Education Beyond the Cloud: Anytime-anywhere learning in a smart campus environment

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***Abstract*—With the advancement in technologies, the last decades have seen a sea change in the way people interact and communicate. For instance, contents, services and applications previously executed locally or on a local network are gradually finding its way to the cloud. As people and environment changes, so must education in order to be able to adapt and embrace to this paradigm shift in the educational landscape. Cloud-based education has thus arisen and has since gathered a lot of interests in the recent years. This paper thus describes the issues that need to be solved in order to arrive at cloud education, including integration, ownership, security and assessment, and offers a holistic approach to cloud education. It also put forward a new perspective in embedding mobile cloud education, an amalgamation between cloud-learning and mobile-learning domains, within a holistic intelligent campus environment.**

***Index Terms*—Educational technology, cloud learning, cloud education, mobile learning, iCampus**

I. Introduction

Societal changes have increased in pace during the last fifty years or so. This phenomenon applies world-wide, but even more so to countries like the UAE, which has developed from a nomadic culture to a high-tech society in time-lapse. As a result, the way people approach education, particularly in terms of learning and teaching, have changed accordingly. The challenge within education is to adapt to this change, rather than to resist to keep a status quo, so as to suit the new educational landscape and enable students to take advantage of new technologies and the skills they acquired with them [1].

The focal point where many of these new technologies come together is cloud computing. Cloud computing is one of the major drivers of change in the industry. While many different definitions exist, it generally denotes the transition from local computing offerings to external ones. These offerings can be fairly simple, services such as virtualised desktop, data storage, and email or whole applications such as office application suite, security package, and collaboration tools.

The move from locally hosted offerings to cloud computing has many consequences. Large one-off setup costs for infrastructure are replaced with regular monthly fees. This means that small schools and universities can make use of these offerings, that otherwise would be impossible to run due to the large initial cost. This is especially true in regions like the UAE where many of its schools and universities are relatively small in size, which consequently could not justify the return-on-investment in the high initial setup cost. Furthermore, as cloud hosted offerings are shared across different schools and universities, novel applications and services can be implemented, such as collaboration tools between students of different institutions, social communities, and more. In fact, this has complementary synergies with the UAE National Research and Education Network (NREN), called Ankabut[1], whose aim is to connect not just the local academic institutions together, but also with the global research and education communities.

A number of online only services such as blogs, microblogging and social networks are coming of age and strongly influence the way people and businesses interact within and with each other. As a result, opportunities arise to not only "do the same online" but also to exploit the inherent advantages of cloud computing, in particular with respect to collaboration and interaction between services and people. However, several issues need to be addressed before such cloud education proposition could become a reality:

- Integration - Incorporation and mobility of different tools/services/data.
- Assessment and Learning - Within a networked class, assigning who did what, who learned what becomes more difficult.
- Identity and Ownership - New definitions are needed for what constitutes original work, individual work, and plagiarism.
- Security and Privacy - Preserving means to protect data, identity, and means to distinguish between professional and private data that is on the cloud.

The rest of this paper is structured as follows. We first give an overview over cloud, cloud education, and mobile cloud education, and its role within the campus of the future (Section II-B). We then address each of the above-mentioned issues individually in Section III. Note that the intention here is not an attempt to provide a working solution, but instead point to methods and technologies that could allow us to address these issues in the near future. Finally, we offer our take on the state of mobile cloud education in Section IV.

[1] http://www.ankabut.ae

II. Mobile Cloud Education

In order to put forward the issues and concepts described in this paper, we first give an overall view of the main elements relevant to this work.

A. Cloud Computing

While there are several definitions in what constitutes cloud computing (e.g. [2]–[4]), they generally agree on a number of key aspects. First of all, three service models can be identified. *Software as a Service* (SaaS) is the most abstract model, where the consumer uses web-based applications that are hosted by the cloud provider. The consumer has no control over the underlying infrastructure. Examples are Google Docs[2] or Microsoft Office 365[3]. Closer to the metal is *Platform as a Service* (PaaS), where the cloud provider, instead of providing fully functional applications, provides a set of services and functionalities together with a development environment which allows the consumer to develop applications using the provided services. While this gives the consumer more control, the provider still dictates where and how the services are run on the servers. Scalability is generally relegated to the services. Examples are the Google App Engine[4] or Microsoft Azure[5]. Finally there is *Infrastructure as a Service* (IaaS). There, the cloud provider essentially allows the consumers to run virtual machines on their infrastructure, in addition to further core provisions such as storage. The consumer has full control over their virtual machines, including the computing resources provided to each instance of a machine. Scalability and elasticity is in the hands of the consumer who has to ensure that enough instances of his system runs, and that the deployed system is actually able to take advantage of replication of virtual machines. Examples are Amazon Elastic Compute Cloud (EC2)[6] and Rackspace[7].

Apart from that, there is generally a distinction in deployment. With private clouds, the infrastructure that hosts the cloud is owned and operated by the consumer. Public clouds are independent companies that offer to run software on their infrastructure. Most of the examples above are public cloud offerings. Finally, hybrid clouds combine private and public clouds – either by running a small private cloud that has "spill over" capabilities, or by outsourcing some of the services to public clouds while keeping, for example, services that are operationally-critical or deal with sensitive-data on site. Depending on the needs of the consumers, such consideration essentially forms part of the trade-off evaluation in determining which and how much of the services that can be hosted on the cloud.

In addition to these aspects, cloud computing is characterized by properties such as elasticity and resource pooling. Elasticity means that resources can be quickly and often automatically scaled up, horizontally or vertically. Resource pooling means that a cloud infrastructure can run various (independent) services. In the case of multi-tenancy models, these can belong to different consumers, while single tenancy models only allow one consumer on a given resource. Such resources can either be computing, storage, memory, specific services or virtual machines. Note also that, as cloud computing virtualizes the actual location of the used services, they can generally be used at any place and at any time (at least in the case of public cloud installations).

It is also worth noting that a simple web-based installation cannot automatically be considered a cloud offering (even though the consumer might not be able to tell), because it lacks the elasticity and scalability inherent to cloud computing.

B. Mobile Cloud Education

Mobile cloud education is a relatively new and leading edge research and innovation — a term coined to signify the novel unification of two main domains of educational research fields, namely cloud learning and mobile learning, so as to be able to realise and extract its holistic cross-synergies between the two. The former is the introduction of cloud computing in education, in its delivery of the appropriate cloud contents, services and applications for learning purposes; the latter, on the other hand, focus on anytime-anywhere context-aware learning via portable devices, such as mobiles, tablets and laptops, by harnessing the smart contextual capabilities of the devices. Figure 1 depicts an overall view of the concept.

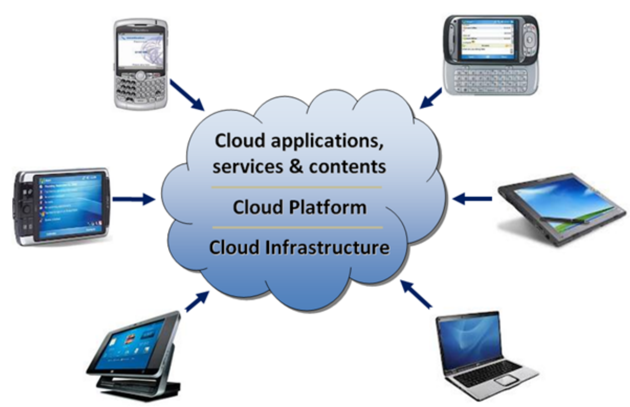

Fig. 1. Diagrammatic illustration of mobile cloud education concept

The application of cloud computing in education have already been discussed in numerous publications, focussing on the different aspects of learning (see e.g. [5], [6]). Also several companies have seen opportunities in the changing and emerging market for cloud based educational offerings. For instance, a number of large software enterprises offer some versions of cloud computing for education, for example IBM [7] and Microsoft [8], as well as more specialized firms, for example LoudCloud[8] which offers a cloud based learning management system. Related are efforts by BT who

[2]http://docs.google.com
[3]http://www.office365.com/
[4]http://code.google.com/appengine/
[5]http://www.microsoft.com/windowsazure/
[6]http://aws.amazon.com/ec2/
[7]http://www.rackspace.com/
[8]http://loudcloudsystems.com

is presently conducting a cloud-education pilot field trial among a small group of schools in the UK. Furthermore, many researchers develop tools that take advantage of the various features of the cloud, often focussing on either specific properties like collaboration [9], [10], specific technologies such as wikis [11]–[13], specific applications, for example creative writing [14] or argumentation [15], or specific tools such as learning management systems [16], [17], for example the Cloud Learning Environment[9] that is based on Google Apps.

C. The Campus of the Future

The global educational landscape is changing; some have termed it as the "climate change" in education. This paradigm shift in education is imminent and has since gathered a lot of interests, among the academics and the industry, in an attempt to bridge the technological gap in the educational sector. To cope with the changing education environment, Etisalat BT Innovation Center (EBTIC[10]) —a joint research centre between British Telecom and Etisalat, in partnership with Khalifa University of Science Technology and Research— has put forward an international iCampus initiative [18] which is aimed to create/adapt a holistic next-generation intelligent campus environment that is suited for the 21st century. A holistic intelligent campus framework has also been derived, encompassing comprehensively all aspects of a smart campus environment (see Figure 2). A number of pillars have been

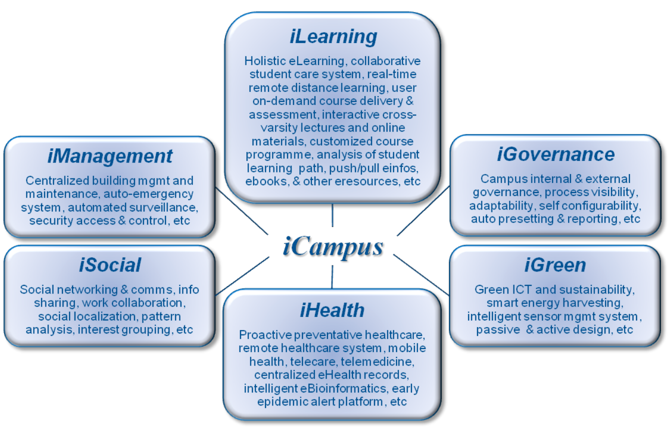

Fig. 2. Pillars of the intelligent campus framework([18])

defined in the iCampus framework, namely the iLearning, iSocial, iGreen, iHealth, iManagement, and iGovernance aspect of the campus. Each of which serves to ensure the proper operation of each function of the intelligent campus environment, which briefly covers the following aspects:

1) iLearning: supports the students and faculty in their task of acquiring knowledge. This includes providing means in the preparation and delivery of contents, but also (and maybe more importantly) providing means for the students to learn, individually or collaboratively, and access to pertinent contents from anywhere and at anytime. Mobile cloud education has a great impact on this pillar.

2) iSocial: focuses on social networking and communities within the campus, hence enabling informal social interactions between people. In here, there are three main areas of concern: campus's core curriculum, extra curriculum, and general social activities.

3) iManagement: encompasses more physical aspects of a campus, such as smart building management, student access and control, security and surveillance, as well as emergency response.

4) iGreen: covers aspects of green ICT and sustainability, smart energy harvesting, and resource management

5) iGovernance: takes care of the organizational aspects of the campus, providing process management, change management and adaptability, and administration aspects.

6) iHealth: finally provides preventive healthcare, remote healthcare and monitoring, and epidemic alert systems.

All of the above pillars, while looking at (more or less) the distinct aspects of a campus environment, come together synergistically under the iCampus umbrella for a holistic approach to the intelligent campus. An iCampus platform (see Figure 3) connects the distinct elements to enable higher–order functionalities that draw from aspects developed or provided by the different pillars.

For example, localization information (from sensors managed by a building management system in the iManagement pillar) can be used in conjunction with the student enrolment data and class locations (coming from a student management system under the iGovernance pillar) to automatically send personalized reminders, to students enrolled in classes, that are timed such that it allows adequate time for the student to get from their current position to the class (or are not sent if the student appears to be close to the classroom or moving towards it). Course materials can automatically be downloaded to the notebook of the student, together with a unified list of relevant bookmarks and notes that fellow students have collected. Attendance can automatically be logged when a student enters a smart classroom, and students can join remotely using any available device (such as mobile phones or desktop computers). These are just some of the scenarios that can be easily implemented within a holistic intelligent campus environment.

III. Challenges

A. Integration

As noted above, there are a host of offerings that could provide (parts of) an intelligent campus. The challenge is to integrate the different services together and make them communicate with each other. For example, many universities offer email, file storage, and learning management systems like Moodle or Blackboard. Additionally, there are student information systems such as Banner, content management systems, and many others on the network. More often than not, each of these typically has different authentication mechanisms, and information needs to be entered multiple times. For instance,

[9]http://gcloudlearn.appspot.com/

[10]http://www.ebtic.org

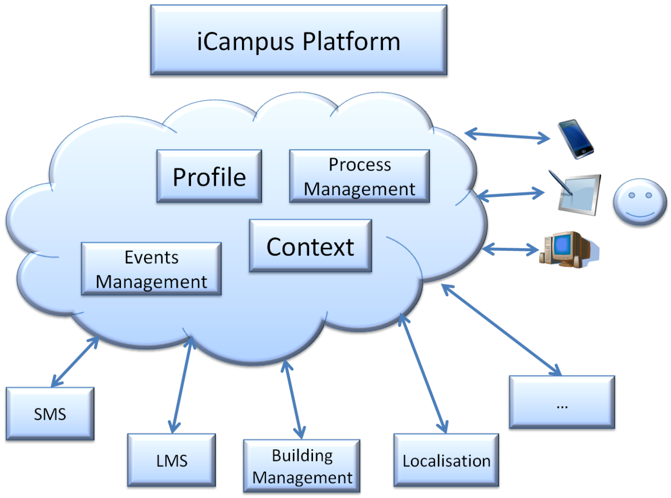

Fig. 3. The iCampus platform

one has to re-enter courses that exist in the student information system in the learning management system, including the enrolment of students and the relevant materials for each course. These examples of course only scratch the surface, but it should be apparent to the readers that the scenarios as sketched in Section II-C require the integration of not only the software but also the hardware and localized services which hence necessitates a different approach.

Two different aspects of integration need to be addressed – services (or functionality) and data (or information). The integration and interoperation of services is generally approached using service oriented or agent oriented approaches. Essential aspects of service orientation are decoupling of interface and implementation as well as composability [19]. Many software packages provide interfaces to their functionalities that can be accessed by other services, using, for example, WSDL (Web Services Description Language) or RESTful (REpresentational State Transfer) services.

However, for services to interact, they first and foremost need to "understand" the data that they have to consume and process. The semantic web augments data with semantic information. While originally, data was semantically described using logic-based ontologies like OWL: Web Ontology Language (see e.g. [20]), more recently the linked data initiative advanced a less formal approach where items in databases are interlinked, thereby essentially creating a huge distributed database [21].

Similarly, the semantic web not only aims at adding meaning to data, but also to augment services with semantic annotations, thereby enabling intelligent service usage, automatic service lookup and autonomous orchestration [22]–[25]. Where services are generally either used in isolation or by rigidly defined processes, agents add some flexibility to the mix [26], [27] through the concept of goal orientation and the use of semantics [28], [29]. In the context of education, agent technology has been used in various settings, for example in [30]–[33].

For the campus of the future, the interplay between different services and the availability of these anytime-anywhere services from any devices is clearly a requirement. Additionally, students and faculty expect not only to have access to these services, but that data is available and usable by different services, so that it is left to the user to combine and mix data and services, rather than having to follow a fixed and limited set of processes. Cloud computing thus plays a vital role in enabling the availability of these data and services within the next generation campus environment.

B. Assessment and Learning

In terms of learning and teaching, new models need to be considered. On the one hand, the wealth of information and the ease with which data can be found requires new skills for analyzing the relevance of sources, and identifying the original research. Also, the sheer amount of data makes it harder for students to actually produce original writing without falling into the plagiarism trap, particularly within the traditional teaching and assessment environments [34].

On the other hand, the production of knowledge and its dissemination is greatly simplified using tools such as blogs, twitter, and other social networking tools. These allow the student to participate in the academic discourse from an early onset, presenting his or her work to peers (classmates and outside researchers), and enabling a form of apprenticeship where students can follow the thoughts and developments of ideas of more senior researchers, in order to try and emulate it — be it within a formal school setting or within an informal outside-school setting [35], [36].

There are a number of different theories of learning, but recently the social learning view [37], [38] has gained much attention. It is based on a constructionist view, whereby we learn by actively creating knowledge based on experience, as opposed to passively receiving it from the teacher. This notion is then refined with learning by observing and modelling the behaviour of others in social learning. Collaborative learning assumes that knowledge can be created by interacting and sharing experiences. It allows the learners to assume various roles including one of a teacher, which is deemed to be another effective method of learning [39]. As such, the authors in [40], for example, have designed teaching agents so that the students can teach in order for them to learn.

As we encourage and promote social interaction and collaborative learning, we need to ensure that the necessary adjustments are reflected in the way that the student assessments are carried out, as well as the tools that we have provided [12], [41]. Take for instance, additional care has to be taken to assess not only the final product but also the process of collaborating [42], [43], or additional means has to be taken to ensure that the individual student's work can be identified within a collaborative assignment setting [44].

As data and services are moved to the cloud, it not only enables new ways of interaction with data, learning objects, and services (as well as fellow users), but it also allows tracking of students' behaviour and information's usage. This in turn opens up the ability to conduct in-depth analysis of each individual student's learning behaviour. Any abnormal deviation can hence be identified and brought to the attention of the relevant parties-of-concern, thereby providing the students with more personal support and assistance. Novel ways of assessment can also be implemented based on the students' usage of learning objects or their interaction pattern with one another.

C. Identity, Ownership, Privacy and Security

On a more abstract level, the move from conventional paper and blackboard based learning and teaching methods towards the use of computers and internet-based (cloud) applications poses a whole new set of opportunities – but also a new set of challenges.

As discussed in the previous section, although the availability of information enables the students to quickly access a wealth of information, it also becomes harder to identify original thought. Related to this is the question of ownership of derivative works. Widely publicized examples where copyright owners took down private videos on Youtube because they used copyrighted songs as background music[11] to questions of where original research ends and plagiarism starts.

Further, through the continuing integration of social networks and the expansion of the internet into more and more areas of one's personal lives, it becomes harder to separate relevant (professional) and irrelevant (private) data and interaction. While the issue of separation is beginning to be addressed by social networks such as Google+ and also Facebook with its lists feature, it still puts the burden on the user, especially when various tools are increasing in many contexts (professional and private), where it is not easily possible to just create numerous online personae or use different services for each context. Approaches like web of identities [45] or federated identities [46], amongst others (for an overview see e.g. [47]) can help to alleviate this issue. There, users have different aspects of their digital identity hosted by various identity providers. Each contains information such as the user's identity and personae (profile data, social graph, files, presence information etc.). Connections between different providers are under the control of the user, so he can manage which information is shared and with whom. While this is a very powerful solution, the challenge lies in the manageability from a user perspective, as these interactions could become increasingly complex.

In certain regions, cultural aspects have to be taken into consideration as well, such as the use of video transmission, or the interaction between males and females. Any viable system needs to ensure that such cultural sensitivities are taken into consideration. This can be done by completely obscuring the identity and gender whenever possible, or by allowing for gender-based selection criteria.

Closely related is the issue of security and privacy. Generally, these have a number of objectives, such as integrity, confidentiality, authentication, authorization, and non-repudiation [48]. It is beyond the scope of this paper to go into each in detail. But to demonstrate how these objectives interact, consider the following instance: for any exam session, it must be ensured that the person taking the exam can be identified to be the one supposed to take the exam (authentication), be able to access the exam (authorization). Further it cannot be doubted later that it was indeed that person doing the exam (non-repudiation), that the answers have not been changed or modified (integrity), and that the results are kept private (confidentiality).

In the context of interaction between users, especially within the education context, the notion of trust and reputation is also important. Trust denotes the ability of users or machines to make statements about the probability that the information is correct, or that a digital ID is correlated to a certain person, while reputation is generally what is said about an object's or a person's standing [49], [50].

Any holistic approach to the campus of the future will have a myriad of services and applications that store various bits and pieces of information about the students and faculty. Some of them are under the control of the university, while others are provided by third parties. Any such system needs to ensure that the data is protected and can only be accessed by authorized users. Federated identities and similar approaches are hence a requirement for the next generation campus environment. Cloud computing, while currently often closed, can support shared ID concepts and allow the providers as well as the users to control access to services and data.

[11] See e.g. Lenz vs. Universal: https://www.eff.org/cases/lenz-v-universal, a legal dispute about a video showing little children dancing to a song.

IV. Conclusion

In this paper, we discussed the relevance of cloud computing for the global education sector in the context of the campus of the future. We identified a number of challenges that need to be addressed, and showed how cloud computing can provide parts of the holistic solutions. A new perspective in the application of mobile cloud education within the next generation intelligent campus environment has also been introduced.

With regards to the international iCampus initiative that EBTIC is leading, different aspects of the six-pillar campus framework, in particular the use of mobile cloud education, are presently being investigated. A number of promising projects have also been put in place as well as implemented that will bring us closer to making the above a reality.

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