International Journal of Pure and Applied Mathematics
Volume 120 No. 4 2018, 573-581
ISSN: 1311-8080 (printed version); ISSN: 1314-3395 (on-line version)
url: http://www.ijpam.eu
doi: 10.12732/ijpam.v120i4.8

CLOUD-BASED ARCHITECTURE OF DISPEL

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Abstract: We present a new architecture of the Distributed e-Learning Platform (DisPeL) for the Cloud using Microsoft Azure. The goals of the new architecture are new features, improved scalability, performance and gradual migration with support for a mixed model – integration of the cloud-based system with existing on-premises systems. We have developed a proof-of-concept implementation using Microsoft Azure technologies.

Key Words: DisPeL, eLearning, cloud, cloud-based architecture

1. Introduction

The Distributed platform for electronic learning – DisPeL enables the conduct of a complete learning process from organization of the learning process to assessment and completion of the learning [1]. DisPeL is used to create a wide range of courses in information technologies and economics [2]–[9].

Starting with its very initial design, DisPeL has always been oriented towards the cloud. Recent years the large cloud providers such as Amazon, Microsoft and Google are constantly introducing new services and improving the existing ones. This empowers developers create more powerful and feature-rich applications.

Received: February 3, 2018
Revised: February 24, 2019
Published: February 25, 2018

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This paper describes a new version of the architecture of DisPeL, which utilizes some of these new cloud services. The goals before the new architecture are:

1. Add new services to DisPeL, based on cognitive services and cloud-powered searching.
2. Extend DisPeL with database analytics and reporting services.
3. Improve performance and scalability.
4. Modernize the technology stack.

1.1. New Services

With the new architecture we extend DisPeL with three new services:

1. Multi-lingual learning content
2. Extensive reporting and data analysis
3. Cloud-powered searching

DisPeL can automatically translate the authored learning content of the adaptive textbooks – one of the core instruments of DisPeL, which provide students with personalized learning process based on their performance and via the personalization features such as notes and highlighting [1]. Translation targets the content of text book, and not the custom notes. Translation is performed via Microsoft Azure Cognitive Services, namely Translator Text [10]. Thus, foreign students may opt to access the learning content in a more preferred language, while tutors can address wider audiences.

DisPeL now integrates with Microsoft PowerBI [11] to provide interactive dashboards and reports for the tutors and the administrators of the learning process. Tutors have better means to monitor the progress of the learners and analyze their performance based on various dimensions – time, learning content chapters, course projects and homework assignments, and self-assessment results.

Last, we improve searching of content by moving from full-text catalogues towards cloud-based searching using Bing Search, now part of Azure Cognitive Services [12].

1.2. Performance and Scalability Improvements

In the first version of DisPeL every request for learning content was effectively redirected to the central database. Although server-side caching was implemented, it turned out inefficient, because most of the time learners requested different content. Another issue was the centralized data storage. All data and resources were stored in a single relational database, which becomes a performance bottleneck and prevents horizontal scaling.

With the new architecture, we allocate storage over different services – relational storage, blob storage for the learning content, reporting storage. We also extend caching by putting static learning content on a CDN.

1.3. New Technology Stack

Technological updates are vital for every software to guarantee maintainability and prospects for new features. The first version of DisPeL was based on Microsoft NET Framework, version 4. Business logic was exposed using SOAP and RESTful web services. In the new version, we chose to migrate the project to NET Core 2.1. Our decision is motivated by the clearer roadmap of NET Core, the fast pace of development of the platform, the higher performance of version 2.1 and the cross-platform support [13]. At the same time, NET Framework 4.x is exhibiting slowing progress, especially when it comes to web development. Further, new services on Microsoft Azure, like Azure Functions, are moving from NET Framework towards NET Standard.

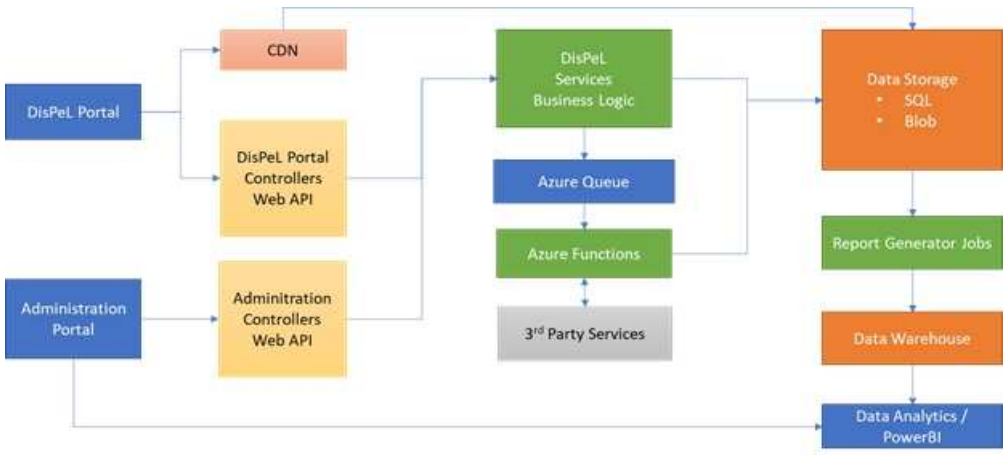
2. Cloud-Based Architecture

2.1. Diagram

2.2. Components

DisPeL Learning Portal

DisPeL Learning Portal (LP) is a web-based application, used by learners and tutors to interact with DisPeL in the process of e-learning. The services of the LP are described in [1]. The Learning Portal is designed as single-page application (SPA). It is implemented using a combination of Angular 4 [14] and a proprietary SPA framework based on jQuery and vanilla JavaScript. The latter is used because we wanted to keep some of the existing code base and



reduce the development efforts at this stage. The LP is backed by the Learning Portal Web Api component and the CDN service.

CDN Service

The CDN service is used to store common resources, such as elements and libraries of the user interface. We extend this to include also learning content. The learning content is generally less susceptive to dynamic changes. At the same time, the volume of the learning content amounts to most of the network traffic in DisPeL. Having the learning content on CDN reduces the load of the backend of the Learning Portal.

We use token authentication [15] to secure the access to the learning content only through DisPeL Learning Portal.

Administration Portal

The Administration Portal is a web-based SPA application for the administrators of the learning process. It is built using Angular 6. It is backed by the Administration Portal Web Api component and the PowerBI [11] services from Microsoft Azure. Technically, it supports both forwarding to Azure PowerBI Pro portal and integration of PowerBI embedded. PowerBI Pro is a choice when the goal is to reduce the costs, while PowerBI embedded is preferred option for a more fluid experience and higher workloads.

Learning Portal Web Api and Administration Portal Web Api

These layers provide a REST API for the Learning Portal SPA and Administration Portal SPA respectively. They serve as an integration point between the Business Logic Services and the SPA. They provide data caching, data

transformation, user login and user session management.

DisPeL Services Layer

This layer implements the actual business logic of DisPeL.

The services are exposed as REST API end-points. Input and output data are in JSON format. This allows the services to be consumed from any type of applications – web, mobile, desktop, and business-to-business solutions.

The layer is implemented as a monolithic service. A micro-service approach was considered and rejected. The usage pattern of DisPeL involves substantial read access to data and little data updates. Therefore, caching is sufficient to achieve the required performance of the system. A microservice approach would have resulted in a very complicated data replication model, which will increase the costs for setup and maintenance of the system.

DisPeL Services Layer achieve integration with 3^{rd} party services using serverless functions and message queues. The Business Layer creates new integration tasks by adding messages to the message queue. The Service Layer has serverless functions which are bound to the message queues and are automatically invoked when new messages arrive. At this version, DisPeL only uses translation services to provide learning content in other languages. The translation function performs the following actions:

1. Extract the original learning content.
2. Create HTTP requests to the third-party services and namely Azure Cognitive Services. Translations into multiple languages are possible and performed concurrently.
3. Stores the translated content into the primary data storage.
4. Notifies the system that new learning content is available, so that it can update its caches.

We use Azure Durable Functions to orchestrate this workflow. We achieve concurrency by fanning out the workflow at point 2, to funnel it back at point 3.

Using serverless functions allows better utilization of available resources and reduced costs. The 3^{rd} party integration services are generally small pieces of code, they are used must less than the other parts of the system, and they are not required to yield results immediately. Using functions reduces the number of web service applications and endpoints that DisPeL needs to maintain.

Data Storage

We use a combination of a relational database and blob storage. The relational database stores data about learners, tutors, administrators, courses, course structure and program, general data for homework assignment, homework results, and examinations. The architecture supports hosting the relational database both on the cloud, or on premises.

The learning content and homework assignments are stored in the blob storage. The system is configured to automatically update the CDN cache when new data is stored in the blob storage. Such setup would require complicated maintenance and administration costs, therefore, at this version of DisPeL, we support only cloud-hosted blob storage services like Azure or Amazon.

Data Warehouse

We use a specialized relational database storage for pre-calculated data for reports. This specialized storage contains only the important data dimensions, facts and pre-aggregated values. The reduction of data and pre-calculated values has several benefits: 1) simplified reports which focus on presentation, not on business logic; 2) denormalized, easy to understand data for data analysists who can further process the data in Microsoft Excel; 3) reduced data volume, which enables the use of a more price-efficient storage service; 4) pre-calculated values simply reports and dramatically increase the performance.

The data warehouse storage can be hosted on the cloud, or on premises. The latter option, however, has a significant impact on the requirements for the data analytics services and PowerBI. Using PowerBI with an on-premises database requires additional software to be licensed and installed [16]. Therefore, to optimize costs, we plan for the data warehouse storage to be on the cloud on a dedicated service tier of lower pricing.

The Report Generator Job is a scheduled job, designed to run on premises, on a cloud-hosted virtual machine. The job runs once a day, usually at night when the general usage is low. It transforms the data from the primary relational database into the warehouse structure, performs the aggregations and stores the results. The Report Generator Job is implemented as a Windows Service application using NET Full Framework 4.6. The ETL tasks are implemented in C# and SQL. The use of a cloud-based ETL solution like Azure Data Factory is avoided because of its costs.

3. Technologies

As previously noted, DisPeL was originally developed using Microsoft NET Framework 4 – ADO.NET, Entity Framework, Windows Communication Foun-

dation (WCF), and ASP.NET.

Business logic was exposed using SOAP and RESTful web services. While SOAP services provide a solid model for reliable messaging and error reporting, they are difficult to be consumed by mobile and SPA applications. In the new version of DisPeL, we redesigned the API of the business layer to operate using RESTful web services and exchange data using JSON.

The technology stack for the new version of DisPeL includes:

- Microsoft NET Core 2.1
- Microsoft NET Standard 2.0
- ASP.NET WebAPI
- Angular 6
- HTML5 / CSS
- Microsoft SQL Server, and Azure SQL Database

The only exception to NET Core is the Report Generator Job. NET Core doesnt support Windows-specific features like Windows Service applications. To guarantee easy migration to NET Core in future, we developed all the functionality of Report Generator Job as a NET Standard 2.0 class library, and only did the application skeleton in NET Framework 4.6. In future we will be able to quickly implement the Report Generator Job as another type of application, supported by NET Core.

3.1. Azure Functions

The server-less functions are developed using C# and NET Standard. We use C# due to the better tooling and fast function start [17]. NET Standard, on the other hand, allows us to use NET Core 2.x with all its improvements; the version 2.x runtime runs on .NET Core 2, which enables it to run on all platforms supported by .NET Core, including macOS and Linux. Running on .NET Core enables cross-platform development and hosting scenarios. By comparison, the version 1.x runtime only supports development and hosting in the Azure portal or on Windows computers [18].

3.2. Azure Translation API

DisPeL 2.0 is build to use version 3.0 of Azure Translator Text API. Microsoft Translator API is a neural machine translation service that developers can easily integrate into their applications websites, tools, or any solution requiring multi-language support such as website localization, e-commerce, customer support, messaging applications, internal communication, and more. It uses Neural Machine Translation (NMT), which Microsoft appoints as the new standard for high-quality AI-powered machine translations. It replaces the legacy Statistical Machine Translation (SMT) technology that reached a quality plateau in the mid-2010s [19].

Version 3.0 of the API supports JSON in addition to XML-based responses.

4. Conclusion

The new version of DisPeL is an evolutionary improvement in three aspects. First, we target better scalability. Second, we extend DisPeL with cognitive services like automatic translations and searching. Third, we provide advanced reporting instruments via dedicated reporting databases and PowerBI.

Acknowledgments

This paper is partially supported by the National Scientific Program "Information and Communication Technologies for a Single Digital Market in Science, Education and Security (ICTinSES)", financed by the Ministry of Education and Science.

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