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Architecture for the management of a remote practical learning platform for engineering education

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Abstract. In the Scientific, Technological and Academic environment in which the world of today is developed, it is important to permanently update the instruments, platforms and elements with which educational requirements are met. In this sense, engineering is one of the disciplines with the greatest changes, emergencies and innovations per unit of time. Learning tools therefore require constant evolution to facilitate the appropriation of knowledge in an easy and continuously available way for students and teachers. So far it is clear that the intervention of laboratory practices as learning strategies, guarantee a solid education for students in engineering. These practices are the scenarios where the student verifies the theoretical knowledge and validates with real results the application of mathematical and statistical models, which are set around a specific learning in engineering. Continue the development of these activities not only in a traditional way, but including innovations that the same engineering allows from the use of different technologies is a challenge, which can be assumed with the application of the same discipline and be projected to other fields of the education, to facilitate personalized and asynchronous learning. This paper presents the design and architecture for the implementation and management of a new educational platform for the development of Remote Practical Learning experiences for electrical machine laboratories. This platform integrates the possibility of remote interaction with the machine and its connection, as well as obtaining test parameters through measurement interfaces and real-time visualization. In this way engineering and technology at the service of Engineering Education is used, which will increase access to higher education to a greater number of people and will make the educational experience much more pleasant

1. Introductio

Advances in communications allow proposing structures in man-machine interfaces that are used in machining and manufacturing centers that reduce operator contact with electrically energized or moving parts. However, these systems are implemented locally at very high costs and are not designed to carry out effective and efficient educational work. Establish an electrical and mechanical arrangement of engines, generators and transformers, which together with the use of information and communication technologies as facilitators of active learning and the safe development of educational practices is the challenge of the future of remote laboratories in this area, consequently increasing flexibility in learning times for each student, considering a permanent availability of the systems to be used.

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The use of automatic systems for characterizing electrical machines then involves the use of electronic devices and control platforms that manage the connections desired by the student for each specific practice remotely. This requires the design of electronic switches governed by the appropriate logic from the implemented control. Added to this is a work network that manages the online operation of each practice carried out remotely [1].

2. Remote Laboratories in Engineering Education

In the conventional laboratories of electrical machines, the practices carried out by the students require a greater amount of time to process and generate graphs and values from which an analysis of information may arise and much more feedback from the teacher. However, it is of greater concern when there is no mechanical and electrical structure previously configured for the connection, at least, manual of the machines. In this case the students must transport the machines, make the electrical connections without terminals arranged and identified with the risks that this practice carries with it [2]. On the other hand, the results obtained will be influenced by the variation of connection impedances and the corresponding time involved in making the arrangement. Consequently, with these characteristics the practical verifications of the theory of existing electrical machines are limiting in the active learning of the students [3].

The remote operation laboratories in this area include the possibility of automatically acquiring the experimental data for different configurations of electrical machines (in AC and DC, motor-generator groups, transformers) remotely in computer equipment with analysis software of data for the interpretation of results and the identification of possible sources of error, which fed back the students' learning [4]. When designing and implementing a laboratory of remote operation electric machines for execution of practices in time, the following added values would be available:

- Innovation in terms of active student learning.
- Reduction in the execution times of student practices and substantial reduction in classroom attendance, as proposed by educational trends.
- Innovation in data acquisition, storage and analysis system [5].
- Automatic construction of equivalent electric models of electric machines.
- Automatic feedback of obtained results.

3. Management Philosophies for remote practical learning platform

Among the developments carried out so far in terms of online laboratories have been different management philosophies depending on the architecture implemented. The architecture of a common remote laboratory includes a virtual working interface, which animates the laboratory, usually in HTML code for the management of the end user. This interface is generally a website executed in a browser that connected to a server interprets the data that the user includes in the virtual access platform. The server sends the respective information to the real actuating elements arranged, so that the latter executes the corresponding action according to the nature of the remote practice implemented. In the same way, the instrumentation records the corresponding measurements and returns said information to the end user through the server provided. The communication systems used operate with the different protocols available by standardized standards [6]. What has been described above is the basic management architecture and philosophy for the operation of a single laboratory, however, with the technological tools available today it is possible to include isolated remote laboratories by modifying their protocols or intervening their coding if these allow [7] [5].

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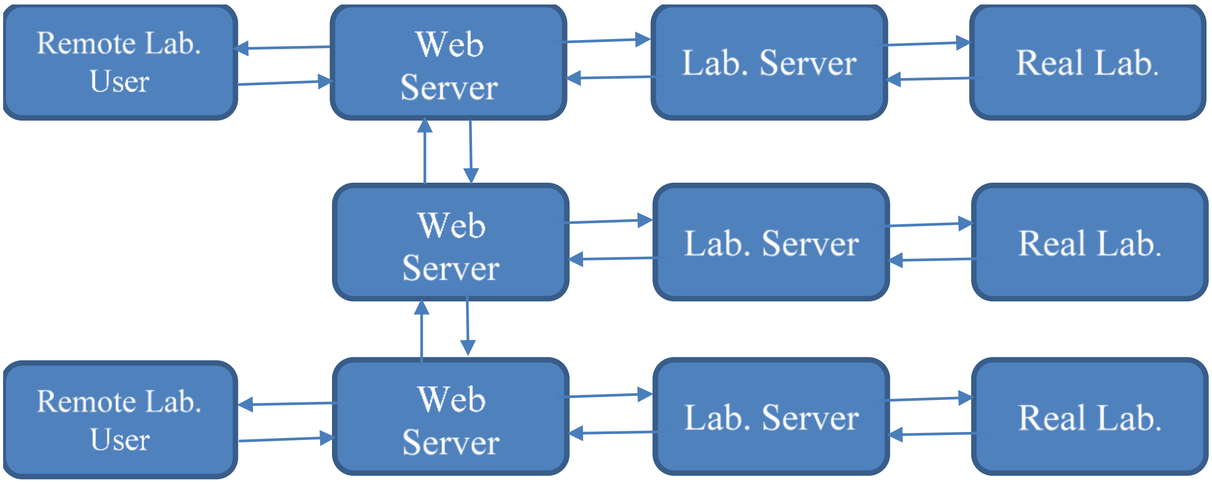

Figure 1. Ideal architecture for a remote laboratories management

A summary of the management architecture of a remote operating laboratory network for different practices and users is presented in Figure 1 [8]. The ideal would then be access to different real practice execution platforms, from different terminals and user interfaces, from any location, taking advantage of the universal access network, internet [9] [10] [11] [1] .

4. Architectural Proposal for a remote practical learning platform

This proposed architecture attempt to collect the most important requirements from others projects to get a generic architecture that allows four aims: security, integration, scalability and decoupling in a learning remote platform. Understanding security like a secure access to the information and resources, extending this definition to any resource schedule access, understanding integration like the ability to provide and consume services between others remote laboratories and the own one, scalability like the ability to increase or decrease the informatics resources according to the new needs of the local and remote users (systems and people) [12], and decoupling like production of the independent modules for the system [13]. The following sections describes the construction of the proposed architecture adding components steep by steep.

4.1. Requirements from previous projects

From [4], is taken the strong need to implement any standard authentication system like SAML, OpenID y OAuth2, in the “StandardAuthentication” component merged with some institution’s Identity Provider (IdP) [4], to manage the access to the provided services by the Learning Manager System (LMS). These authentications methods are in the security layer which will protect and control the access to the LMS (Figure 2), even more, the “StandardAuthentication” module can implement others authentication methods like in [5] using social network authentication methods according to the policies for the institutions. The “StandardAuthentication” component also must work like functionality provider of the “IdP” component, which should take the final decision about the access over resources or services, like information about the experiments, results, data raw captured in an experiment, student information and results, etc. This security layer must control the access to information, resource, and experiment for a user according to a given role in the system, example an administrator can see all information, but a student only can use a remote experiment. The component Laboratory Management System (LMS) is the learning and experiment process in itself.

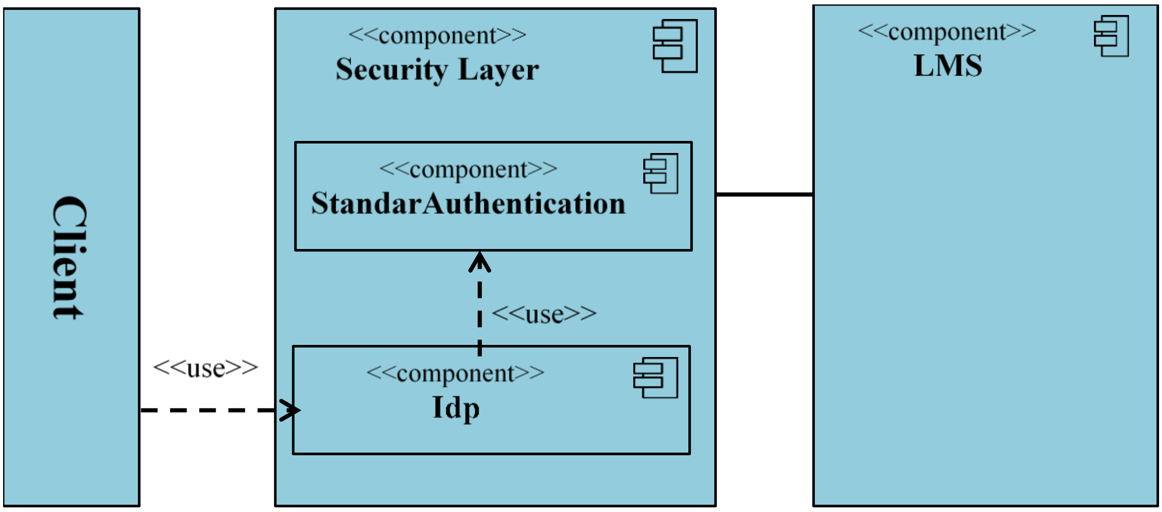

Figure 2. LMS with Security layer.

The scheduling is also an important part for a LMS, because give to the system the ability to optimize the use of the resources, managing the user access to the system avoiding unexpected users concurrence, that may will cause a failed access to the experiment representing a bad user experience [14]. Then appear the component called "Scheduling" to provide information to "IdP" about the user access rights over a resource or information in a specified time. This component have to provide all needed interfaces to: check and consult for resources availability, schedule available resources, release reserved resources, and manage the resource use log. In this way the "Scheduling" component interact with the "IdP" component and any system or user that want to use the system, like shows the Figure 3.

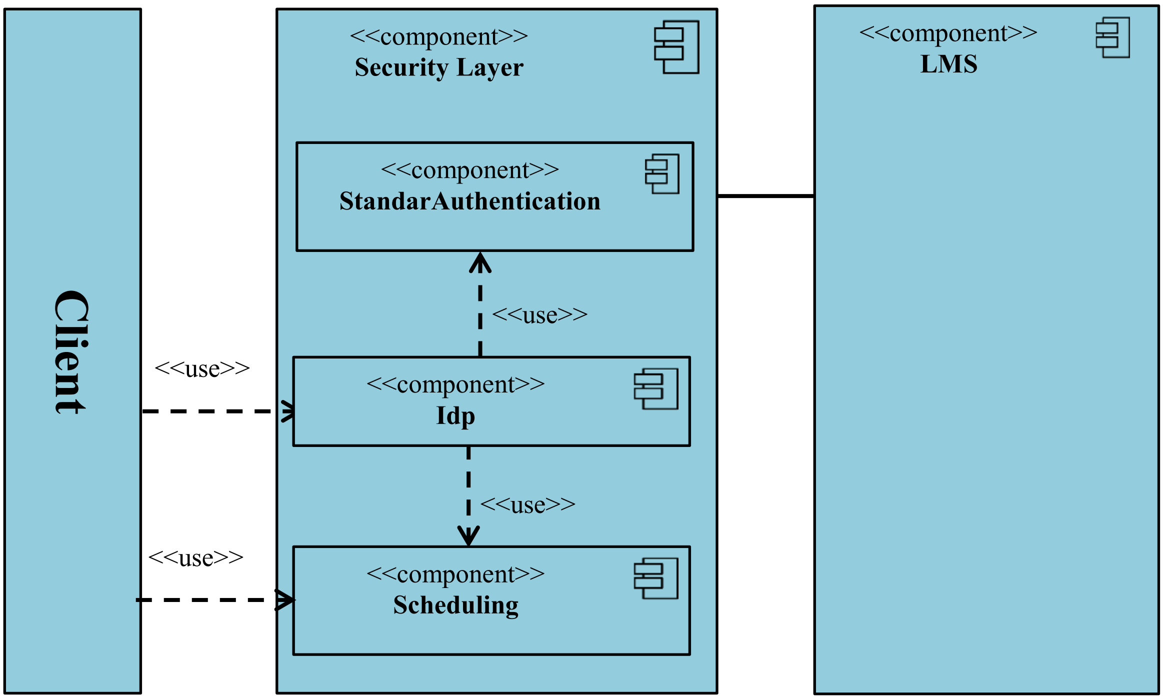

Figure 3. LMS with Security layer and scheduling.

4.2. The functional requirements from the learning business

The LMS have to contain some components that help to reach its main goal, learning and practice, then is necessary some basic services like, the first one, access to remote lab and practices, evaluation sub systems, laboratory guides, and others, each one create a new component into the "*LMS*" component, evolving the architecture to the showed in the Figure 4, into the "*LMS*" component.

The proposed components for a basic system are:

- RemoteLaboratory: Allow interactions between the real laboratory and the remote user, for example will get the measurement from a network analyzer and send it to a client, receive a command from a client and close an automatic switch, or read the image from an oscilloscope and send it to the client, or the oscilloscope data. Also can be associated with an experiment guide, or an evaluation items.
- ExperimentGuides: Store the procedure that the user should follow to accomplish an experiment successfully.
- Evaluation System: Manage the items to evaluate an experiment, the expected results, the results obtained by a user, may be a student, and the evaluation for this results.

The use of the modules by some client are independent, which means a client can use just the guides or the evaluation system, or a full experiment, always according to the rights in the "Scheduling" and "IdP" modules.

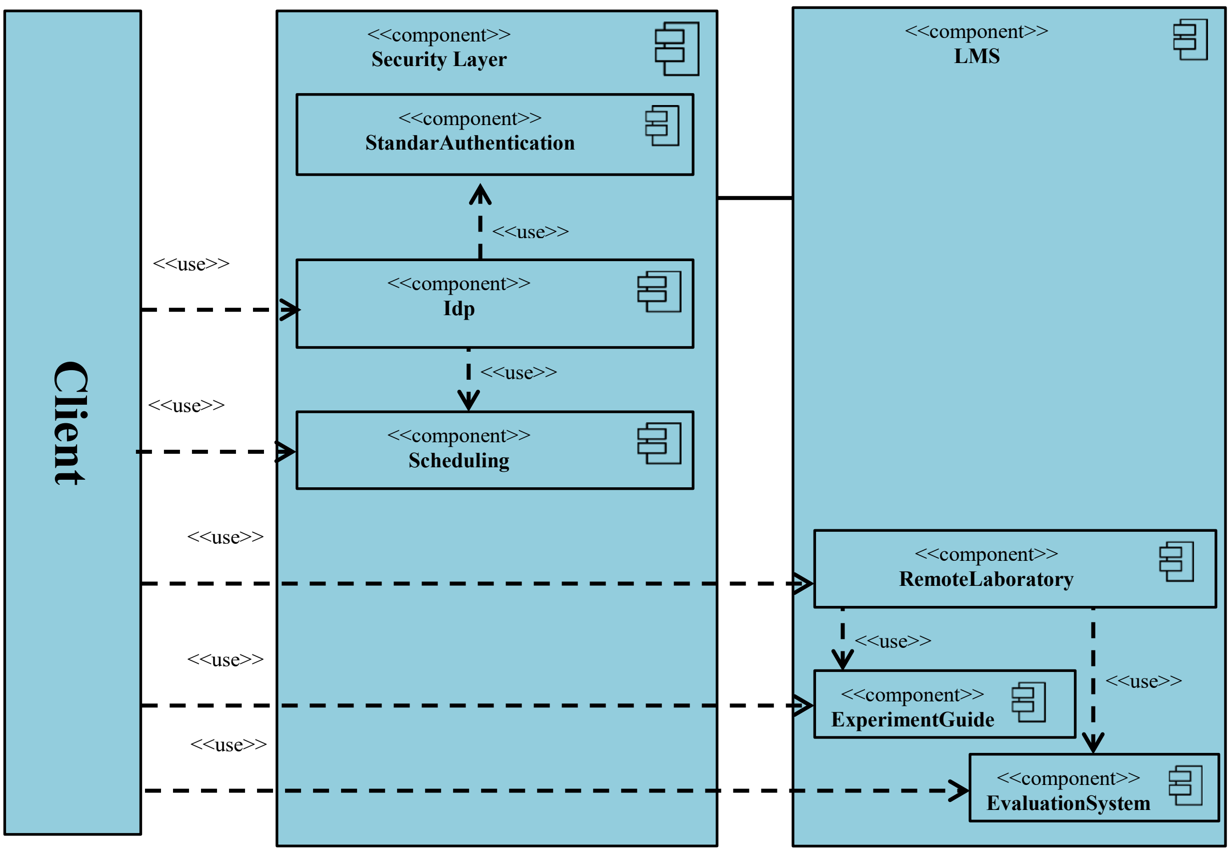

Figure 4. LMS architecture with business requirements.

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4.3. Applying non-functional requirements

Some non-functional requirements detected for any actual system can be included in the model:

- Persistent storage: Is usually the database system to storage the system information, like configurations, user's roles access, scheduling by user, evaluation criteria and the results, data from the experiments and so on.
- Log user or client actions: This component store any action made by any user or client, should be classified according to the specific needs, but is very important log any activity. Some calcifications can be: access granted, access denied, access to a resource by user o client, etc.

From above, the architecture now looks like in the Figure 5.

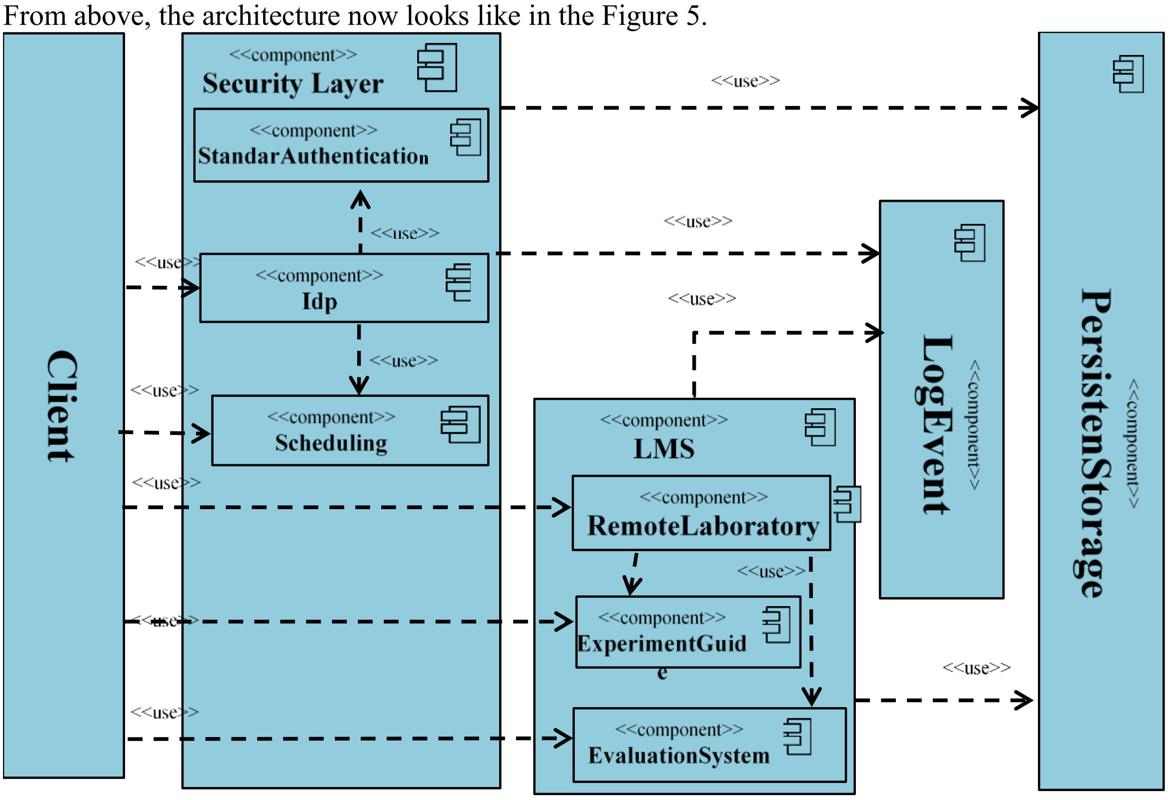

Figure 5. LMS architecture with non-functional requirements.

4.4. Appling new technology tendencies

To create an architecture focused on provide an API through services enabling an easy development of system clients in standard programing languages like JavaScript, Java or C# [15], but this architecture cannot take in account use components from other systems and not specify how to connect to the experiment in self. The current systems try to serve its remote laboratories but are not oriented to use other laboratories services or other system services, creating frameworks instead real services.

Also in most documented cases, the presented architectures are oriented to single, and may be small, development teams, and the development efficiency is not evaluated, that will generate an unsupported systems and sort time systems, especially because the current LMS are development by educational institution teams, these teams are very volatile, change the developers frequently.

Appling the growing concept of Microservices to the above architecture can solve some of this problems. The Microservices architecture is the evolution of Services Oriented Architecture (SOA), and can be defined like "… an autonomous software service which is built to perform a single, specific, and granular task …" [16]. The Microservices architecture is showed in the Figure 6. The API Gateway is the entry point for a client, when a client request for a service the API Gateway receive the request and call the appropriated Microservice, decoupling the client and the services used in fact. The Identity

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Provider is the manager for authentication and access to the system. The Microservices are small and very simple services that can be development in different technologies, by different person, by different development team, that mean they are loosely coupled in many levels. Management and Service Discovery are responsible for managing nodes and update entry points for Microservices. Remote services are services consumed by the system. Finally the architecture provide options for some classical web content through the Content Delivery Network and static content modules.

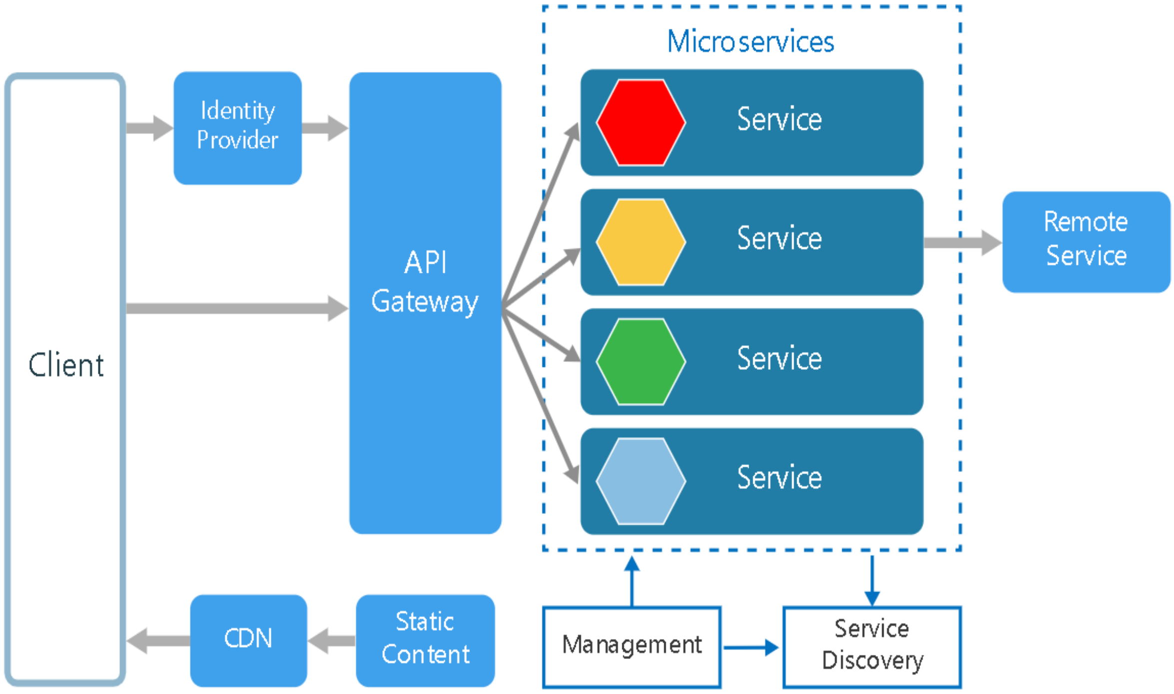

Figure 6. Microservices architecture. Image taken from: https://docs.microsoft.com/en-us/azure/architecture/guide/architecture-styles/microservices

A Microservices architecture warranty scalable systems, and like SOA, provide loosely coupled applications and high systems integrations and shared functionalities [17] [18] [19][20][21]. To apply the Microservices architecture philosophy into the proposed architecture, is necessary include the API Gateway services layer, the identity provider role is taken by the "SecurutyLayer", and all components into "LMS" component turn into Microservices. The Management and Services Discovery will not implement at this moment, but can be implemented. Is important define in this architecture every sensor and every actuator like a service that require a little high effort to develop interfaces between hardware and the LMS, but give to the LMS the capabilities to use, and reuse sensors components, the new proposed architecture is showed in the Figure 7.

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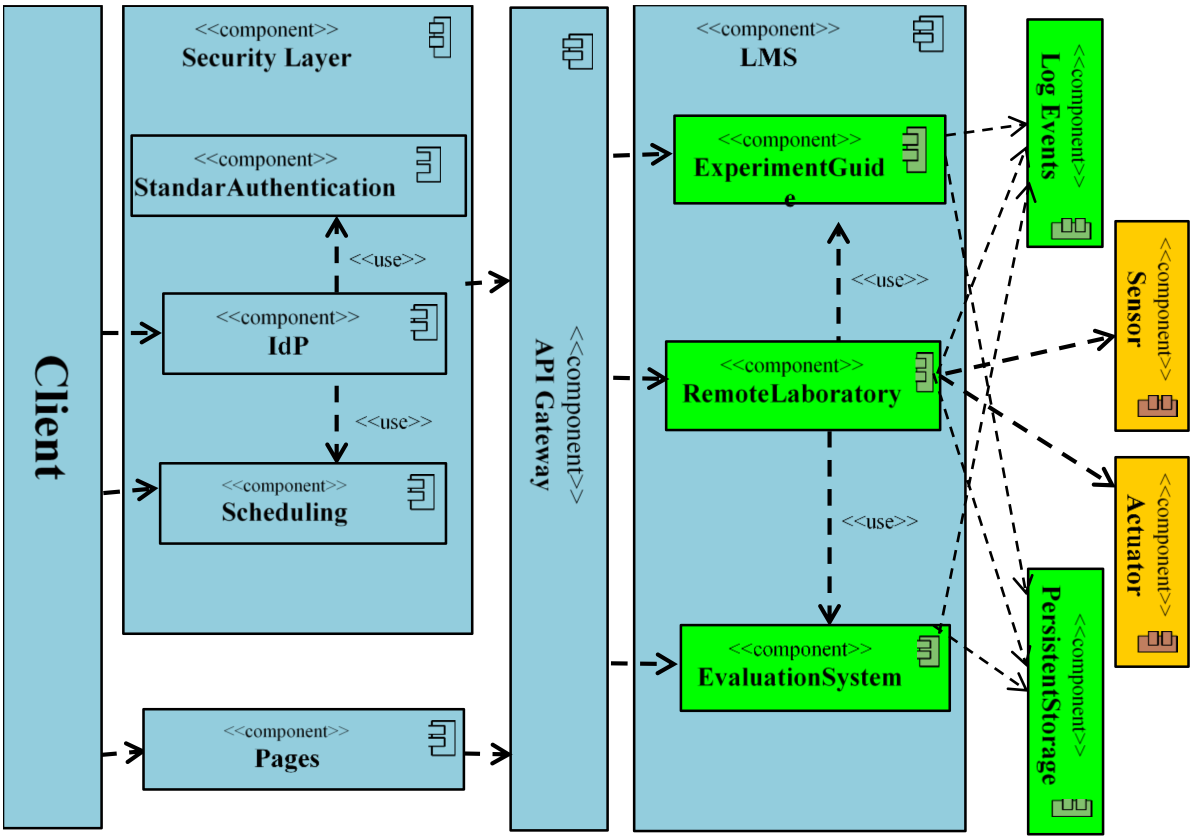

Figure 7. Final proposed architecture applying Microservices architecture.

In a real implementation some Microservice component will be splitted into many Microservices and some not. For example "ExperimentGuide" Microservice can serve all guide documents and process about all experiments, but the "RemoteLaboratory" component should create one Microservice for each experiment, anyway, the granularity for these Microservices is up to the solution's architect.

5. Analysis of Proposal Operation

The *"StandardAuthentication"* component will be so strong like the implemented methods, and will give an integration limitation according to how many standard methods implement, that mean, you can only give services or access services with the same authentication protocols implemented in "*StandardAuthentication*" module, more protocols implemented in this component open the system to use other systems and provide services to more other ones.

The implementation of this architecture, will allow access any resource independently and consume resources from other providers, and give the flexibility to use just one physical or virtual server, or implement different servers for each component. Even more, allow the possibility to have the same experiment twice, for example, use one like main experiment, and use the other like backup, if the first one is busy or not available, the user just access the same page and access the second experiment that is the same like the first one but implemented in other place, of course, is important implement Manager and Service Discovery layers.

In [9] the author concludes that on line laboratories are not a trivial issue, this way, many groups are growing and working in get a standard, like Global Online Laboratory Consortium, or adopting a common platform o framework. The above concept, can create a segmentations of groups, not a standard, because everyone try to push to their initiative, this is the reason because the authors of this paper thinks that is necessary a created standard by an international and recognized institution. Anyway, the proposed architecture, because its implementation of micro-services architecture style, is ready to

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the integration with any service oriented standard, in the future, because is decoupled throw its service layer, and inclusive can serve other protocols to interchange services.

6. Conclusion

In this paper was presented the architecture for implementation and management of an educational platform for development Remote Practical Learning experiences in electrical machine laboratories. This platform integrates the possibility of remote interaction with the machine and its connection, as well as obtaining test parameters through measurement interfaces and real-time visualization. In this way engineering and technology are uses as service of Engineering Education.

The article includes a proposed architecture attempt that collected the most important requirements from others proposals to get a generic architecture that allows four aims: security, integration, scalability and decoupling in a learning remote platform.

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