

DAT250 FeedApp Report

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Abstract

Live polling applications need to keep data consistent across many users while staying fast and responsive. FeedApp is a real-time polling platform where users can create polls, vote, and discuss results in comment threads, with updates appearing instantly for everyone. This project evaluates Apache Kafka against RabbitMQ as event streaming platforms for handling real-time updates in web applications. We built the system with a Spring Boot backend and React frontend, using Kafka's topic-per-poll approach along with Redis for caching and WebSockets for push notifications. Through benchmarking with OpenMessaging Benchmark framework, we tested hypotheses around throughput, scalability, and latency under different workloads simulating high-volume vote ingestion and real-time fan-out to clients. Our experiments showed that Kafka achieved significantly higher throughput and better horizontal scaling for write-heavy workloads, while RabbitMQ demonstrated lower latency at low message rates due to its push model. However, Kafka's performance advantage increased under high load as RabbitMQ's per-message overhead became more costly. Creating separate Kafka topics for each poll worked well for keeping things isolated, though it required extra management overhead. The main takeaways from this project are understanding the throughput-latency trade-offs between log-based and queue-based messaging systems, when event-driven architectures like Kafka justify their complexity, and how to handle cache invalidation properly in distributed systems.

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1 Introduction

1.1 Project Overview

FeedApp is a small web app for running live polls. Users can create a poll with options, vote, and discuss the results in a comment thread. The goal is to make collecting feedback simple and fast. Instead of refreshing the page or counting results by hand, the app pushes updates in real time so everyone sees new votes and comments right away.

The system has two parts: a backend and a frontend. The backend exposes REST endpoints for polls, votes and comments, and it emits events when data changes. The frontend shows the latest state, listens for WebSocket messages, and keeps the UI in sync with the server. The project is also used to try out event-driven ideas and see how they scale when more users join.

1.2 Technology Stack Summary

Backend: Java with Spring Boot and Spring Security for REST APIs, validation and auth. During development we store data in an in-memory H2 database. Redis is used as a cache for frequently read data like poll results. Kafka is our messaging backbone for domain events (for example, a vote that was cast).

Frontend: React with TypeScript for a simple, component-based UI that reacts to server events over a single WebSocket connection.

Infra: Docker and Docker Compose run all services with the same settings on any machine.

We chose this stack because it is familiar, easy to set up, and supports horizontal growth. Kafka helps decouple writes from notifications, Redis improves read performance, and WebSockets keep the UI responsive.

1.3 Project Outcome

The prototype supports creating polls, voting with instant updates, and threaded comments with edits and replies. We also compared Kafka with RabbitMQ for the event stream. In short: Kafka handled higher throughput and scaled better under heavy write load, while RabbitMQ showed slightly lower latency at low message rates. Our topic-per-poll approach in Kafka kept events neatly separated, and Redis caching reduced repeated work on popular polls. Everything is containerized so the full stack starts with one command.

1.4 Report Organization

This report is organized as follows. Section 2 explains the design: main use cases, the domain model, and the overall architecture. Section 3 introduces Kafka (and the supporting tech), and outlines our experiment plan and assumptions. Section 4 describes how we built the prototype, how services talk to each other, and how to run it locally. Finally, Section 5 sums up what we learned and lists possible next steps.

2 Design

Around 5 pages about functional aspects of the FeedApp application.

2.1 Use Cases

Describe:

- Main functionality from the user's perspective,
- Actors: Guest User, Registered User, System,
- Core use cases: Register/Login, Create Poll, Vote, Comment and Managing Polls,
- Brief explanation of real-time updates and visibility (public/private polls)

Optional:

- Use Case Diagram (Figure: Use case overview)

2.2 Domain Model

Describe:

- Core domain entities (User, Poll, Vote, VoteOption, Comment(?)),
- Relationships between them (one-to-many, many-to-one),
- Persistence through JPA/Hibernate

Optional:

- UML Class Diagram (Figure: Domain Model Overview)

Show main entities, attributes, and associations

2.3 Architecture (including applied technologies)

Describe:

- High-level architecture (frontend–backend–infrastructure),
- Backend layers: Controller, Service, Repository,
- Key technologies: Spring Boot, H2, Redis, Kafka, WebSocket, JWT,
- Frontend technologies: React, TypeScript, REST API communication,
- Interaction between components (data flow from frontend to backend),

Optional:

- Architecture Diagram (Figure: System Architecture)
- Show containers/components (Frontend, Backend, Redis, Kafka, DB, WebSocket)

2.4 Summary

Summarize:

- How the design supports scalability, modularity, and real-time updates,
- The rationale behind chosen technologies,
- How the design connects to later implementation and deployment steps

3 Technology Assessment

(Remove later: Introduce in sufficient depth the key concepts and architecture of the chosen software technology. As part of this, you may consider using a running example to introduce the technology.)

At its core, Apache Kafka is a distributed event streaming platform. Think of it as a highly scalable, fault-tolerant, and durable "log file" that different parts of an application can write to and read from

simultaneously. The FeedApp project uses these core concepts to decouple tasks. When a user votes, the system does not immediately try to update every other user's screen. Instead, it publishes an "event" to Kafka, and other services (like the WebSocket broadcaster) react to that event.

Event:

An event is the most basic unit of data, representing the fact that "something happened." In the FeedApp, an event is a `Map<String, Object>` that gets serialized into JSON. For example, when a poll is created, the `PollEventListener` creates an event with the `pollId`, `question`, and `eventType`. The consumer listens for vote change events, which it receives as a Map containing the `pollId` and `optionOrder`.

Topic:

A topic is a named "category" or "feed" where events are stored and published. A cluster can host many topics, and with KRaft mode, the number of topics can now scale into the millions [2]. The FeedApp uses a dynamic topic strategy. Instead of one giant votes topic, the `PollTopicManager` creates a unique topic for every single poll. For example, for a poll with ID 10, the topic name would be `poll.voteChange.10`.

Producer:

A producer is a client application that writes events to a Kafka topic. The `ProducerService` in the FeedApp project is a classic producer, using Spring's `KafkaTemplate` to send events. This service is used by the `PollEventListener` to send a message after a new poll is successfully saved to the database. With the 3-node cluster, the producer (our backend) is given a list of all three brokers (`kafka-1:29092,kafka-2:29092,kafka-3:29092`) via its environment variables. The Kafka client uses this list to discover the entire cluster.

Consumer:

A consumer is a client application that reads (subscribes to) events from one or more Kafka topics. The `ConsumerService` acts as the consumer. It uses a powerful feature to match the dynamic topic strategy: it listens to a `topicPattern` (`"poll.voteChange.*"`) instead of a fixed topic name. This allows it to automatically discover and consume from new poll topics as soon as they are created.

Consumer Group:

A set of consumers that work together to process events from topics. Kafka guarantees that each event in a topic's partition is delivered to only one consumer instance within that group. The FeedApp defines the consumer group ID as "poll-app" in its `application.properties` file. If one were to run multiple instances of the backend service for scalability, they would all share this group ID. Kafka would then automatically balance the load of all the poll topics among them.

Partition:

Partitions are the core of Kafka's scalability. A topic is split into one or more partitions. Each partition is an ordered, immutable log of events, which can be hosted on different brokers. The FeedApp project makes a specific design choice. When the `PollTopicManager` creates a new topic, it is configured with one partition to guarantee strict event ordering for that poll. To match the 3-node cluster's fault-tolerant design, the replication factor is set to 3. This is implemented by calling `NewTopic` with the parameters `(topicName, 1, (short) 3)`. This configuration ensures the single partition is copied to all three brokers, providing fault tolerance and high availability.

Broker:

A broker is a single Kafka server. Brokers receive messages from producers, assign offsets to them, and commit them to the partition log on disk, which provides Kafka's durability. The provided `docker-compose.yml` file defines three distinct broker services: `kafka-1`, `kafka-2`, and `kafka-3`. Each of these nodes is configured with the `broker` role.

Cluster:

A Kafka cluster is a group of brokers working together to provide scalability, availability, and fault tolerance. Partitions are replicated on multiple brokers based on the topic's replication factor. The three brokers (`kafka-1`, `kafka-2`, `kafka-3`) form the cluster. This is where the concept of a replication factor of 3 becomes reality. When `PollTopicManager` creates `poll.voteChange.10` with 3 replicas, that topic's single partition is copied to all three brokers. One broker is elected "leader" for that partition (handling all writes), while the other two are "followers." If the leader fails, a follower is promoted, ensuring no data loss. This entire process is managed by the KRaft controller quorum, which in this 3-node setup consists of all three nodes (`KAFKA_CONTROLLER_QUORUM_VOTERS: '1@kafka-1:9093,...'`).

This part and other parts of the report probably needs to refer to figures. Figure 1 from [1] just illustrates how figure can be included in the report.

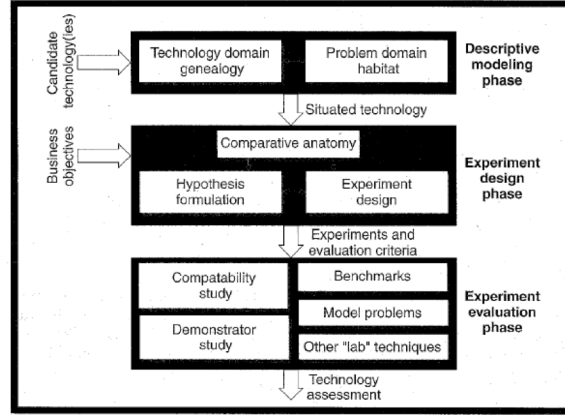


Figure 1: Software technology evaluation framework.

3.1 Descriptive Modeling

write where the technology comes from, its history, its context and what problem it solves. Consider drawing a graph like in [1].

3.2 Experiment Design

Write your hypotheses about what benefits the technology bring and how you can support or reject them via experiments.

3.3 Experiment Evaluation

Write about the results of your experiments, either via personal experience reports, quantitative benchmarks, a demonstrator case study or a combination of multiple approaches.

For some reports you may have to include a table with experimental results are other kinds of tables that for instance compares technologies. Table 1 gives an example of how to create a table.

Config	Property	States	Edges	Peak	E-Time	C-Time	T-Time
22-2	A	7,944	22,419	6.6 %	7 ms	42.9%	485.7%
22-2	A	7,944	22,419	6.6 %	7 ms	42.9%	471.4%
30-2	B	14,672	41,611	4.9 %	14 ms	42.9%	464.3%
30-2	C	14,672	41,611	4.9 %	15 ms	40.0%	420.0%
10-3	D	24,052	98,671	19.8 %	35 ms	31.4%	285.7%
10-3	E	24,052	98,671	19.8 %	35 ms	34.3%	308.6%

Table 1: Selected experimental results on the communication protocol example.

4 Prototype Implementation

This section summarizes how the FeedApp prototype has been implemented, focusing on the core technical components and how developers can run or extend the system.

4.1 Setup and Deployment

The FeedApp prototype runs as a multi-container application orchestrated by Docker Compose with four services: backend (Spring Boot, port 8080), frontend (React/Vite, port 5173), Redis (cache, port 6379), and Kafka (event bus, ports 9092/29092). The backend reads infrastructure dependencies from environment variables: `SPRING_KAFKA_BOOTSTRAP_SERVERS=kafka:29092` and `SPRING_REDIS_HOST=redis`.

To run locally, developers execute `docker compose up -d` and access the frontend at `http://localhost:5173`. The system can be stopped with `docker compose down`.

```
1 backend:
2   ports: ["8080:8080"]
3   environment:
4     - SPRING_KAFKA_BOOTSTRAP_SERVERS=kafka:29092
5     - SPRING_REDIS_HOST=redis
6 frontend: { ports: ["5173:5173"], depends_on: [backend] }
```

The frontend communicates with the backend via REST APIs and maintains a WebSocket connection for real-time push notifications.

4.2 Backend Implementation

The backend uses Spring Boot with a layered architecture: Controllers handle HTTP mapping, Services contain business logic, and Repositories manage persistence. The system supports two persistence strategies via Spring profiles: `HibernatePollService` (JPA/Hibernate for production) and `InMemoryPollService` (for testing). Activate the desired mode with `spring.profiles.active=in-memory` or `spring.profiles.active=database` (for example in `application.properties` or as an environment variable). A `CachingPollService` decorator adds Redis-based caching with Jedis, improving performance for frequently accessed data like poll results.

4.2.1 Authentication and Security

The application implements stateless JWT authentication with BCrypt password hashing. The `/api/auth/login` endpoint authenticates users and returns a JWT token, while `/api/auth/register` creates new accounts. The `JwtAuthFilter` validates tokens on each request, making the authenticated user available via `@AuthenticationPrincipal`.

```
1 // SecurityConfig (rules excerpt)
2 http.csrf(AbstractHttpConfigurer::disable)
3     .sessionManagement(s -> s.sessionCreationPolicy(STATELESS))
4     .authorizeHttpRequests(a -> a
5         .requestMatchers("/api/auth/**", "/rawws").permitAll()
6         .requestMatchers(HttpMethod.GET, "/api/polls/**").permitAll()
7         .requestMatchers(HttpMethod.POST, "/api/polls/*/vote").permitAll()
8         .anyRequest().authenticated());
```

This configuration allows public access to viewing polls and voting while protecting write operations. CORS is configured for localhost development.

4.2.2 Core APIs and Real-Time Updates

The REST API provides two main resource groups: `/api/polls` (CRUD operations, voting, comments) and `/api/users` (profile management with authorization checks).

```
1 // PollController (excerpt)
2 @PostMapping("/{id}/vote")
3 public boolean castVote(@PathVariable Integer id,
4                         @RequestParam Integer presentationOrder,
5                         @AuthenticationPrincipal User user) {
6     return pollService.castVote(id,
7                                 user == null ? Optional.empty()
8                                     : Optional.of(user.getUserId()),
9                                 presentationOrder);
10 }
```

When data changes occur, the backend emits Kafka messages and broadcasts lightweight WebSocket notifications to connected clients:

```
1 // on create/update/delete
2 RawWebSocketServer.broadcast("pollsUpdated");
```

This ensures all clients stay synchronized without polling. Basic unit and integration tests in `backend/src/test`

verify the main flows.

4.2.3 Kafka Integration

Kafka is used as the backend's event bus to decouple write operations from real-time updates and cache invalidation. When a vote or comment is stored, the service resolves a per-poll topic name (e.g., `poll.voteChange.<pollId>`) and publishes a compact JSON event using Spring Kafka's `KafkaTemplate`. A lightweight consumer subscribes to all poll topics using a pattern and reacts by invalidating Redis caches and nudging the WebSocket layer to refresh.

```
1 // ProducerService (excerpt)
2 public void sendEvent(String topicName, Map<String, Object> data) {
3     kafkaTemplate.send(topicName, data);
4 }
5
6 // ConsumerService (excerpt)
7 @KafkaListener(topicPattern = "poll.voteChange.*", groupId = "poll-app")
8 public void onVoteChange(Map<String, Object> event) {
9     // read pollId, invalidate caches, and (optionally) broadcast WS hints
10 }
```

The broker address is provided via `SPRING_KAFKA_BOOTSTRAP_SERVERS` (see Docker Compose). Topics are created or ensured at runtime through a small helper that uses `KafkaAdmin`. See Section 3 for the Kafka assessment and results.

4.3 Frontend Implementation

The frontend uses React with TypeScript, bundled via Vite. Key components include `CreatePoll`, `VoteOnPoll`, `ManagePolls`, `CommentSection`, and `Login`. The application uses a hybrid communication strategy: REST for data operations and a single WebSocket for real-time events.

```
1 // ws.ts
2 export const onWs = (f:(e:unknown)=>void) =>
3     (listeners.add(f), () => listeners.delete(f));
4
5 export function connectWs() {
6     const u = `${location.protocol}=="https:"?"wss":"ws"}://${
7         location.hostname}:8080/rawws`;
8     const ws = new WebSocket(u);
9     ws.onmessage = ev => {
10         try { emit(JSON.parse(ev.data)); }
11     }
```

```
11         catch { emit(ev.data); }
12     };
13 }
```

The App component listens to WebSocket events and selectively refreshes data:

```
1 // App.tsx
2 useEffect(() => onWs(m => {
3     if (m === "pollsUpdated") refreshPolls();
4     if (m === "commentsUpdated") bumpCommentsVersion(activePollId);
5 }, []);
```

When a poll is created, the UI automatically switches to the "Vote" tab and refreshes, allowing immediate verification. A `WebSocketMessages` component displays a rolling log of events for development debugging.

4.4 Extensibility and Future Work

The layered architecture and Spring profiles make the system easily extensible. For example creating an app for iOS or Android would primarily involve building a new frontend that consumes the existing REST and WebSocket APIs. The modular design ensures incremental feature additions without disrupting existing functionality. Security improvements could be made by implementing refresh tokens and stricter CORS policies for production.

5 Conclusions

Concludes on the project, including the technology, its maturity, learning curve, and quality of the documentation.

The references used throughout the report should constitute a well chosen set of references, suitable for someone interesting in learning about the technology.

References

- [1] A.W. Brown and K. C. Wallnau. A framework for evaluating software technology. *IEEE Software*, 13(5):39–49, September 1996.
- [2] Confluent. Kafka topics and producers faqs. Accessed: 2025-11-12.