University of St.Gallen - Exercise Submission

Course Information

- **Course:** Event-driven and Process-oriented Architectures FS2024
- **Instructors:** B. Weber, R. Seiger, A. Abbad-Andaloussi

Deadline

- **Submission Date:** 02.06.2024; 23:59 CET
- **Work distribution**

Final Report

Code

Release

General Project Description

What Services did we implement? Here you can see an enhanced diagram of the flowing-retail application with two additional microservices: Mailing and Factory

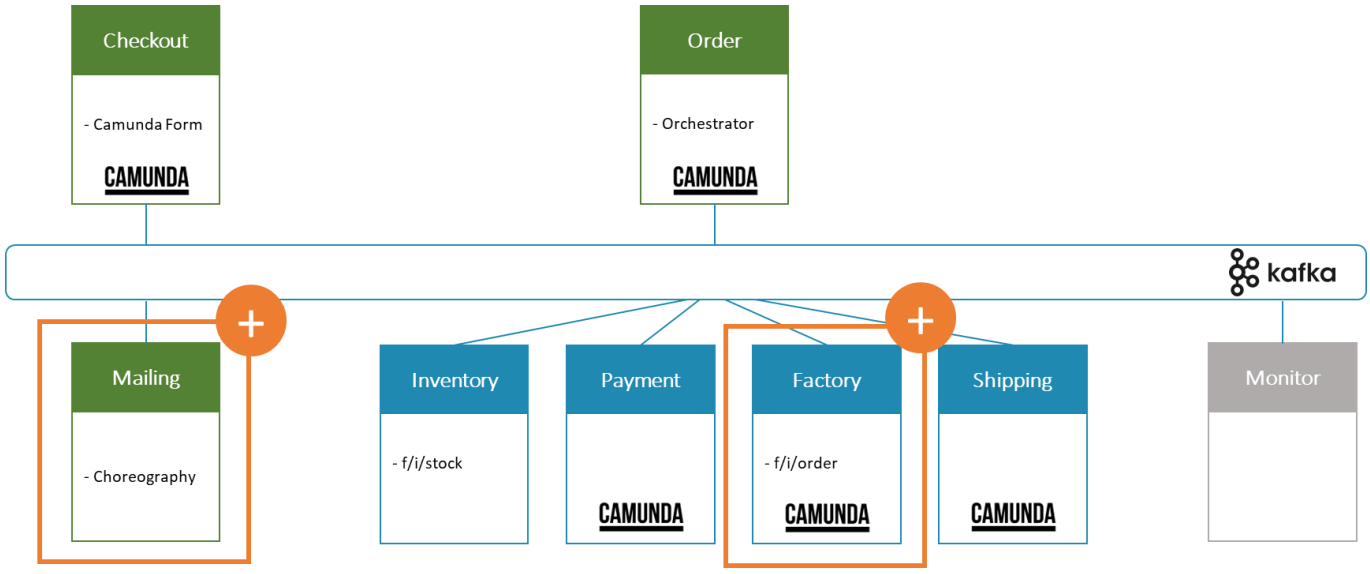
The mailing service is choreographed and is listening to all events happening in the flowing-retail process. Its primary role is to keep our customers informed every step of the way by dispatching timely update emails in response to various events triggered throughout the retail process.

Under the choreography section, we have the Checkout Service, which was enhanced to initiate the flowing retail processing via a camunda form (which you will see in the next slide).

Transitioning to the orchestration aspect of our enhancements, we introduce the VGR, or smart factory service. With this service we ensure that the order's lifecycle is monitored from the factory onwoards. Furthermore, this service actively reacts to order updates and inventory changes within the smart factory setting.

The Services Inventory, Payment, Factory and Shipping are all orchestrated by the order service.

Additionally we enhanced the inventory and factory service with MQTT which is subscribed to the smart factory topics "f/i/stock" for inventory and "f/i/order" for the factory service.



Where does the Choreography end and orchestration start

In our Flowing Retail application, we dip into the rich landscape of service coordination, articulating the nuanced dance between Orchestration and Choreography. The Checkout Service, initiates the sequence of events to start processing the order.

The Checkout Service plays an important role because it embodies the principle of orchestration. When an order is placed, this service takes action, wielding authority over the entire operational process. It is uniquely informed about every step that must be taken, from order validation to final confirmation, ensuring that each phase seamlessly transitions into the next. Because of this high level of semantic coupling, the service knows exactly which process to initiate and manage at each stage, making it essential for carrying out complex, multi-step transactions that require precise coordination and consistency. The orchestration process ensures that each component service, such as payment processing and inventory management.

In contrast, our Mailing Service demonstrates Choreography. Unlike Orchestration, where a central system directs interactions, Choreography entails services acting independently based on event triggers and established protocols. The Mailing Service does not receive direct instructions from a central authority. Instead, it listens for specific events, such as order confirmations, and then performs the task of sending order-related emails to customers autonomously. This decentralization enables a scalable and adaptable system in which services react dynamically to changes and events in the ecosystem. Each service understands its role and interacts with other services through a series of reactive, self-managed actions that contribute to the overall workflow while avoiding centralized control.

This distinction between Choreography and Orchestration in our application provides a solid framework for understanding how various services interact within a complex system, emphasizing the strengths and appropriate use cases for each approach in service-oriented architectures.

Workflow

In the streamlined orchestration of our Flowing Retail application, events and commands work in concert to drive the process flow. Let's dissect the mechanics of this interaction:

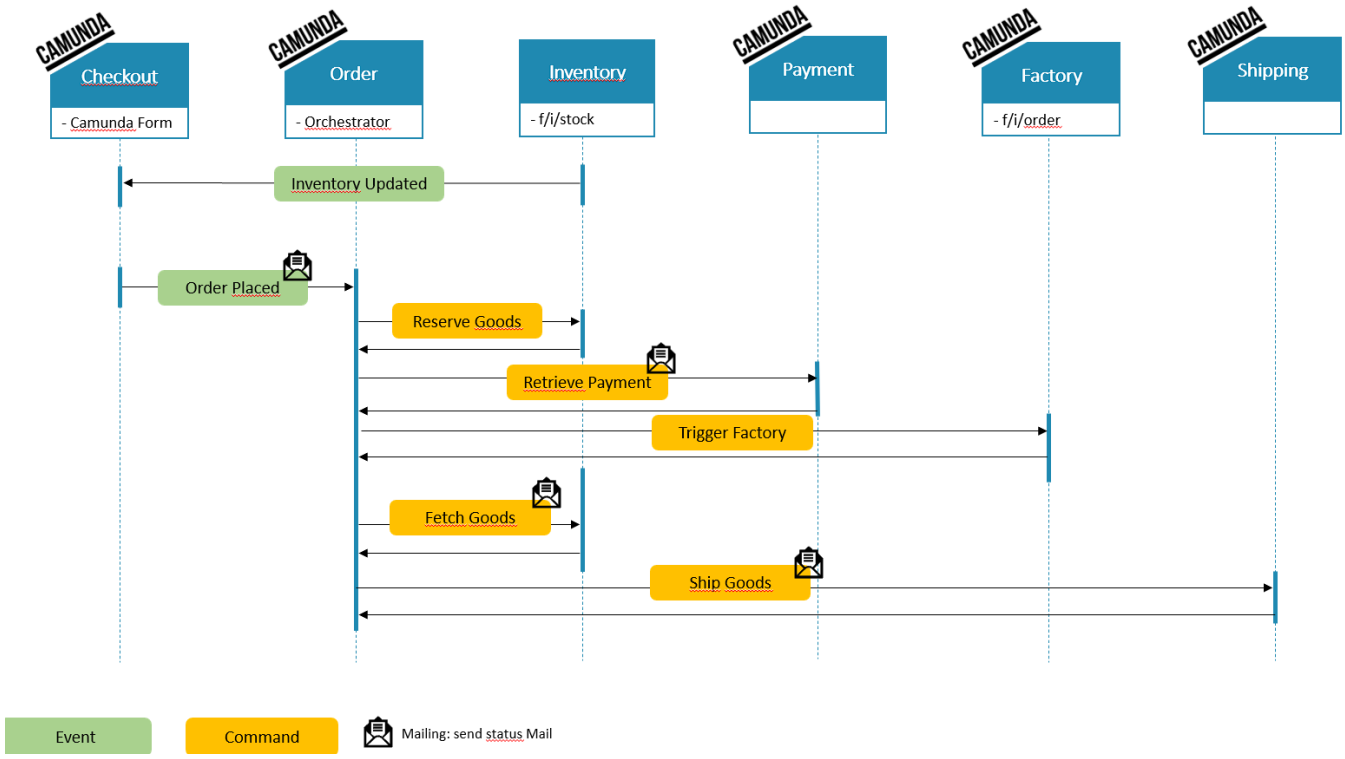
When a customer completes an order, the Inventory service is prompt to respond with the 'Reserve Goods' command, a critical maneuver to lock in product availability and prevent the risk of overselling. This immediate action is taken upon the order placement and is a testament to our system's responsiveness.

The Inventory is subscribed to the 'f/i/stock' topic. When stock levels change, the Inventory service publishes an ' Inventory Updated' event, a beacon to all listening services, including the Checkout service. This service reacts by saving most current inventory status.

Progressing to the 'Retrieve Payment' command, we ensure that our Payment service only proceeds with financial transactions once product reservation is confirmed. It's a sequential safeguard that fortifies the integrity of our process. Once the payment is successfully retrieved, a ripple effect is triggered, culminating in the 'Trigger Factory' command. This signals the Factory to start production

As we near the completion of the order's journey, the Inventory service is once again mobilized to 'Fetch Goods,' arranging them for the final stage - shipping. This preparation is a choreographed prelude to the Shipping service's execution of the 'Ship Goods' command, where products are dispatched to their final destination.

Throughout each milestone of this journey, the Mailing service, ever attentive, dispatches status updates to our customers. This choreographed communication ensures transparency and engagement, turning the order lifecycle into a narrative shared with the customer.



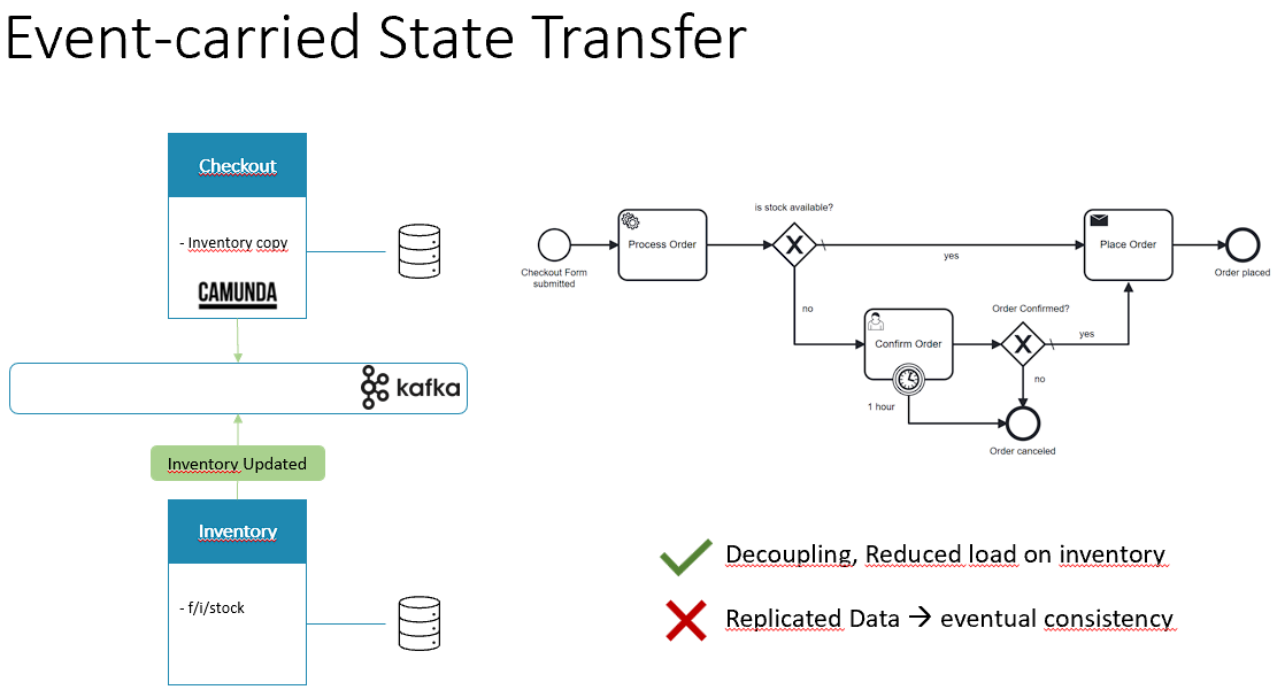
Event-carried State Transfer

Every time there's a change in the inventory levels, the Inventory service broadcasts this information as an "Inventory Updated" event. The Checkout service listens to these events and maintains an up-to-date internal copy of the stock levels.

When a customer submits an order through the checkout form, the service can immediately verify if the requested items are available by checking this internal copy, thus avoiding the need to directly query the Inventory service. This results in a more efficient system with reduced load on the Inventory service and quicker feedback to the customer.

If an item is not available, the checkout process doesn't stop there. Instead, it triggers a user task within the BPMN process that asks the customer to confirm or cancel their order.

The system is designed for eventual consistency, meaning that while the Inventory and Checkout services may temporarily have different views of stock levels, they will synchronize over time as new inventory events are received. This design offers a good balance between system responsiveness and data accuracy



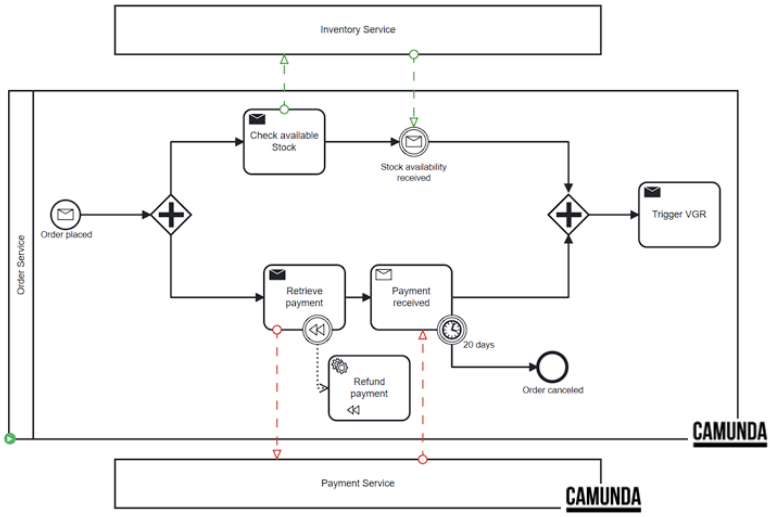
Inventory Service

In the diagram we have the Order Service which starts two activities in parallel. On one side retrieving the payment, on the other side checking and reserving the materials needed for manufacturing.

While on the payment side everything works as expected, the Inventory struggled with message duplication. As you can see on the left, the GoodsAvailableEvent got processed multiple times.

Our preferred solution here was to Implement idempotent processing logic in the Inventory Service.

The Idempotent Consumer pattern ensures that even if the same message is consumed multiple times, the business logic that processes the message only has an effect once.



✓ Parallel Gateway, check the inventory while payment is retrieved

✗ Message duplication

Event Flow

The idea of an Idempotent Consumer is to track received message IDs in the database. The message ID commit happens in the same transaction as any other database writes, making these actions atomic. This will prevent a message being processed twice and ensures data consistency.

Since the Inventory service will also emit an event upon successful processing, we have to ensure reliable message delivery, even in the presence of failures, by integrating an 'outbox' table where messages intended for publishing to Kafka are first stored as part of the business transaction.

A polling loop will continuously check if new messages have been added to the outbox and will eventually send them to kafka and marking them as done.

Given that the inventory service does not use a persistent database, we can simplify those patterns to an in-memory implementation. A Redis DB could be used to scale along multiple instances and ensure persistence across re-starts.

As we can see from the event flow, the GoodsAvailableEvent is now only processed once. The logs show that duplicates are being skipped.

Event flow

Event: OrderPlacedEvent (from Checkout)

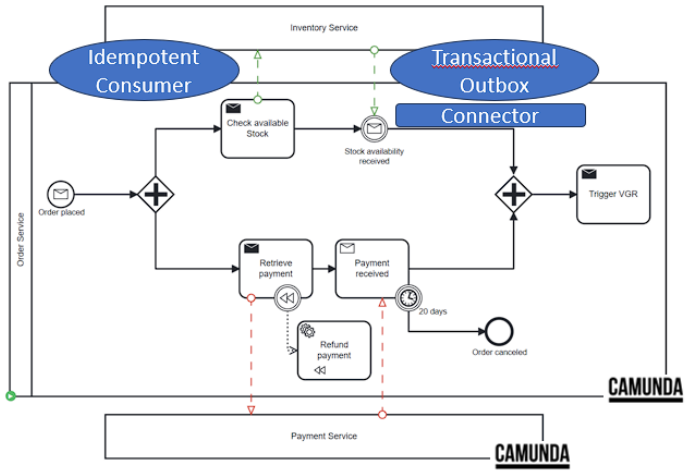
Command: RetrievePaymentCommand (from Order-Camunda)

Event: CheckAvailableStockEvent (from Order-Camunda)

Event: CustomerCreditUsedEvent (from Payment-Camunda)

Event: PaymentReceivedEvent (from Payment-Camunda)

Event: GoodsAvailableEvent (from Inventory)



Received CheckAvailableStockEvent
MessageListener: Check if stock available
Added to outbox: Message [type=GoodsAvailableEvent,
Outbox Poller: Successfully sent message from outbox

Received CheckAvailableStockEvent
Duplicate CheckAvailableStockEvent detected for refId:., skipping processing.

❌ Message duplication
Inventory does not use Camunda

Reflections and lessons learned

One of the most profound realizations from this project was the inherent complexity of distributed systems, especially when integrating multiple microservices that operate on different parts of a transaction. Implementing Zeebe to manage workflows highlighted the importance of clear boundaries and responsibilities among services, which helped in mitigating complexities related to state and event management.

The Power and Pitfalls of Choreography and Orchestration Through the implementation of both choreographed and orchestrated processes, we learned valuable lessons about when to employ each strategy:

Choreography is powerful for decoupling services and allowing for independent scaling and development. However, without a central point of control, it became challenging to handle errors and recover from them uniformly across all services. Orchestration provides a more centralized approach, which simplified some aspects of error handling and made the system's overall behavior more predictable. However, this came at the cost of tighter coupling and potentially reduced flexibility in how services could evolve. Idempotency and Event Deduplication One technical challenge that stood out was managing duplicate messages—a common issue in distributed systems with asynchronous messaging. Implementing an idempotent consumer pattern was essential for ensuring that operations such as inventory checks and updates are performed only once, regardless of how many times a message is received. This not only prevented data inconsistencies but also improved system resilience.

One notable feature of our architecture was the use of Kafka, which, while powerful, frequently felt like a "black box" due to the opaque nature of its internal message handling. This opacity made it difficult to trace and debug issues in our message flows. We worked a lot with system prints to trace our progress and be able to see how we transformed our messages during the process.

Furthermore, significant time was spent refining the business logic within each service to accommodate the complexities brought on by distributed processing and asynchronous communications. This emphasis on business logic, while necessary, diverted attention away from other potential optimizations and improvements

to our system architecture. Consider prioritizing sustainable business logic for future projects. Balancing the application's administrative tasks proved challenging.

Team Collaboration and Workflow

This project also underscored the value of effective team collaboration. Utilizing tools like Git for version control and collaborative coding was indispensable. Regular meetings and clear communication channels enabled timely resolution of issues and helped synchronize work across different parts of the project. Each team member's unique skills were leveraged to enhance the project's overall quality and innovation.

It was interesting to implement a variety of patterns and technologies, such as the Outbox Pattern, Zeebe, and Kafka, to address different aspects of distributed systems design. These experiences deepened our understanding of how to build resilient, scalable, and maintainable systems in a distributed environment. Also to implement BPMN with Camunda 7 and 8 (Zeebe).

This project was not only a technical journey but also a comprehensive learning experience that challenged our understanding of complex system interactions, resilience patterns, and workflow management using modern event-driven architectures. The lessons learned here will undoubtedly influence our future projects and potentially guide our architectural decisions in professional environments.