Design plan for Distributed Systems Fall 20222

Team

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Project Topic

The aim of this project is to create a simple webshop, where the worker nodes updating warehouse inventory are distributed to different geograpic regions. Another theme is to explore a public cloud PaaS (Platform-as-a-Service) service offerring and reference architectures for building a modern, fault-tolerant high-availability system. The public cloud chosen for this project is Microsoft Azure.

Project Technical Description

The webshop we are building has several architectural layers:

- Frontend, a single page app made with React.js and backend functions, hosted in Azure Static WebApps.
- A messaging layer that frontend calls, which distributes frontend messages for the worker nodes. It also distributes events from worker nodes to other worker nodes. Azure Event Grid is used as messaging service.
- Backend layer that consists of the geographically distributed worker nodes hosted in Azure Serverless Functions.
- Data layer emulating a warehouse. Data will be stored in an nosql-database and worker nodes use a simple DB API to fetch and update data from DB. The database will also host separate data stores for each worker node, where they store their individual state of events completed by all nodes.
- Logging is handled by Application Insights, where all the functions will be connected.

Nodes

Worker nodes are responsible for querying and updating data in warehouse database, and simulate a high-availability scenario where the nodes have been deployed to different geographic regions in Azure cloud. They subscribe to Event Grid Topics where messages from Frontend are pushed into, consume messages with HTTP trigger functions that execute a specific task.

As we are dealing with a high-availability scenario and services in different Azure regions are notoriously wobbly (not really, but we can simulate this by turning off functions), we also need to implement fault tolerance to the nodes. Event Grid does not care what happens to a message after it's consumed, so the worker nodes must each keep note what was the last message it consumed and wheter that execution was succesfully completed. If not, it needs to consume the message again. This is also implemented via the Event grid Topics; each node push notifications on succesfull transactions to Event Grid, where other nodes consume the notifications and store them locally (though we probably implement these local states as just separate collections in the shared database).

Messages

The frontend implements three different API calls: GET all the items and their current quantities, GET the current quantity of a certain item, and UPDATE the quantity of a certain item.

Azure Event Grid Event schema describes the full event schema and an example of custom event we are using would be:

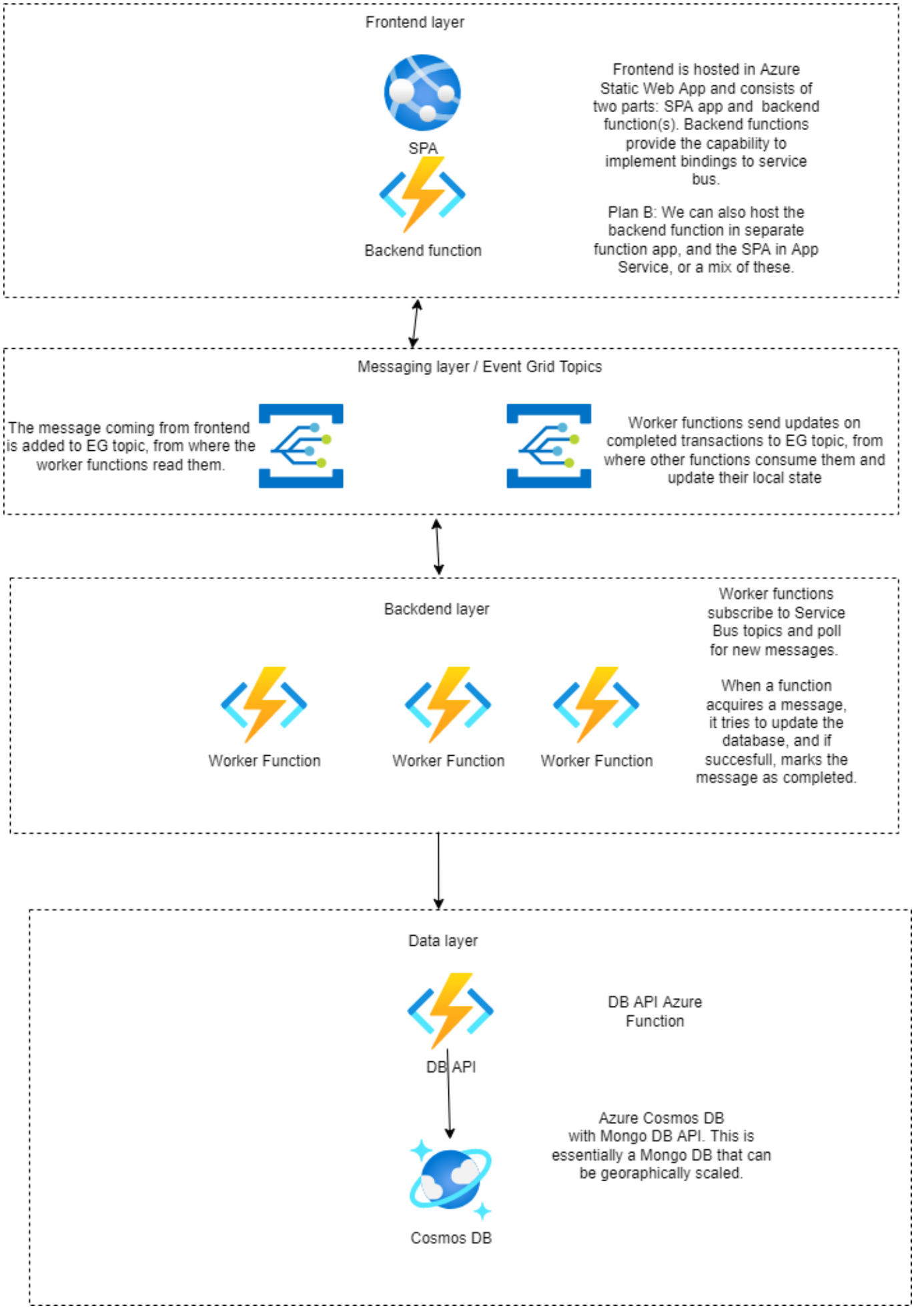
```
[{
  "id": "1807",
  "eventType": "recordUpdated",
  "subject": "warehouse/products/orange",
  "eventTime": "2017-08-10T21:03:07+00:00",
  "data": {
    "products": [
      {
        "id": 1,
        "ean": 1111,
        "name": "Orange",
        "saldo": 5
      }
    ]
  },
  "dataVersion": "1.0",
  "metadataVersion": "1",
  "topic": "/subscriptions/{subscription-id}/resourceGroups/{resource-
group}/providers/Microsoft.EventGrid/topics/{topic}"
}]
```

Where *data* element describes the actual payload of the event message.

An event sent by the worker node completing the previous event would be:

```
[{
  "id": "1808",
  "eventType": "transactionCompleted",
  "subject": "webapp/workers/transactions",
  "eventTime": "2017-08-10T21:03:08+00:00",
  "data": {
    "transaction": "1807",
    "status": "completed",
    "timestamp": "2017-08-10T21:03:07+00:00"
  },
  "dataVersion": "1.0"
}]
```

Some Architectural choices


Frontend layer
SPA
Backend function
Frontend is hosted in Azure Static Web App and consists of two parts: SPA app and backend function(s). Backend functions provide the capability to implement bindings to service bus.
Plan B: We can also host the backend function in separate function app, and the SPA in App Service, or a mix of these.
Messaging layer / Event Grid Topics
The message coming from frontend is added to EG topic, from where the worker functions read them.
Worker functions send updates on completed transactions to EG topic, from where other functions consume them and update their local state
Backdend layer
Worker Function
Worker Function
Worker Function
Worker functions subscribe to Service Bus topics and poll for new messages.
When a function acquires a message, it tries to update the database, and if succesfull, marks the message as completed.
Data layer
DB API
DB API Azure Function
Cosmos DB
Azure Cosmos DB with Mongo DB API. This is essentially a Mongo DB that can be georaphically scaled.

Frontend

Frontend is hosted in Static Web Apps, which actually offers hosting of two different services: the single page app and and backend functions (which are just Azure Functions deployed into the Static Web App resource). In this case, it is easier to create the bindings for Event Grid in the function code than it is in the SPA.

Azure Static Web Apps Overview

Plan B for frontend is to implement direct Event Grid bindings to SPA.

Messaging

Azure offers two separate messaging services that could be used to distribute messages to worker nodes: *Event Grid* and *Service Bus*. Event Grid is the simpler of the two as it is meant only to distribute events that other services react to, and it does not really care who reacts or acts on the messages. Service Bus, on the other hand, would be used in a real high availability scenario.

For this project, we chose Event Grid as messaging middleware, as we want to implement both messaging between frontend and database (via the backend nodes) and messaging between nodes through the same middleware.

Event Grid vs Event Hub vs Service Bus
Azure Event Grid

Plan B for messaging layer is to implement Service Bus queues for same use cases.

Worker nodes

Worker nodes are implemented as serverless Azure Functions, which are stateless (unless we really really need stateful functions). Functions subscribe to Event Grid topics, and are triggered by incoming events. While the functions are stateless in technical sense, they do store every event they complete in their own database collection. We then either implement a logic for re-trying to execute an event which was consumed, but not succesfully executed, or a logic where every worker checks if an event was already executed by another node, before executing it by themselves.

Note: This will probably lead all kinds of interesting synchronization issues, but solving those is probably the meat of this exercise anyway. If solving these becomes too hard, we can always utilize plan B and use Service Bus.

Requirement mapping for nodes

- Running on a separate computer / virtual machine: We create each function as it's own resource and deploy them to separate Azure Regions.
- have its own IP-address: See naming and node discovery below.
- communicate with at least two other nodes only by using Internet protocol based message: At least 3 nodes that communicate via events (see event schema above) exchange
- be able to express their state and/or readiness for sessions towards other nodes: Publishing and subscribing to events on which node has completed which frontend event should be sufficent for this.

Plan B for worker nodes is to implement them as full nodejs applications running in Azure App Service (each with it's own App Service Plan or web server, as they are deployed to different regions).

Data layer

Data layer is implemented as Azure Cosmos DB database with MongoDB API, and a simple DB Api service implemented in Azure Function. Cosmos DB would permit us using a distributed data layer, but that is an advanced topic that can be explored if time permits (then the obvious choice is to use Azure CosmosDB and distribute it to same geographic locations where worker nodes are, and play with the consistency levels).

Plan B for data layer is some simpler Azure-hosted nosql database.

Required Functionalities

Shared Distributed State

This is implemented in the worker nodes and in it's simplest it is logging of the events received (from frontend) and executed by the worker, which could then be used for re-consuming an event that was not succesfully executed. The state needs to be stored somewhere, and the easiest option would be just to store the state in database.

One option would be to implement a pattern, where every consumed message is stored into an Azure Storage Account by the function reading the events/queue, and another function would consume the event/message and perform the actual action against the database. But this feels like too complicated approach for this project.

Naming and Node discovery

Azure Functions are assigned an unique url of (resource name).azurewebsites.net, and in case of functions directly messaging each other, we can store a list of the function urls and form a complete url of a function call by combining the address and path to a speficic function like https://myworkernode1.azurewebsites.net/api/helloworld.

A more refined way of handling the intra-node messaging would be to just implement an Event Grid or Service Bus topic where the nodes are registed as message consumers, but not sure if this would be considered as a discovery of nodes.

Third option would be to create a public or private DNS zone and create DNS records with a friendly name; using a private DNS zone would require creating a virtual network and configuring the services to use it (with Event Grid having some limitations) and would likely be too time consuming approach for this project.

Synchronization and consistency

Using Event Grid as messaging layer requires us to implement these in some form (using Service Bus would probably solve them for us), so we need to implement an Event Grid Topic through which nodes communicate which frontend events they have completed.

Consistency could be implemented by distributing the data layer as described in the Data Layer above. Using an eventual consistency mode of Cosmos DB would probably lead to implementing all kinds of interesting synchronization things into the worker nodes, as the database shards in different geograpchies might hold an entirely different opinion of what amount of which item is available at any given time (not a really realistic scenario, but whatever).

Fault Tolerance

Same as above; with Service Bus, a lot of the fault tolerance issues are handled by the messaging service. With Event Grid we need to implement node-to-node communication. So our fault tolerance approach is to ensure that every event is executed at least once by implementing a re-execution if no node has a succesful execution of a certain event in their local state.

We deploy the worker node to different Azure regions, which gives us some fault tolerance in the technical sense (Azure Regions usually have three separate datacenters, so our nodes are covered for major outages, which should be enough for this project - no need to go full High Availability here, we hope).

Consensus

Given our scenario, implementing some kind of joint decision -making -mechanism does not really make sense. We might be able to implement something if we decide that nodes handle the re-tries of failed events - they might decide between themselves if they agree that a certain event has not been processed and which node would then re-consume the said event.