A real-time service system in the cloud

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Abstract
Recently, we have witnessed unprecedented use of cloud computing and its services. It is influencing the way software is built, as well as company’s resources such as servers, workstations or generally hardware are used. This paper aims to examine the benefits of cloud usage to support real-time service systems, using the Salesforce platform. First, we explore the meaning and the role of cloud computing for the real-time service systems efficient functioning. Then, we build a service management platform for the Polish Billiards and Snooker Association (PBSA), based on a real-time system located in the cloud. This way, PBSA managers are able to complete their tasks in this system on-demand. Moreover, it is set up as a private cloud to grant access only to the snooker organization employees.

Keywords Cloud computing · Real-time service system · Salesforce platform · SaaS cloud

1 Introduction
Ubiquitous development of Information and Communication Technologies (ICTs) involves the evolution of commonly adopted computer systems and applications. One of the fastest growing trends in the IT environment is the cloud. It is influencing the way of the software building, as well as companies or end users exploit resources such as servers, workstations or generally hardware, which in turn can become deprecated quickly. Cloud itself can be referred to as cloud computing or public cloud; e.g., online disks designed for data storage and easy access to it. Accordingly, business/private users can manage their businesses or processes using any device that has an Internet connection (Mell and Grance 2009, 2011; Jin et al. 2010; Qi et al. 2018).

From the research point of view, cloud computing is an interesting field as it is one of the fastest developing domains in modern businesses and classical computer science. It brings a lot of opportunities in response to on-demand access to data resources; but, at the same time, there are many concerns about the safety of such solutions. Often information that users decide to store online is sensitive. In a certain sense, there is some risk involved when using cloud computing as beneficiaries must trust and rely on the service providers. On the other hand, the growing number of users who takes advantage of cloud solutions force cloud providers to assure an appropriate level of security. Hence, more and more organizations decide to move their data into the cloud (Tang et al. 2010; Sriram and Khajeh-Hosseini 2010; De la Prieta et al. 2017). As an example, an organization that lacks a service management computer system, we analyze the Polish Billiards and Snooker Association (PBSA). It is a Polish federation representative for two sports disciplines—snooker and English billiards. Its main occupation embraces organizing tournaments, the popularization of mentioned disciplines, representation of Poland on the international arena and choosing players to the national team.

Polish Billiards and Snooker Association does not have distributed computing infrastructure. Also, the activities on behalf of this organization are not the main occupation of people from it, rather just hobby. The cloud approach with its advantages seems a reasonable solution to build a system that could help to manage snooker tournaments. Cloud
platform enables access from personal computers or smartphones from anywhere as long as an Internet connection is available (Sadiku et al. 2014; Poniszewska-Maranda et al. 2017; Chen et al. 2018).

There are many aspects that would make the organization of such competition more efficient. For example, the main referee should have a tool that allows managing the schedule of matches and notifying players about their next match, generating match report, and generating tournament bracket automatically. Accordingly, we examine the capabilities of cloud in relation to the real-time service systems, considering Salesforce platform.

This paper is organized as follows. Section 2 describes the idea of real-time system and cloud computing common usage. This section also describes cloud, key characteristics, deployment and service models. Section 3 reveals the information about Salesforce platform—what it is for, and what tools it offers to build our proposed system. Section 4 deals with the building of the proposed system, including the development of the requirements, architecture and logic layer. Section 5 provides a summary of the results and proposed future work.

2 Cloud computing for real-time service systems

Polish Billiards and Snooker Association (PBSA) service management platform is developed as a real-time system located in the cloud. It allows PBSA managers and employees to call up this system on-demand. It is deployed as a private cloud with restricted access to the employees of the snooker organization only. This section describes a real-time system functionality and its usefulness for our proposed management system. Then, a categorization of cloud capabilities in relation to the research problem is discussed.

2.1 Real-time systems

The term real-time system sometimes can be easily misunderstood. One might probably think of a complex system that processes data, operates and responds to the user almost immediately. In fact, this concept is much wider. The crucial thing is to distinguish the difference between real-time system and computer real-time system (Shin and Ramanathan 1994). A definition proposed in (Laplante 1994; Schoch and Laplante 1995; Laplante and Ovaska 2011) states that not only computations correctness is important in real-time systems, but also the fact that they follow events happening in real time. In this case, it means that the essential requirements are punctuality (meeting time constraints) and continuous operation. According to a concept proposed in (Kopetz 2011), such systems are divided into the set of subsystems, referred to as clusters (Kopetz 2011). Figure 1 depicts the components of real-time systems.

Based on this view, a computer real-time system is just one of the clusters of a bigger system where computations take place. Hence, the relation through the man–machine interface is obvious—a man operates a computer that processes data related to a controlled object. An interface, in turn, consists of sensors and actuators that process physical signals and transfer them to or receive them from the computational cluster (Gomaa 1993; Liu et al. 2000; Kopetz 2011).

Real-time systems can be divided into two categories, namely: hard and soft. The most crucial factor here is time. A computer real-time system should operate within a requested time constraint referred to it as a deadline. Hard type of real-time systems means—every deadline must be met; otherwise, the system can result in a total failure. Such breakdown could cause a disaster, even for humans. Such disasters can happen in chemical plants or in air traffic control, which are in turn real-time systems (Mattai 1995; Kopetz 2011; Laplante and Ovaska 2011). On the other hand, soft type of real-time systems does not cause any danger when the deadline is not met. When a failure occurs in this case, a system might become just annoying for the user or may result in some financial losses. A good example to illustrate this problem is an online reservation system. Missing a time constraint would result in unsuccessful operation, but no danger for people (Krishna 2001; Kopetz 2011; Laplante and Ovaska 2011).

Another classification of real-time systems involves event-triggered and time-triggered systems. A trigger can be defined as an event that entails further actions or computations in the computer. Hence, in time-triggered systems, any activities taken by it happen at a predefined earlier moment. This makes the whole system inflexible since it handles only events that had been defined before. On the other hand, actions in event-triggered systems are started immediately after any event other than set earlier to happen at a given time triggers the system (Kopetz 2011; Klein et al. 2012).

Within the context of this work, a system is developed for practical purposes that can be defined as a soft real-time system. In case of total failure, naturally there is no a significant danger for people or surroundings. It is a tool designed for improving the efficiency of management sports tournaments. Therefore, if it doesn’t work properly, people in charge have to operate just like they are doing it now—without any automation. Hence, the time constraint involved here should be such that the work with this system is fluent, approximately 2–3 s per action invoked by a user. It is also an event-triggered system, because it reacts to the results on the tournament. As this is not so complicated, from the theoretical point of view of real-time systems, the instrumentation interface is rather neglected. This is because we can not define the controlled object as one physical object.
In this case, it rather refers to the tournaments as a whole—matches, calculation of results and registration process.

### 2.2 Cloud computing

Mell and Grance from National Institute of Standards and Technology (NIST) defined cloud computing as a model that provides end users with access from any device, which has an Internet connection, to a shared set of resources such as servers, applications or services (Computer Security Division 2018; Mell and Grance 2009, 2011). Therefore, the most crucial fact in the cloud computing concept is that the software being used is not installed on a device from which it is accessed. Appropriate services do not involve companies’ infrastructure, they are available over an Internet connection, ready to use (Leavitt 2009; Tang et al. 2010). One of the first companies, who started to offer cloud services over the Internet was Salesforce. A further example was Amazon Web Services that enabled users the possibility to store data online and perform computations (Barry 2003; CRM Software & Cloud Computing Solutions 2018).

NIST provides four deployment models: private cloud, community cloud, public cloud, and hybrid cloud (Angeles 2013; Computer Security Division 2018; Barry 2003; Sriram and Khajeh-Hosseini 2010; Mell and Grance 2011). Besides, it considers three main service models. These are Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). Service models and deployment models are strictly connected with each other. Besides, it is important to remember that no matter whether the end product is delivered in IaaS, PaaS or in SaaS—it can be built on any of deployment models (Cusumano 2010; Sadiku et al. 2014; Sultan 2014). In the following, we provide some implementation examples of cloud service models.

In the first model, Infrastructure as a Service (IaaS), a customer is given computing resources such as virtual server space, networking, operating systems so that it can deploy and run the software. Companies such as Amazon, Rackspace or GoGrid are examples of IaaS providers. Resources given to the customer are distributed across data centers, which are maintained by the provider. Customers, in turn, can work in virtualized components and deploy their own platform. The reason for employing the IaaS model in companies is that it allows moving expenses of managing hardware to the cloud provider. Infrastructure as a Service allows the consumer to build scalable system as resources based on their needs (Angeles 2013; Computer Security Division 2018; Barry 2003; Sriram and Khajeh-Hosseini 2010; Mell and Grance 2011).

The next service model is Platform as a Service (PaaS). The customer is again given the cloud infrastructure and can deploy their own system into the cloud utilizing tools available by the cloud provider such as programming languages, libraries or database management systems. Moreover, available tools do not exclude the usage of libraries and tools from other integrated sources. Examples of PaaS providers are Google App Engine, Microsoft Azure, Force.com and Amazon. Cloud infrastructure is maintained by the cloud provider, where application programmers can fully concentrate on the system development. Moreover, the tools provided in the PaaS model often enable developing applications without the knowledge of programming. For example, Force.com platform allows building parts of a system using one-click functionalities (Angeles 2013; Computer Security Division 2018; Barry 2003; Sriram and Khajeh-Hosseini 2010; Mell and Grance 2011).

The last model mentioned in NIST definition is Software as a Service (SaaS). In this case, a customer does not build its own system but makes use of a ready system prepared
by the cloud provider and running it in the cloud. Examples of SaaS providers are Salesforce, Microsoft Online Services, and Google Apps. Applications created by SaaS providers are accessible from any device with Internet connection. For example, a user can download a program from Google and use it on his/her smartphone, or a company with Salesforce licenses can take the advantage of ready to use applications from Salesforce’s marketplace—AppExchange (Computer Security Division 2018; Sriram and Khajeh-Hosseini 2010; Mell and Grance 2011). Figure 2 illustrates the main elements that constitute these models (Salesforce Developers|API Documentation, Developer Forums & More 2017).

In this paper, the real-time service management system advanced is built on two service models. The final solution delivered to the Polish Billiards and Snooker Association, from the point of view of this organization, is given in Software as a Service model since it is ready to use the system in the cloud. During its development, Force.com platform provided by Salesforce is used, which involves another model; i.e., Platform as a Service. Issues related to the Salesforce functionality and its PaaS platform are described in the next Section.

3 The functionality of Salesforce cloud service delivery platform

This section provides a detailed description of Salesforce components that are used to build our proposed system. Salesforce mainly provides customer relationship management (CRM) software, primarily cloud-based. Salesforce has a high reputation among its beneficiaries as it is confirmed by numerous awards for the best CRM system given by magazines Enterprise CRM, Mid-Market CRM or being a leader in ranking of recommended CRM’s led by Software Advice based on customers’ reviews (CRM Salesforce 2017; Youssef et al. 2008; Benioff and Adler 2009; Trailhead 2017).

3.1 Database in Salesforce

The database represents the persistence layer of each application. In the case of Salesforce, users and developers are not responsible for managing this part of the system as there is no software that has to be installed for that purpose. Instead, the platform delivers the database that can be used when building the applications using Force.com. It is a relational type, but there are a few differences in comparison to the database management systems in traditional applications. In the latter, data is kept in tables which consist of columns defined by a particular data type. Information might be retrieved among rows of the concrete table. Furthermore, these tables can be associated with each other with the use of a primary key in one table and foreign key in the related table.

Object replaces the table in Force.com database. In Salesforce nomenclature, it is crucial to differentiated from so-called sObject, which can be described as an object materialized in the platform’s object-oriented programming language, Apex. This term is introduced to differ such objects from instances of classes. Hence, the main function of Salesforce’s object is to store the data. Objects can be related to each other via relationship fields. There are two types of them in Salesforce, namely: Lookup and Master–Detail. In both cases, the ID of the related object is saved in the relationship field. The first type reflects the relationship of type “one-to-one” or “one-to-many” and creates a link between two objects. Among standard Salesforce objects, there is always a relationship of Lookup type between Account and

![Fig. 2 Elements of cloud service models (Computer Security Division 2018; Mell and Grance 2011)](image-url)
Contact. The latter has the Lookup field that stores the ID of a related object, in this case—Account.

The Master–Detail relationship is used when two objects are tightly bounded with each other. Deletion of parent record in this relationship entails deleting all child records. This kind of relationship might reflect “many-to-many” relationship. It happens with the use of so-called junction object that has set up Master–Detail field to two other objects (Salesforce developers). Force.com platform offers a special language dedicated to retrieving data from its database, called Salesforce Object Query Language (SOQL). Its statements are very similar to the well-known language of relational databases. The basic structure of SOQL query is presented in Fig. 3.

### 3.2 Apex

The Salesforce platform is using Apex which is an object-oriented programming (OOP) language. Its syntax strongly bears resemblance to Java as it is based on its conceptual principles. Additionally, it supports the OOP paradigm such as classes, inheritance, and interfaces. Apex is executed and saved on the Force.com platform. The working principles of this language is presented in Fig. 4.

Apex enables the conditions and statements available in the majority of programming languages, such as variables, constants, if-else statements, loops, and array notation. However, in the case of this language, an array is the same as one of the collections, i.e. list. Other collections available in Apex are sets and maps. What makes Salesforce’s programming language unique is that the Cloud is the place where the code is executed and compiled. Apex also enables SOQL calls and assigning its results to the chosen collection. Moreover, it supports Data Manipulation Language (DML) operations, which can insert, update or delete the records from the database.

### 3.3 Visualforce: client-side language

Visualforce is a framework that enables web development within the Salesforce platform as such creating customized user interfaces. All interfaces are built using of this language may consist of Visualforce tags, starting from prefix ‘apex’ (e.g., the starting tag <apex:page>), plain HTML and optionally styling elements such as css elements that can be uploaded into Salesforce. Moreover, Visualforce can comprise JavaScript. The working principle of this framework is depicted in Fig. 5.

Each interface has its own unique URL address through which it can be accessed. Then, it can interact with the system logic, defined in Apex classes (custom controllers) or triggers or in standard controllers, enabling automatic access to data in Salesforce. Custom Visualforce interfaces might be used in various places inside the platform. To give an example, standard Salesforce interfaces for editing or creating a new record can be overwritten by Visualforce ones. They can be also accessed through the custom buttons created by a user. The other options are embedding custom interface into a standard layout or to open it through the custom tab (trailhead and Salesforce developers).

### 4 Real-time service system based on the Salesforce platform

This section provides a practical example of real-time system employment into cloud computing. It is a system we developed with the use of the Salesforce platform named Top 16 Manager. The main goal of this system is to examine
Salesforce platform capabilities in the context of real-time systems and cloud computing. For that purpose, the system which can be classified as the soft real-time system is created in the private cloud, taking advantage of Force.com tools and programming languages. One of the best advantages of Salesforce is that customizations can be achieved by using few administration tools offered by Force.com platform. Applications in Salesforce are mainly built for business purposes, where there is a possibility to define Email Alerts with their contents defined in an Email Template. This can be invoked using other Force.com tools, namely: Workflows and Process Builder. Both of them are used to automate the processes used in Salesforce application. Their creation starts from defining which object is going to entail further actions. For example, these include updating the field value on defined records or sending an email according to Email Alerts indicated earlier. Actions set in these tools might be either immediate or time-dependent. The difference between these two tools is that the Process Builder allows updating child records what is not allowed in workflows. All described processes are created only by clicking and setting right options, no code is involved in such cases.

Salesforce may have many users; therefore, there is a need to define who can access what. It can be achieved by setting appropriate profiles using another Force.com tool which does not involve any technical knowledge. Users’ profiles are set of permissions and their settings regulate which resources a particular user can access. For example, they can control view, update, create or delete the permissions for each object defined in Salesforce, which fields and buttons are visible for the user or which Apex class or Visualforce interface can be executed by a particular user (Salesforce developers). Although Salesforce is 17 years old and many users claim that the design of the platform is old-fashioned, many functionalities are stated that makes it so powerful to build the CRMs in the cloud. However, with the release of the Salesforce1 mobile application, platform’s creators decided to move its design into the desktop version of Salesforce. This is also done to meet the expectations of users for which the design of the system is its important part. For that purpose, Salesforce launched lightning experience; a new graphical user interface of the whole platform. What has changed apart from the overall design of the platform is, for example, navigation menu, record layouts, list view, and dashboards. Salesforce has also released Salesforce lightning design system (SLDS); a CSS stylesheet consistent with lightning experience principles. It is also possible to develop the interfaces in Visualforce and apply lightning styling on them. Except for improved look of the platform, lightning entails changes in the programming conventions in Salesforce. The new user interface framework is released in order to develop the applications on the desktop and mobile versions of the platform. It is called lightning components. Just as in Salesforce classic, the server side is handled by Apex. However, client-side in case of lightning components is served by JavaScript. It enables an interaction with custom controllers and with the database. Lightning components might be accessed in the system through the tab, they can be the part of custom interfaces or they can be defined under quick action which may be applied to each record. Typically, a single component consists of a few elements put in definition bundle. It comprises of a component in which a user interface is defined and JavaScript handlers: controllers and helpers. Optionally, CSS definition of a component might be included (Trailhead).

Salesforce is undoubtedly an interesting platform as it is leading CRM software provider as well as from the cloud computing research point of view. It connects its two service models (PaaS and SaaS), as the final product used by customers is ready to use the software while developing applications in Salesforce that involves Force.com platform. A big advantage of Salesforce is the fact that except for technical
tools, programming languages dedicated specially for this
platform, it also has ones that require setting correct options
and processes within a few clicks. It is worth to notice cur-
rent development of the platform, especially with the release
of lightning as every upgrade brings new functionalities and
possibilities of application creation.

4.1 System requirements

The main function of the Top 16 Manager system is the
management of the snooker tournaments TOP 16 organ-
ized periodically by Polish Billiards and Snooker Associa-
tion. Such an event is a challenge from the organizational
point of view. Usually, there is only one person, i.e., the
main referee who is responsible for the efficient conduct
of the tournament. It embraces managing the start time of
each match, their order, assigning referees and placement
of matches on available tables. What is more, the main ref-
eeree must inform every player about their incoming match,
which sometimes quite challenging. The functional require-
ments for the Top 16 Manager are as follows: putting match
scores to the system, calculation of table in the group stage,
generation of bracket for the knock-out phase, possibility of
referee, table and status assignment for all matches, match
report generation, e-mail notification for players about the
next match, and mass e-mail message to players taking part
in the tournament.

The basic feature of the Top 16 Manager is the ability to
put match scores to the system and calculate the table of each
group in the tournament. The system automatically draws
groups for the tournament and presents the list of matches.
After the end of the group stage, it is possible to generate
a bracket of the tournament based on scores from the first
phase. In this way, quarterfinals, semifinals and final games
are presented in the system. When a match of the knock-out
phase is finished, the bracket is automatically updated. The
panel of tournament matches is constructed in such a way
that the main referee can easily assign to the single match the
following: a referee, table and status, which makes managing
them more efficiently as all required information is in one
place. Figure 6 illustrates the use-case diagram with all the
functional requirements of the Top 16 Manager. It embraces
only one actor that is the main referee as it is the only user
in this system due to limitations of the developer edition.
With a license of multiple users, it is possible to add to this
diagram other actors, such as players.

4.2 Top 16 Manager system architecture

The architecture of any Salesforce application is defined as
a multitenant architecture. It means that users of the plat-
form share the same resources and tools provided by Force.
com. At the same time, individual users of Salesforce can
take advantage of the customization built on the platform
especially for them. Moreover, Salesforce utilizes metadata-
driven architecture. All platform customizations such as
interface layouts, objects definition, workflows, processes
or Apex code are stored as metadata. In the Salesforce data-
base, no tables are created such as in traditional relational
databases. What is more, the code from the Apex classes and
triggers are not compiled. Instead, stored metadata is used
by system engine at runtime to generate virtual application.

The multitenant data model of discussed platform con-
sts of multitenant metadata, multitenant data, and mul-
titenant indexes. Multitenant metadata comprises internal
tables called MT_Objects and MT_Fields. These tables store

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![Use-case diagram of Top 16 Manager](image-url)
information in the form of metadata about objects together with organization ID, to which these objects belong and about fields that are defined on objects. Multitenant data, in turn, stores individuals’ data inside Salesforce application that can be mapped to their objects and fields defined in MT_Objects and MT_Fields. This data type can be available on the Salesforce platform; for example, number, text, date, formula. It is also possible to store long text information as character large objects (CLOBs). Finally, multitenant indexes allow cataloging data stored in the cloud so that retrieving this data and access to it during runtime is optimized. Schema of the multitenant data model is depicted in Fig. 7.

The Top 16 Manager system comprises of three main components, for managing TOP 16 tournaments, namely: Match management, Players notification, and User interface. Match management component is the most important component among others, as it is responsible for handling the basic functionalities of Top 16 Manager—input of match scores and calculation of tables. The logic of this component is defined in Apex classes—controllers for Visualforce interfaces, on which the main referee operates. The other component is Players notification that has the responsibility of sending messages to the players taking part in a particular competition. This component is not critical for the correct operation of Top 16 Manager. It also communicates with Match management component, because any notification send to players is based on the match details. The logic of players’ notification component is defined in Process Builder as well as in Apex classes. The last component, User interface, is responsible for the arrangement of the Visualforce interfaces customization that overrides the standard ones, but also for all the layouts of object interfaces, related lists and search layouts. It is defined through a set-up of the Salesforce platform user interface capabilities. Figure 8 depicts the component diagram of Top 16 Manager.

4.3 Data model

To fulfill the required functionalities of the proposed system, the following five custom objects are developed: Tournament, Player, Tournament Appearance, Match, and Referee. The main developed object is the Tournament, which is the starting point of the system. It is related to the Match object via a one-to-many relationship. Every tournament is connected to it matches; at first 24 in the group stage and then 7
more at the knock-out phase (quarterfinals, semifinals, and the final). This reflects the type one-to-many relation, as the single tournament has multiple matches related to each other. Match is connected with Player, which contains two Lookup fields as two players take part in a single match. It is also connected with the Referee object because a referee is always assigned to a match.

Tournament appearance object is developed to reflect the relationship of type many-to-many as multiple players can take part in many tournaments. This object acts as a junction object; it has fields of type Master–Detail to Player and Tournament objects. It also contains a few fields needed for calculating the table during the group stage of each tournament. Figure 9 illustrates the data model of the snooker management system, from a platform Schema Builder view point.

All fields marked by red vertical lines are either standard ones, such as Created By Last Modified By and Owner, or the required ones, such as Master–Detail fields on Tournament Appearances object. A standard field is also the name of each object’s record. It can be either text or an auto number. Tournament object contains fields that describe the date and place of the single competition and technical Checkbox fields which are used as flags for the logic flow. Fields in the Player object describes the data about a player. One important information is the e-mail as it allows receiving the notifications about next matches.

4.4 Logic layer

The system development within the Salesforce platform involves model-view-controller (MVC) pattern. The system is divided into three separate layers for easy maintenance and to provide modularity. In this case, the model is defined in the standard and in the custom objects, or in Apex classes. View layer comprises of Visualforce interfaces and components, which are rendered on the server and displayed in the web browser. The logic (controller) layer might be customized. It is defined programmatically in Apex classes or triggers, but it can also use standard controllers generated by Force.com platform. It embraces; for example, binding of the input fields on the interface with the object, or with actions such as saving or cancel. MVC pattern in Salesforce is depicted in Fig. 10.

The logic of Top 16 Manager is customized programmatically in Apex and in various Force.com administration tools. The first step in the platform configuration is to define the appropriate profile, which could be assigned to the account.
for the main referee. In the definition of this profile, all tabs for standard objects have been hidden since they are unnecessary from the system point of view. Instead, it has been set that visible tabs are those related to five custom objects used in Top 16 Manager. Moreover, read and write permissions have been given for the required objects. Access to every Visualforce interface in the system has been allowed for users with that profile.

If there is a need to add more users to the system, new profiles should be created. This concerns players as an example. In such a situation, their permissions for objects can be different. For example, they are not supposed to have edited and created access for such objects as Matches, Referees, and Tournaments. Due to the fact that Tournament is the main object in Top 16 Manager, functionalities are mainly executed from the view of records of that object. It involves creating a few custom buttons, which open Visualforce interface where a user can operate. The list of buttons belonging to Tournament object is presented in Fig. 11.

A user can enroll the first players to the tournament with the use of custom interfaces. Logic defined in Apex working under that interface creates the records of Tournament Appearances object connected with the tournament, from which this action is fired with the selected players. The system checks whether the user selected 16 players or not. If yes, then it saves it to the newly created map Tournament Appearances. Next, with the use of the random function it assigns to the appearance group A, B, C or D, in which a player is going to compete. After that, it saves the appearances to four lists according to their groups, which have been drawn. Finally, it inserts into the database six matches in each group, as every player must play against every other player in his/her group. Those matches assigned relation to the tournament and the status is set to Match Ready in the moment of insertion.

All records that are planned for insertion are first saved to the list, which is then inserted entirely, instead of inserting every record separately, based on Apex development guidelines. This is done to reduce the number of Data Manipulation Language operations, which is limited to the Salesforce platform. Then, actions are related to the matches of the given tournament Fig. 12 depicts an activity diagram of the process of the players enrolled in the tournament.

In the current system, Visualforce interface lists the games into groups. It is possible to put the score there and update its data as status, date and time, table and referee that are connected with a given match. It should be noted that update logic is defined in Apex. However, before a record of Match

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**Fig. 10** MVC pattern in Salesforce (Salesforce developers)

**Fig. 11** Tournament object in Top 16 Manager
object is updated, it is checked with the use of a few Validation Rules set on this object. If the criteria defined in the Validation Rules are satisfied, then the system creates the lists of matches’ records, according to the groups in which they take place. It also creates four lists of Tournament Appearances object, to calculate the table of each group, since this object stores information about the points gained in the group stage. The system creates a map, where the key is the player’s ID, and the value is his/her appearance. When the main referee updates matches’ results, the procedure goes through matches on the interface, where there is information about the player, and then comparing which of the players has won more frames. Then, it retrieves player’s appearance from the map and updates this appearance; accordingly, points are awarded to the winner. Consequently, the group tables are updated. The system queries for the appearances in each group and sorts lists with players by points, the difference between frames won and lost, and frames either won or lost. Figure 13 illustrates the activity diagram of updating group matches.

An example of usage of administration tools is the functionality that sends.

An e-mail, set by the referee on the Visualforce interface, is sent to both players after the match time is one example of the administration tools that can provide. The view of this process is depicted in Fig. 14.

As soon as the group stage of the tournament is over, the main referee can generate a bracket for the knock-out phase. This demonstrates the functionalities that are invoked from another Visualforce interface and has the logic defined in Apex controllers. The custom controller assigns seeding to players.

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**Fig. 12** Activity diagram of enrolling players to the tournament in Top 16 Manager

![Activity diagram of enrolling players to the tournament in Top 16 Manager](image)

**Fig. 13** Activity diagram of group matches updating in Top 16 Manager

![Activity diagram of group matches updating in Top 16 Manager](image)
according to their performance in the first phase based on
the points they have collected, and the difference between
frames won and lost and a higher number of frames won. If
all the parameters are equal, then the draw decides which of
the players is seeded higher. The system dedicated for this
process queries for the appearances of the given tournament
and sorts them in the same way as in the group stage. Then,
the system inserts it into the quarterfinal matches database. The player
that is seeded with number 1 competes with the player with
number 8. The order is as follows: 2 vs. 7, 3 vs. 6 and 4 vs.
5. The system also inserts the semifinal and final games but
does not assign any players for those matches yet. When the
tournament bracket is generated, the main referee performs
the same actions as in the group stage. However, at this time,
the system forms the map in which the key is the matching
symbol. For example, QF1, QF2, SF1, etc., and the value is
Match record. After each update, conditional statements check
the winner of each match and assigns him/her to the match in
the next round, i.e., either semifinal or the final.

It is possible for the main referee to send a broadcast email
to all players taking part in the given tournament by filling
the simple form on another custom interface. When the ref-
eree submits it, the system queries for the e-mail field of
every player taking part in the given competition. Then, with
the use of Apex Messaging class, it sends all emails. The last
custom interface shows the positions that players took in the
current tournament that uses jQuery plugin TableSorter.

To conclude the analysis of actions performed so far,
we can confidently say that it is possible to develop a man-
agement system based on the Salesforce platform. It is not
necessary to be developed for business-oriented purposes,
although Salesforce is mainly aimed for businesses environ-
ments. Moreover, it is possible to develop systems to manage
individuals’ data, using this platform.

4.5 GUI layer

The implementation of our proposed Top 16 Manager sys-
tem is based on the classic version of Salesforce. To improve
the design of the whole system, SLDS is utilized. It is a CSS
stylesheet compatible with the lightning experience. What
is more, the standard interfaces for creating and editing five
custom objects used in Top 16 Manager system are over-
ridden by custom ones, which are also styled according to
SLDS CSS. To override the standard Salesforce interface,
it is necessary to create a custom Visualforce one. For this
purpose, a few classes from SLDS stylesheet is applied to
make a better look for Top 16 Manager system. Listing 1
presents an example for SLDS classes.

It is possible to merge HTML code with Visualforce. There-
fore, CSS classes are used in the Listing 1 such as slds-
form-element, slds-form-element__label or slds-input, ena-
bling to style the input fields according to Lightning design
style wrap the apex:inputField element, which in fact it is
also rendered to HTML that captures the user input. The
example shown in Listing 1 styles only one element from
a single interface. According to this approach, all Visual-
force interface are styled to achieve the Lightning look. In
order to take advantage of SLDS stylesheet, it is loaded from
the static resource, where it is uploaded at the beginning.
Nevertheless, during the development of Lightning styled
interface a few problems are encountered such as SLDS does
not support input fields of type Lookup. Moreover, the usage
of standard inputs like a date with the intention to display a
date picker has damaged the styling of the whole interface.

Listing 1. An example of SLDS stylesheet classes in overridden standard Salesforce

Fig. 14 The process of sending an e-mail to players with information about next match time
Due to these facts, the open source solutions are applied to render the mentioned fields properly. These are a special Visualforce component that displays Lightning styled inputs in Salesforce Classic (Sultan 2014) and the date picker taking advantage of Appiphony Lightning JS library (Yousef et al. 2008). Unfortunately, it was not possible to write New or Edit interface for Tournament Appearance object, since Visualforce component used in the system supports inputs of type Lookup but does not support inputs of type Master–Detail.

5 Top 16 Manager in action

This section demonstrates the practical functionalities of the proposed system in Salesforce platform. It is a framework for main referees of the TOP 16 tournaments. It is presented from the perspective of the system administrator’s account.

When a user (not a system administrator) successfully login to the platform, he/she can see a panel with tabs at the top of the screen. By default, the tab to which the user is redirected is Tournaments tab as it is the main object in the system. The other tabs concern another custom object presented in the system, including Matches, Players, Referees, and Tournament Appearances. There are also two more default tabs Home and Chatter. They are in the platform to allow users saving some notes, marking important dates in the calendar and for interaction with other users as Chatter that can be described as a company intranet. However, the use of these two tabs is neglected in snooker management system as there is only one user, i.e., the main referee created as an end user and a system administrator. The min GUI promoted to the user is depicted in Fig. 15.

This interface allows a user to select a particular tournament and view its details. It is also possible to expand the View list and choose the list view, which displays all records.
according to the given conditions. After a successful creation of Tournament record, a user is redirected to record’s details. It contains all related lists of Matches and Tournament Appearances that are connected with a new tournament. Tournament detail interface has buttons under which there are appropriate functionalities, including: Entries, Matches, Bracket, Mass Email, Results. Figure 16 shows Tournament record interface.

The first step in a tournament management process is to enrolling players to the competition. In our current implementations, there are 20 players, but there might be a necessity in the future for the main referee to add another player. The main referee must tick 16 players that are going to take part in the competition. An updated view of the interface is presented in Fig. 17.

Figure 18 illustrates an interface that shows the desired information about the Matches. Through this interface, the main referee can update matches’ details.

Match management interface allows updating the current situation in each group. Through this interface, a user not only adds the scores of the finished match, but also update its status (Waiting, Match Ready, In Progress, Finished). A user also is able to generate a report in PDF format and assign a time to each match. Every time the score is added, the information is updated accordingly. The reschedule is constructed even in case of inputting a wrong score. The proposed system does not allow assigning In Progress status without a referee assigns it to the match. It also prevents unexpected inputs of score to TOP 16 tournament. Tie score is not allowed. The winner must have 4 frames won. Also, it is not possible to set two matches with status In Progress at the same table. All the aforementioned situations are handled; and the user is prompted with a message on the top of the interface. Every time the main referee updates the time of a single match, the system generates an email to both players with information about match time. It is also possible to send a broadcast email to all players that take part in the given competition.

The last stage of the tournament management process is an update of positions that players took in the competition. Under Results button on the Tournament details interface, there is a custom interface, which displays the final classification of the tournament, as shown in Fig. 19.

To sum up, all the processes that the main referee is interested in are five custom objects defined especially for the purposes of the required functionalities. Initially, the process starts from either adding a new tournament or finding a proper one. Then, invoking management action from a few custom Visualforce interfaces that are provided on the tournament details interface. A user can also view the data about players or referees. On the related lists of those objects, there is information about achievements or performances. For example, players have their positions taken in each tournament, and referees have listed matches that they
Fig. 18  Match management interface in Top 16 Manager

Fig. 19  Tournament results interface Top 16 Manager
Conducted during TOP 16 tournaments. User are informed in case incorrect input data.

6 Conclusions and future work

In this paper, we examined the Salesforce platform capabilities within the context of the real-time service systems and cloud computing. The research work performed in this paper proved that the combination of real-time systems and cloud computing allows building efficient systems that could be used for different purposes. Additionally, the Salesforce platform enables the creation of not only the event-triggered real-time systems with the use of Apex Triggers, workflows and Process Builder but also time-triggered systems. This is because it is possible to define the time-dependent actions using Process Builder. We also developed a Salesforce system, i.e., Top 16 Manager which aims to help managing the processes of the series of TOP 16 snooker tournaments held by Polish Billiards and Snooker Association. The results showed that the Salesforce platform is an environment where it is possible to develop a soft real-time system as private cloud. The developed system is a combination of Software as a Service, from the perspective of the end user, and Platform as a Service, from the perspective of the developer. It should be noted that Top 16 Manager significantly improves managing of TOP 16 snooker tournaments that comprises some functionality that is not available for use by main referees. In the future, we plan to make it generic and usable for other types of snooker tournaments and taking advantage of more Salesforce functionalities such as reports, dashboards or workflows. We also plan to make Top 16 Manager as a component of a larger system dedicated to snooker federations from different countries where snooker competitions take place.

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