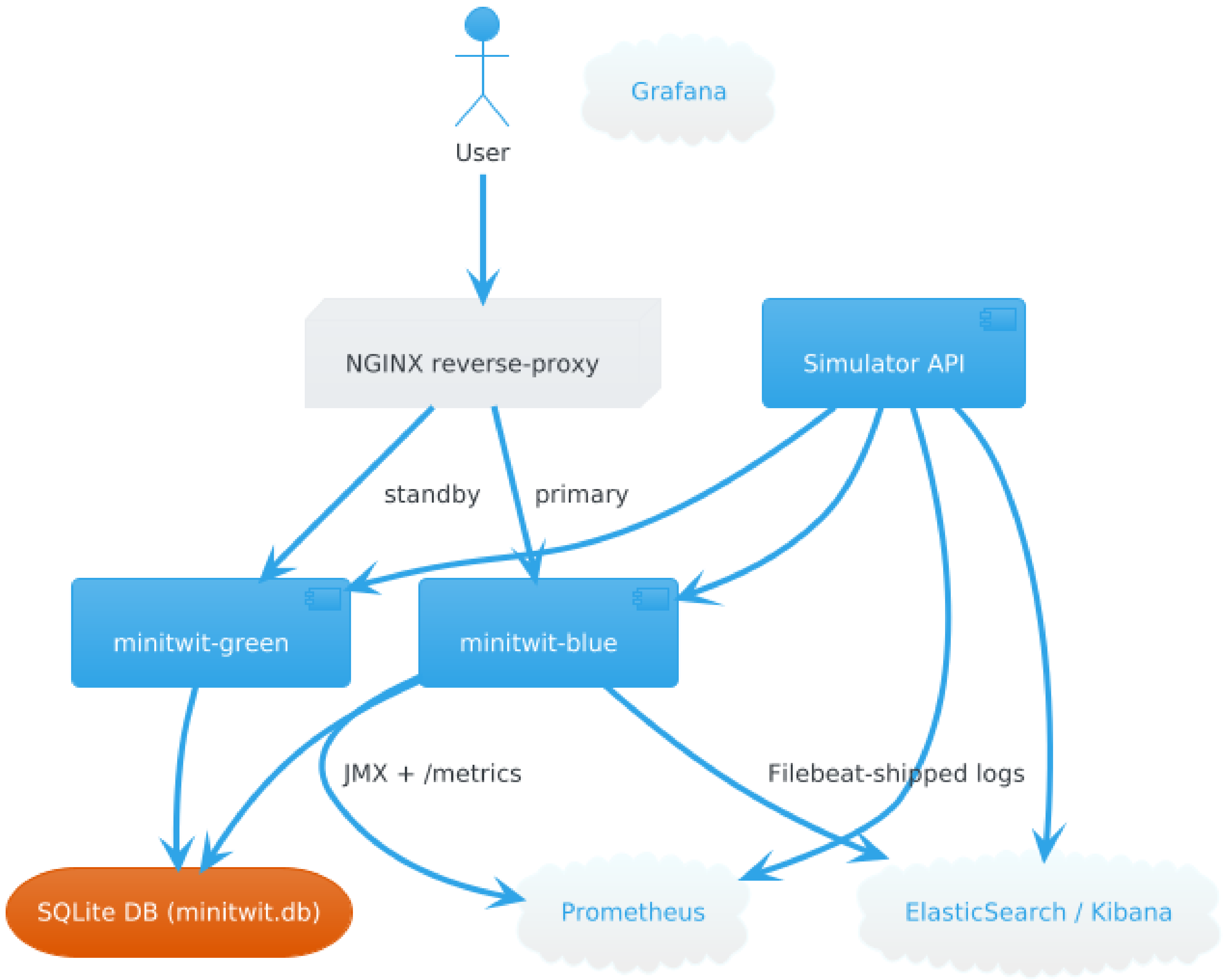


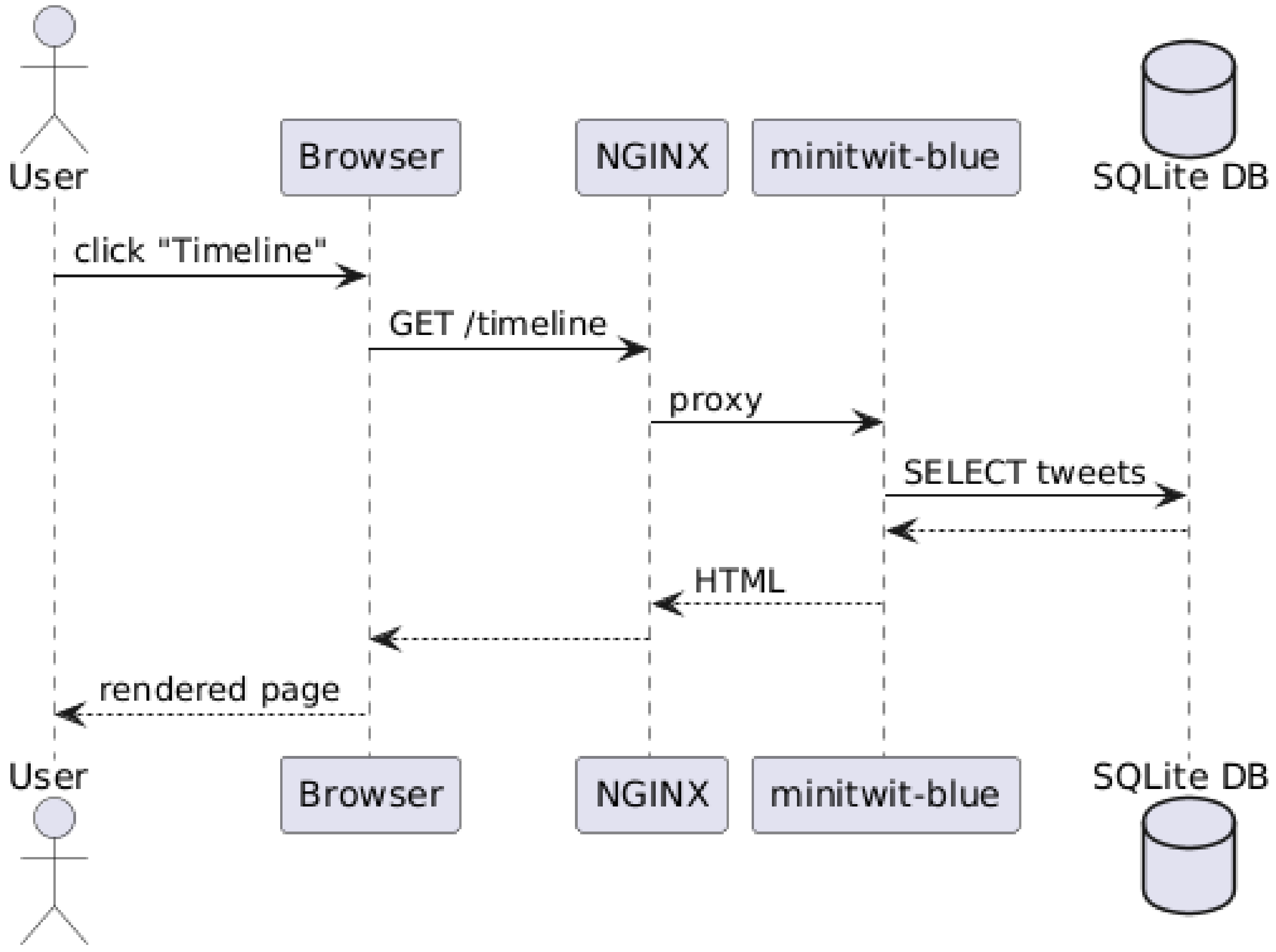
Figure 1. Logical architecture, deployment footprint and cross-droplet flows.

1.2 Technology & Tool Dependencies

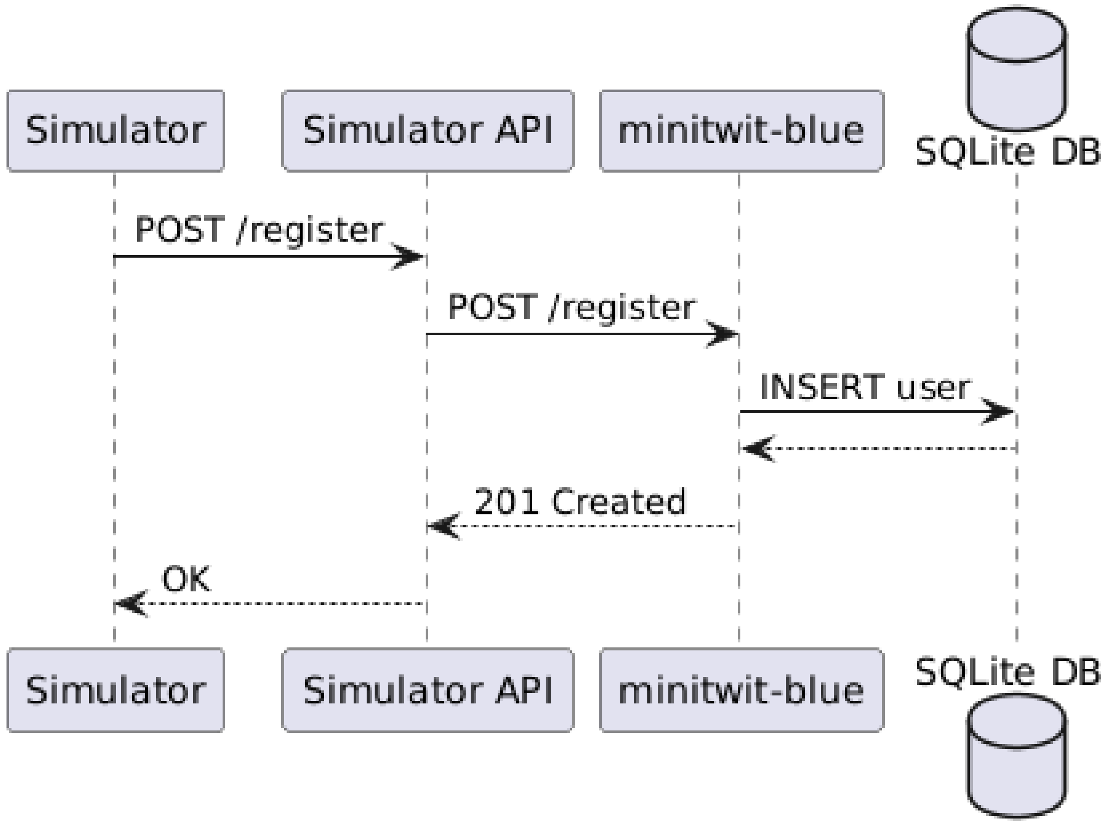
Layer	Technology / Tool	Purpose
Cloud & Infra	DigitalOcean Droplets & VPC	Low-friction IaaS, static IPv4, private networking
Runtime	Java 21 (Temurin)	Virtual threads (Project Loom), LTS support
Web Framework	SparkJava 2.9	Lightweight functional HTTP routing
Templating	Freemarker	Server-side HTML rendering
JSON	Gson	JSON marshalling/parsing
Security libs	jBCrypt	Password hashing
Logging	SLF4J + Logback	Structured JSON logs
Metrics client	Prometheus Java client & JMX agent 0.18	JVM & HTTP metric exposition
Data	SQLite (WAL)	Zero-ops DB, write concurrency
Containerisation	Docker + Docker Compose	Environment parity, blue-green pattern
Observability platform	Prometheus, Grafana, node-exporter, cAdvisor	Metrics scrape & dashboards
Log stack	Filebeat, Elasticsearch, Kibana	Structured log shipping & search
Build & Test	Maven 3.9, JUnit 5, Rest-Assured, SpotBugs, Checkstyle	Deterministic builds, unit/API tests, static analysis
Security tooling	OWASP dependency-check, Trivy	Dependency & container CVE scans
CI/CD	GitHub Actions, appleboy/ssh-action	Build, test, push, blue-green deploy
Infrastructure-as-Code	docker-compose.yml (app), monitoring/docker-compose.yml	Declarative stack definition

1.3 Subsystem Interactions

1.3.1 End-user HTTP request



1.3.2 Simulator request path



1.4 Current System State & Quality Metrics

In our CI/CD pipeline's test-java stage we now invoke one automated static-analysis checks immediately after compiling and running any unit tests:

Checkstyle (mvn checkstyle:check) to validate code style against our project rules, By wiring each plugin into the POM (configuring Checkstyle's rule set), any new rule violations or emerging vulnerabilities automatically fail the build—ensuring that only clean code, ever reaches deployment.

1.5 Rationale for Technology Choices (MSc)

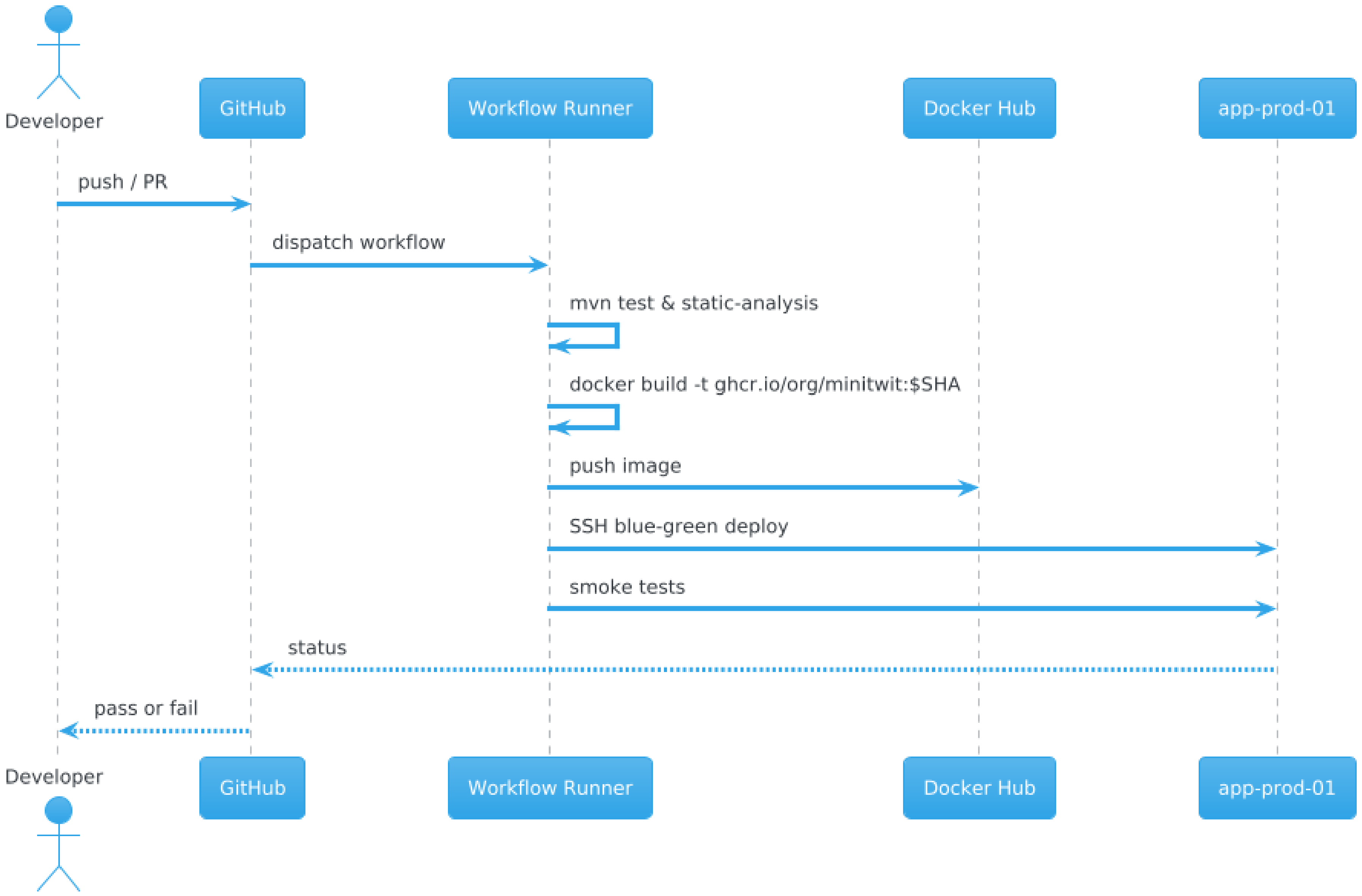
1. **Java 21 LTS** – Virtual threads reduce thread-per-req overhead, ensure future-proof support.
2. **Docker/Compose** – Reproducible local dev & prod, blue-green implemented via container labels + NGINX.
3. **SQLite** – Meets workload (< 500 req/s), zero-maintenance, mitigated via WAL + pool.
4. **Prometheus/Grafana** – Open, query-flexible, no external latency.

5. **ELK** – Full-text debugging faster than Loki; Filebeat lightweight.
6. **DigitalOcean** – Simpler pricing vs. AWS, gives floating IPs & VPC out-of-box.
7. **GitHub Actions** – SaaS runners, secrets ephemeral, direct SSH deploy fits blue-green pattern.

---

2. Process Perspective

2.1 CI/CD Pipeline (GitHub Actions)



We performed a structured literature- and feature-based comparison before committing to **GitHub Actions**. The criteria below are the same ones we use throughout the project (cost, maintenance effort, ecosystem fit, security, and learning value).

Criterion	GitHub Actions
Native integration with our code host	Lives inside every GitHub repo; PR checks and annotations appear exactly where we review code.
Cost for a student project	Free unlimited minutes for public repos and generous private-repo allowance under the GitHub Student Pack.
Maintenance overhead	Fully managed runners; updates, patching and autoscaling are handled by GitHub.
Action marketplace	20 000 + reusable actions (e.g. `setup-java`, `trivy-action`, `appleboy/ssh-action`).
Secrets management & supply-chain security	Encrypted repository and environment secrets; built-in OIDC tokens for cloud deploy.
Container & service support	Jobs run in Docker-enabled Ubuntu images; `services:` stanza spins up multi-container integration-test stacks that
Learning curve vs. course time-box	Declarative YAML, mirrors examples shown in the lectures.

Tools Used:

- **GitHub Actions**: CI/CD orchestration
- **Docker Compose**: Service definitions and environment management
- **Maven**: Java build and testing
- **Python (requests)**: API endpoint tests
- **SSH Deploy (appleboy/ssh-action)**: Remote deployment to Droplet

Stages:

1. `test-java` – Java Unit Testing:
   - Build the simulator backend using Maven
   - Runs unit tests with `mvn clean test`
2. `lint` – Config Validation:
   - Validates `docker-compose.yml` and monitoring configs
3. `build-and-test` – Integration Testing:
   - Builds `minitwit` and `simulator-api`
   - Runs in isolated throwaway containers using test-only volumes
   - Waits for the health endpoint (`/health`)
   - Runs **functional API tests** (register/login/post timeline)
4. `deploy` – Blue-Green Deployment:
   - Pulls new code on the Droplet
   - Builds and deploys to the *inactive* version (blue or green)
   - Runs health checks on the new container
   - Swaps NGINX config symlink
   - Gracefully stops and removes the previous version

2.3 Monitoring & Alerting

Tools Used:

- **Prometheus**: Metrics scraping
- **Grafana** (implied for dashboards)
- **cAdvisor**: Container-level CPU, memory, I/O metrics
- **Node Exporter**: OS-level system metrics
- **Custom App Metrics**:
  - HTTP latency (per route)
  - DB query latency

Prometheus Targets:

- `app-http`: HTTP metrics from `minitwit` and `simulator-api`
- `app-jmx`: JVM metrics (on separate ports)
- `cadvisor` and `node-exporter`: Docker and system stats

2.4 Logging & Aggregation

- **Log Format** – Logback JSON encoder (timestamp, level, traceId, userId, message).
- **Collection** – Filebeat side-car tails `/var/lib/minitwit/logs/*.log`.
- **Indexing** – Elasticsearch ILM keeps 7 d hot, 21 d warm, 30 d delete; <4 GB/day.
- **Kibana** used for exploration and visualization

2.5 Security Hardening

In our security assessment of ITU-MiniTwit, we identified that the highest risks to user confidentiality and session integrity stem from XSS, session hijacking (missing HttpOnly/Secure flags), and SQL injection, with additional concerns around CSRF, session fixation, brute-force logins, insecure TLS, and deployment misconfigurations. To address these, we've enabled Freemarker auto-escaping and a strict CSP, converted all database operations to parameterized JDBC prepared statements, and configured session cookies with HttpOnly, Secure, and SameSite attributes while regenerating IDs on login. We also enforce anti-CSRF tokens, rate-limit authentication attempts, require HTTPS with HSTS, and harden our DigitalOcean droplets (SSH-key only, minimal firewall rules). Finally, we centralize JSON-formatted security logs and integrate OWASP Dependency-Check, Trivy scans, and periodic DAST/SAST into our CI/CD pipeline to catch and remediate vulnerabilities continuously.

2.6 Scaling & Upgrades Strategy

Strategy:

- **Blue-Green Deployment** implemented:
  - Two identical service definitions (`minitwit-blue`, `minitwit-green`)
  - NGINX switches between them via symlinked config

    - Ensures zero downtime
    - Rollbacks are instant by swapping symlink back

Scaling:

- Shared Docker volumes used for data and logs
- Metrics and logs are centralized and decoupled from app containers
- With containerization, horizontal scaling is trivial (can spin up more app containers behind a load balancer)

Upgrade Notes:

- Every deployment builds a fresh image from Dockerfile
- Health checks (`/health`) used to verify readiness before switching traffic
- Deprecated containers are cleaned up post-deployment

AI use

in this project AI was used as a helper, and advicer. Co-pilot is connected to VS code and made some code suggestions. GPT was unable to provide solutions that were 100% correct. More likely around 30%. Therefore you need to be careful of what to use and how you use it.

3. Reflection Perspective

During this project, our two-person team confronted tight deadlines, infrastructure quirks, and operational surprises. Below we summarise the biggest challenges, our solutions, and the key takeaways in **evolution**, **operation**, and **maintenance**.

3.1 Evolution and Refactoring

Challenges:

- **Single-database simplicity**: We used only SQLite throughout—no full ORM or multi-DB layering—leading to manual SQL scattered in DAO-like methods and occasional repetitive code.
- **Scope management**: As a team of two, balancing feature scope versus stability was tough; early attempts to over-engineer (e.g., planning microservices) had to be shelved.

Solutions:

- Embraced SQLite's simplicity: centralised connection logic in a helper class (`Database.java`), documented common patterns, and reused SQL snippets in a shared utility to reduce duplication.
- Adopted an MVP-first mindset: focused on core flows (register, post, follow) before any advanced refactoring or secondary features.

Lessons Learned:

1. **Keep it simple**: For small teams, minimal abstractions accelerate progress. SQLite served well at our scale and avoided operational overhead.
2. **Prioritise core functionality**: Building a minimum viable pipeline prevented wasted effort on unneeded complexity.

3.2 Operation

Challenges:

- **Deployment headaches**: Configuring NGINX on `161.35.71.145`, handling blue-green symlinks, and ensuring zero-downtime flips often hit port conflicts or stale socket files.
- **Firewall and VPC quirks**: Blocking by DigitalOcean firewalls and misconfigured port whitelists meant our monitoring droplet (`68.183.210.76`) couldn't scrape metrics until rules were tightened.
- **Logging setup**: Initial Filebeat configuration shipped logs over public network by mistake; securing the VPC tunnel and adjusting `filebeat.yml` took several debugging sessions.

Solutions:

- Created idempotent `deploy_blue_green.sh` that cleans old sockets, verifies NGINX config, and only flips the upstream if health checks pass.
- Standardised firewall rules in Terraform-like shell scripts, versioned under `infrastructure/`, to reproduce across droplets.
- Shifted Filebeat to use private VPC IP addresses and enabled TLS between Filebeat and Elasticsearch, updating `filebeat.yml` and `elasticsearch` certs.

Lessons Learned:

1. **Automate deploy scripts**: Manual NGINX edits led to downtime; scripting ensured consistency and quick rollback.
2. **Test infra changes**: Adjust firewall rules in a staging droplet before prod to avoid blind spots.
3. **Secure defaults**: Always assume networks are hostile; configure logging agents to use private IPs and encryption.

3.3 Maintenance

Challenges:

- **Workload balance**: With only two contributors, reviews and testing overlapped, causing merge bottlenecks.
- **Documentation lag**: Keeping docs up-to-date with code changes was deprioritised under tight deadlines.

Lessons Learned:

1. **Regular communication**: Even small teams need structured check-ins to avoid duplicated effort.
2. **Docs-as-code**: Automating documentation reduces drift and ensures accuracy under time pressure.

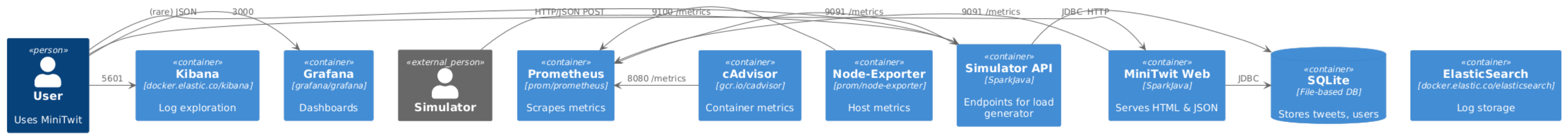
3.4 DevOps-style Work Approach

- **Survival development** – Tried to cope with the high workload, was hard to manage as only two people
- **"You build it, you run it"**
- **Automated everything** – One-click (`gh workflow run deploy.yml`) recreates stack from scratch; mean time to recover (MTTR) < 5 min.

Key Takeaways

1. **Observability first** – Surfaced latency anomalies before users complained.
2. **Small, safe releases** – Blue-green eliminated rollbacks pains (no DB migrations during cycle).
3. **Shared responsibility** – Ops knowledge spread across team $\rightarrow$ no gatekeepers.

Appendix A


(rare) JSON
3000
HTTP/JSON POST
9100 /metrics
9091 /metrics
9091 /metrics
JDBC
HTTP
«person»
User
Uses MiniTwit
5601
«container»
Kibana
[docker.elastic.co/kibana]
Log exploration
«container»
Grafana
[grafana/grafana]
Dashboards
«external_person»
Simulator
«container»
Prometheus
[prom/prometheus]
Scrapes metrics
8080 /metrics
«container»
cAdvisor
[gcr.io/cadvisor]
Container metrics
«container»
Node-Exporter
[prom/node-exporter]
Host metrics
«container»
Simulator API
[SparkJava]
Endpoints for load generator
«container»
MiniTwit Web
[SparkJava]
Serves HTML & JSON
JDBC
«container»
SQLite
[File-based DB]
Stores tweets, users
«container»
ElasticSearch
[docker.elastic.co/elasticsearch]
Log storage