A secure infrastructure for mobile blended learning applications

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1. ABSTRACT

New trends like The Internet of Things, Wearables and BYOD pose new challenges to existing IT infrastructure and applications. Especially the increasing amount and heterogeneity of devices demands changes on existing IT systems. Further degrees of automation are required to successfully operate existing IT infrastructure and applications. Many students try to individualize the existing services using own software. These changes in student behavior have led us to the creation of an infrastructure designed for secure mobile access. After three years of operation this infrastructure has evolved to deliver far more than only access to legacy systems and is now supporting several blended learning scenarios and other university processes.

2. MOTIVATION

Due to increased mobility and the rising number of students the universities have to standardize existing processes, improve cooperation between institutions, reduce overall costs or increase efficiency. Also the students have changed the demands on their universities and its employees. Previously various processes that are supported by IT infrastructure and applications were introduced to serve this purpose. Not only are IT infrastructure and applications becoming more important to the universities' processes and employees but also the students and their daily life. This leads to increased competition among the universities to present the best and most appealing services to their students.

The Horizon Report is one of the most regarded studies concerning the development of education. In the 2015 report (The New Media Consortium 2015 – The NMC Horizon Report, 2015) the upcoming major developments in the higher education sector are identified as follows:

- Less than a year:
  - Bring Your Own Device (BYOD)
  - Flipped Classroom
- Two to three years:
  - Makerspaces
  - Wearable Technology
- Four to five years
  - Adaptive Learning Technologies
  - The Internet of Things

Both, these developments and the organizational challenges need to be faced by the universities IT infrastructure and applications in the near future to remain operational and meet the expectations of governments, employees and students.

The technical challenges of increasing device heterogeneity and count is accompanied by an increasing urge of individualization. Especially students from technical fields seek to customize, improve and extend the existing means for their personal scenario. Leaving the individualization of certain IT applications to the users themselves may reduce efforts when developing the applications in first place but also needs defined processes, guidelines and interfaces that allow controlled access to the needed data in a machine readable way for every student.

3. GOALS

To better cope with the latest development and fast changing requirements, increased mobility and higher degree of personalization Service Oriented Architectures (SOA) are widely used. However due to the broad fields of application of SOA during the past years a multitude of incompatible standards, formats and architectures have been developed and are now part of virtually any application framework. While choosing the right SOA is a critical step for the short term success it is most important to build a comprehensive and consistent model of the data exchanged between the systems. To generate this common model several processes at the university need to be analyzed in how they use the available data.

In any software system if it is a SOA or a more traditional monolithic architecture a central asset of the collected data is reliability. While in a monolithic environment reliability of the data may be controlled centrally in a SOA other assertions have to be provided. In terms of data security there are three key concepts: confidentiality, integrity and availability. As the SOA will participate in a multitude of processes these need to be strictly enforced by the architecture (security by design). Further security and reliability needs like authenticity, non-repudiation, accountability or anonymity should also be included into the design of the architecture.

According to the need for reliability and security of the owners and curators of the data, the protection of personal data needs to be enforced. By extending processes and sharing data across system boundaries, data will be accumulated to datasets and may become available to a broader audience. Especially for personal data the general right of personality needs to be protected.

4. CURRENT ARCHITECTURE

Generally the infrastructure was designed to combine different existing source systems already used by the students and university staff for E-Learning, Campus Management, Identity Management and other purposes (Politze & Decker, 2014). Data preparation and data consolidation between these systems and attached apps is done utilizing existing standards: REST, SAML and OAuth2. The data is then rendered on the smart device using client technologies like the Cordova Framework.

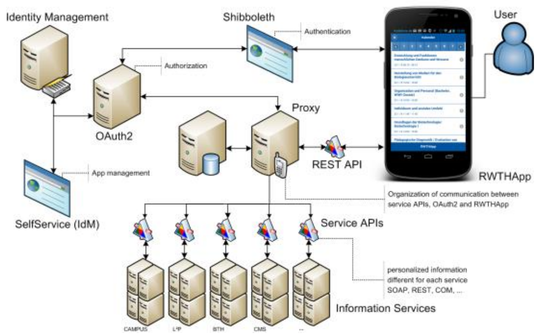

Figure 1 Schema of the Proxy service accessing legacy systems.

The infrastructure designed for RWTHApp consists of two main services shown in Figure 1: (1) The Proxy service forms the central component to make data from legacy systems accessible from smart devices in a secure and consistent fashion. (2) The authorization service (OAuth2) that handles the consent of the users to access their data in the legacy systems.

From an architectural point of view the Proxy service is primarily intended to deliver data to smart and mobile devices. Nevertheless some more traditional web applications are also already taking advantage of the centralized implementation of the services. Even though the Proxy Service centralizes the access to legacy systems it is built using some of the paradigms introduced by micro services: primary the independence of functional units to access the independent legacy systems.

These functional units are then centrally published and appear as a single web service instance using consistent access and naming conventions.

The design of the proxy service also tries to increase availability and speed of the legacy systems by introducing automated and semi-automated caching layers. To increase overall performance and user experience the cache is filled with information a priori using a probabilistic, proactive model to predict future web service calls. For the proactive caching system, all requests are divided into separate user sessions which form an item set. Such an item set then contains all requests made by a single user on a single device within a certain time frame. Association rule mining is then used to find patterns.

The OAuth2 protocol allows secured, personalized access to the web services and handles the authorization from the user without supplying credentials to the app itself. This also paves the way for third party developers accessing the proxy service.

To access the API third party developers have to perform a simple registration process. During this process apart from a contact name and email address the developers have to supply the use cases their app covers and what data is needed from the API to perform these tasks. The register of all applications is publicly visible to all users. The OAuth2 process can then be used by other developers to provide additional functionality that is not covered by existing IT systems and applications themselves.

Furthermore the implemented OAuth2 system is capable of handling authorizations for multiple attached services and therefore cannot only be used for the Proxy service but also for other services running in the university context. Allowing not only the reuse of already established infrastructure but also use OAuth2 authorization for inter process communication.

5. CASE STUDIES

In the field of E-Learning next to a centralized Learning Management System (LMS) several distributed systems are used for additional processes. Thanks to the efforts in the RWTHApp project most of these have been extended by an interface to allow exchange of data across process and system boundaries. Furthermore there is a trend to develop applications for smart and mobile devices supporting very specific blended learning settings. These settings are quite unique it is usually not desired to embed the functionality within RWTHApp.

One of these applications was created by the Department of History at RWTH Aachen University: an interactive guide through archeological sites in the vicinity of Aachen. To support this application a set of flexible and available services is needed. Figure 2 depicts a web interface built upon Microsoft SharePoint that allows the users to compose articles and enrich those using media files such as images and videos. A WYSIWYG editor that renders the articles as they appear on the mobile device is used to conveniently edit the articles. Figure 3 shows a prototype of the mobile application accessing the articles from SharePoint. The integration of SharePoint into the mobile service infrastructure allows simple applications to profit from advanced editing and document management abilities of the platform.

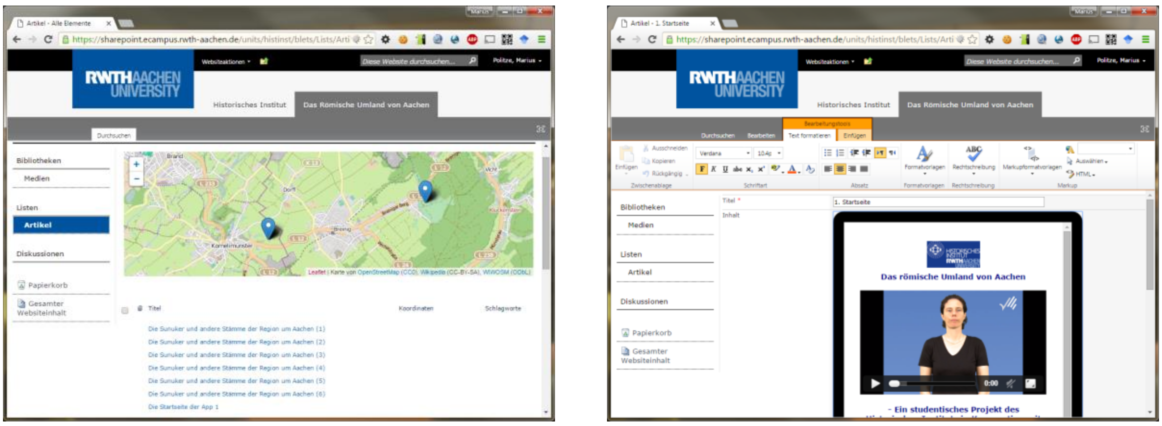

Figure 2 Articles and media can be entered and managed using WYSIWYG editors.

Figure 3 Prototype of the app articles and interactive maps.

Another successful blended learning scenario is the audience response system (ARS) that was developed as part of RWTHApp. In contrast to previous cases completely new processes were implemented both in the application and in the server infrastructure. The ARS supports a variety of different settings and can be used by every teacher at the university according to their wishes (Politze M. , Decker, Schaffert, & Küppers, 2015). Among text and photo messages teachers have the ability to initiate polls. Based on the existing infrastructure the ARS will be further extended to allow more interactions with the students for example using prepared quizzes from the E-Learning system already connected to the infrastructure.

The simple integration of external processes is of course not limited to mobile devices. Using the defined interfaces it is possible to register students into E-Learning course rooms in an automated way. This paves the way for decentralized distribution of classes. This was especially helpful for organizations within the university that do not participate in the regular curriculum (e.g. language classes) but distribute the students manually to the offered classes. Instead of setting up a dedicated LMS using this degree of automation afar from the default use cases allowed the usage of the centralized solution.

The OAuth2 system further allows integration of external systems into the LMS. The external systems are embedded into the LMS website. With an OAuth2 access token these systems can then access the LSM in the context of the current user. This allows external systems that are mainly implemented by the different institutes for their specific teaching scenario to integrate seamlessly and to work with the data stored in the centralized LMS.

To reduce the impact of the security vulnerabilities of Eduroam discussed in (Brenza, Pawlowski, & Pöpper) the creation of device based credentials for Eduroam was also implemented on the infrastructure for mobile services, even though not a blended learning scenario. This risk mainly originates from the fact that Eduroam credentials, that can be retrieved using a man in the middle attack, are mostly the same credentials as for other university services. To reduce the risk of identity theft, credentials can be generated per device and are therefore not usable to access other university services (Decker & Politze, 2015). While the generation of credentials and set up of Eduroam on the device currently requires several manual steps the service endpoints to generate device based credentials have been added to the infrastructure for mobile services. This allows in a future version to automate the setup process using an app directly on the mobile phone.

6. RELATED RESEARCH

Various research groups and projects reduce complexity building SOA by modelling and try to find iterative or partial solutions to some facet of the aforementioned challenges. Generally there are three main areas that contribute with their work to the complex: (1) Business Process Management and (2) Software Architecture delivering general approaches for SOA and (3) Pervasive University delivering more specific insights into the applications at universities.

To overcome the gap between modelled processes and the supporting software Zimmermann et al. propose an integrated service oriented architecture (SOA) that allows adoption to changing business processes and needs (Zimmermann, et al., 2013). Even SOA that are modelled using the same architecture may still be incompatible. This also led Taheriyan et al. to propose a method to integrate traditional SOA with each other using linked data (Taheriyan, Knoblock, Szekely, & Ambite, 2012). Rathfelder et al. introduce a method to evaluate the maturity of a SOA. This model does not only evaluate the technical maturity but also considers the organizational domains like organizational structure, development and governance processes (Rathfelder & Groenda, 2008).

However more specific SOA for smart and mobile devices are being developed. These focus on technologies like web services and cloud infrastructure to compete with the growing and changing market. Micro service architectures as proposed by Namiot et al. are used to reduce dependencies in the software development process often found in monolithic applications (Namiot & Sneps-Sneppe, 2014). Schleicher et al. show that an additional dependency is introduced as virtualization and cloud environments pose different requirements to the deployed software (Schleicher, Vogler, Inzinger, & Dustdar, 2015). While SOA have solved some of the challenges that come up with the increasing number of smart and mobile devices there are still legacy systems that were not designed using SOA. As remarked by Serrano et al. the existing legacy systems are usually not well documented and too expensive rewrite. Therefore it may be desirable to wrap existing systems with a service layer (Serrano, Hernantes, & Gallardo, 2014).

Especially the fields of Education and Research (E-Learning and E-Science) are in focus of several research groups and projects. Barkhuus and Dourish have discussed the different needs of students related to ubiquitous services offered by their university (Barkhuus & Dourish, 2004). While the technological basis has severely changed since the study in 2004, the social roles, relationships and responsibilities of the students are mostly comparable. Juling describes that mobility and ubiquity of information technology and therefore global accessibility, reachability have become part of our daily life (Juling, 2009). Lucke and Tavangarian introduce a model for the pervasive university that takes the heterogeneous existing systems in the field of E-Learning into account (Lucke & Tavangarian, 2009). This model was later extended with a concept to integrate multiple context aware E-Learning services (Lehsten & Tavangarian, 2013). The works of Mincer-Daszkiewicz and Barata et al. show two practical examples of SOA in the field of E-Administration (Mincer-Daszkiewicz, 2014) (Barata, Silva, Martinho, Cruz, & Guerra e Silva, 2014).

7. LESSONS LEARNED

With three years of experience in running an infrastructure for mobile access and blended learning scenarios several conclusions and recommendations can be derived. First of all we could observe tremendous interest by the students but also by employees of the university who wanted to tailor existing systems to fit into their specific scenario. These applications have existed before but were not using officially maintained services resulting in frequent bugs or incompatibilities when source systems changes for example due to updates.

The OAuth2 subsystem implemented in the infrastructure allows fast integration of new backend services as well as the integration of new applications. Also the secure exchange of information between systems using the OAuth2 protocol is now used in several occasions within the IT landscape of the university. As more and more services are able to offer an SOA that can work with OAuth2 tokens the interoperability is increased and it is possible to integrate small subsystems and developments directly based on the needs and requirements of the users. The OAuth2 system is further being used to deliver single sign on functionality between some of the integrated systems.

Since the OAuth2 system and the proxy service have been used to automate certain processes they have become a critical resource in the universities IT services. These processes partially or entirely are based on the newly created infrastructure. The first obvious effect is that errors and failures in these systems cause failures in the relying processes. This can be worked against by introducing redundancy at all levels. The second effect is due to the number of attached legacy systems failures and errors in these systems now attract attention in the proxy service. Due to the architecture much more tracing information is available compared to errors that occur to the users. This makes monitoring and testability easier for some of the legacy systems.

While the first intention of the infrastructure was to provide access to the legacy systems on campus it has shown that many applications require additional more basic services. These are usually less specific like database or storage access. Most of them are available as a service offered by the IT Center already but are not accessible from mobile and smart devices easily. The infrastructure for mobile services therefore needs to be extended by a general purpose object storage service or document store to enable low threshold development of further applications. In our case we will use a SharePoint based solution that extends the existing document library by an Amazon S3 compatible layer. This allows future apps to store small files up to 250MB without the need of implementing specific services.

Table 1 shows the effects of the proactive caching compared to naïve least recently used (LRU) cache on the performance of the provided APIs. The hit rate increased from under 50% to slightly over 70%. This was also the main goal of the implementation and the result shows that the general idea is working. The changes in request durations are caused by the increase of hit rate because a cache hit also leads to a faster response time. It can also be noted that globally, the additional requests caused by the proactive caching do not decrease the performance for the end user, as the average request duration is lower than without proactive caching. The change in dirty read percentage is small enough that it could be insignificant.

Table 1 Effect of proactive caching to overall performance

	LRU-Cache	Proactive-Cache
Hit rate	48.32%	70.89%
Avg. duration	1557ms	1004ms
Requests <700ms	81.03%	87.63%
Dirty reads	2.27%	2.29%

Using the presented infrastructure we are now able to serve 40,000 installations of RWTHApp on 6 different operating systems. During this semester we were also able to serve over 50 courses with our blended learning services in the app. The infrastructure also serves 96 applications from external developers (mostly students) with about 30,000 users that use the provided APIs for more specialized scenarios. Currently 10,000 devices are already connected using device based Eduroam credentials.

Last but not least we were able to observe a speedup in developing new applications on top of the defined services. While it was certainly an investment to build this interface in our current projects we can see that due to better standardization and clear access guidelines the development of all new applications on top of the service layer gets easier, more understandable and more maintainable.

8. FUTURE CHALLENGES

Compared to the structures in E-Learning there is currently no widely used centralized system supporting E-Science processes. However at the university there is an initiative to set up an integrated Research Data Management (RDM) system within the next years. Since the actual implementation of the system is not yet finished the capabilities of the system can yet be influenced to support the efforts towards a more complete university programmable interface. Apart from the integrated system several institutes and organizations have set up their own RDM systems and usually offer only very restricted access to the contained data.

As in the case of E-Learning there are several ideas for applications for smart and mobile devices in E-Science. Again these are usually very specific to certain institutes or organizations and their processes. While most of these applications originate from the local context they often reach out to other organizational processes in the field of E-Administration (e.g. employment status).

RWTHApp will continue to support more processes of the students' daily routines. This functionality can be extended in such a way that students no longer need to actively query the app for information but RWTHApp suggests the most relevant information for the students. This behavior poses additional challenges to the infrastructure as queries to the information systems in the cooperate context are no longer based on the interaction with the users but may be collected automatically.

The device based generation of Eduroam can be published further to be used by students of other universities. This lifts the current implementation from the local to the federative context. Findings from this case study will provide more input of how the infrastructure scales across these contexts.

To evaluate the current case studies a formal definition of the requirements posed on the infrastructure is needed. Based on the current state and related research, these requirements will further disambiguated and show how to measure if the infrastructure fulfils the current and future requirements. To support the continual improvement process the findings of the definition will then be applied to the set of case studies.

The Ultimate goal is to develop a programmable interface for every process of the university. However due to the massive amount and complexity of processes, contributing systems and stakeholders a full implementation is questionable. The presented infrastructure should provide a solid basis for future implementations and adoptions of processes within the university. To verify the resulting good-practice infrastructure it will then be used as a basis for future case studies that are implemented in the university context.

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