INTERACTIONS NOVEMBER–DECEMBER 2016 VOLUME XXIII.6

Association for Computing Machinery

Human Computer ~~Interaction~~ INTEGRATION

Special Topic on Sustainable HCI Education

Design Without a Future

Citizen Interaction Design

In this forum we celebrate research that helps to successfully bring the benefits of computing technologies to children, older adults, people with disabilities, and other populations that are often ignored in the design of mass-marketed products.
— Juan Pablo Hourcade, Editor

A Conceptual Framework for the Analysis and Visualization of Uruguayan Internet for Education

Cristóbal Cobo, Fundación Ceibal, **Matías Mateu,** Plan Ceibal

Uruguay, a country of 3.4 million people, has a per capita GDP of 21,200 USD [1]. In the past decade, the Uruguayan government has made significant investments in its digital inclusion strategy. Plan Ceibal became the first nationwide ubiquitous educational computer program in the world based on the 1:1 model (one computer per student) [2]. The plan showed measurable impacts on digital divide reduction, centering around three pillars: equity, learning, and technology.

With regard to Internet access, the Economic Commission for Latin America and the Caribbean classified Uruguay as the most egalitarian country in this region [3]. Up to 72 percent of homes have Internet access. As of 2014, Uruguay registered 24.58 fixed broadband subscriptions per 100 people. As a reference, Organisation for Economic Co-operation and Development (OECD) member states registered 28.18 subscriptions per 100 people, while Latin American and Caribbean countries recorded only 9.83 [4].

As of 2007, Plan Ceibal has covered all public schools, providing every student and teacher in kindergarten, primary, and middle school with a laptop or tablet and Internet access in their classrooms (connectivity is provided in over 2500 public education centers). To date, Plan Ceibal has close to 750,000 beneficiaries, each with their own device. Since 2011, the Plan has focused on providing the learning community with a wide range of digital content to enhance the teaching and learning process, most notably learning-management systems, a mathematics adaptive platform, remote English teaching, and an online library. Today, Plan Ceibal operates and integrates large-scale databases fed by a number of management and educational activities.

During the second half of 2014, the Plan Ceibal network implemented a national bring-your-own-device (BYOD) policy focused on the secondary education system. It provided access in 400 facilities, benefiting 300,000 users. This policy also allowed students and teachers to access the network from their own devices, which may be one of the drivers behind the explosive increase in connections per antenna [5]. It also suggests that even though the number of connections to the network has doubled (on average) every year since 2011, the ratio of *traffic per connection* [6] dropped consistently in the secondary education system.

Insights

- This work provides an overview of a unique national-scale education and technology monitoring system to be built in Uruguay.
- Different explorations are being conducted to adopt alternative metrics to monitor learning regardless of where it takes place. This work aims to provide effective information tools for that purpose.

This work is conducted within the framework of previous large-scale "big data"-oriented initiatives from Plan Ceibal and the Ceibal Foundation [2,5]. These, among other initiatives, will evolve into the creation of a learning analytics data center focused on providing information tools to support teaching practices, a project in partnership with the Inter-American Development Bank.

Currently, in the academic [7] but also the industrial [8] sector, different explorations are being conducted to adopt alternative metrics for this purpose. In this context, Plan Ceibal today is facing a turning point focused on diversifying the tools and metrics it uses to analyze learning regardless of where it takes place.

OBJECTIVES

The general objective of the work we discuss here is to generate evidence-based knowledge that can help Plan Ceibal make more informed decisions in their upcoming strategies. The idea is to design a conceptual framework to be used for conducting advanced analysis of educational-system datasets to better understand students' and teachers' online teaching and learning practices throughout different virtual learning environments.

Our first objective is to present the key aspects and dimensions of the *global monitoring system* for network visualization to be deployed in Uruguay by Plan Ceibal. This monitoring system integrates *access* and *use* variables such as location of connection, type and brand of

device (provided either by Plan Ceibal or by users), content and services requested, traffic load, and number of simultaneous connections, among others.

Our second objective is to present a case study based on a synthesis of the work in [5] in which *access variables* are examined. We then describe a number of conclusions on the potential for strategic planning in the field of educational technology.

The global monitoring system is conceived as a user-oriented information tool that can help school principals and educators interested in understanding how the Internet is used in their schools. An additional goal is to serve end users through personalized tools with comprehensive information on their practices and preferences, and based on that to help them make better decisions.

KEY VARIABLES OF ANALYSIS AND VISUALIZATION

The main variables we considered in the analysis are *access* variables and *use* variables. Access variables include upload and download traffic (per site, user, or application), number of connections (per site, user, or service), and multiple families and generations of devices (laptops, tablets, smartphones, others). Use variables include taxonomy of traffic (pedagogical or educational, recreational or entertainment, among others), origin and destination of traffic (school, home, domestic, or international, for instance), and content production versus consumption (either created, acquired, or modified per user).

The group of variables related to access illustrate, for instance, which online services demand more Internet bandwidth and access points than others, whereas the use describes the type of use as well as the motivations for getting online.

ACCESS VARIABLES: A CASE STUDY

The following case study, an excerpt of Mateu's 2016 study [5], focuses on a set of critical variables. Although not all the variables listed are included, the study contains information drawn from Plan Ceibal's networks from 2011 to 2015.

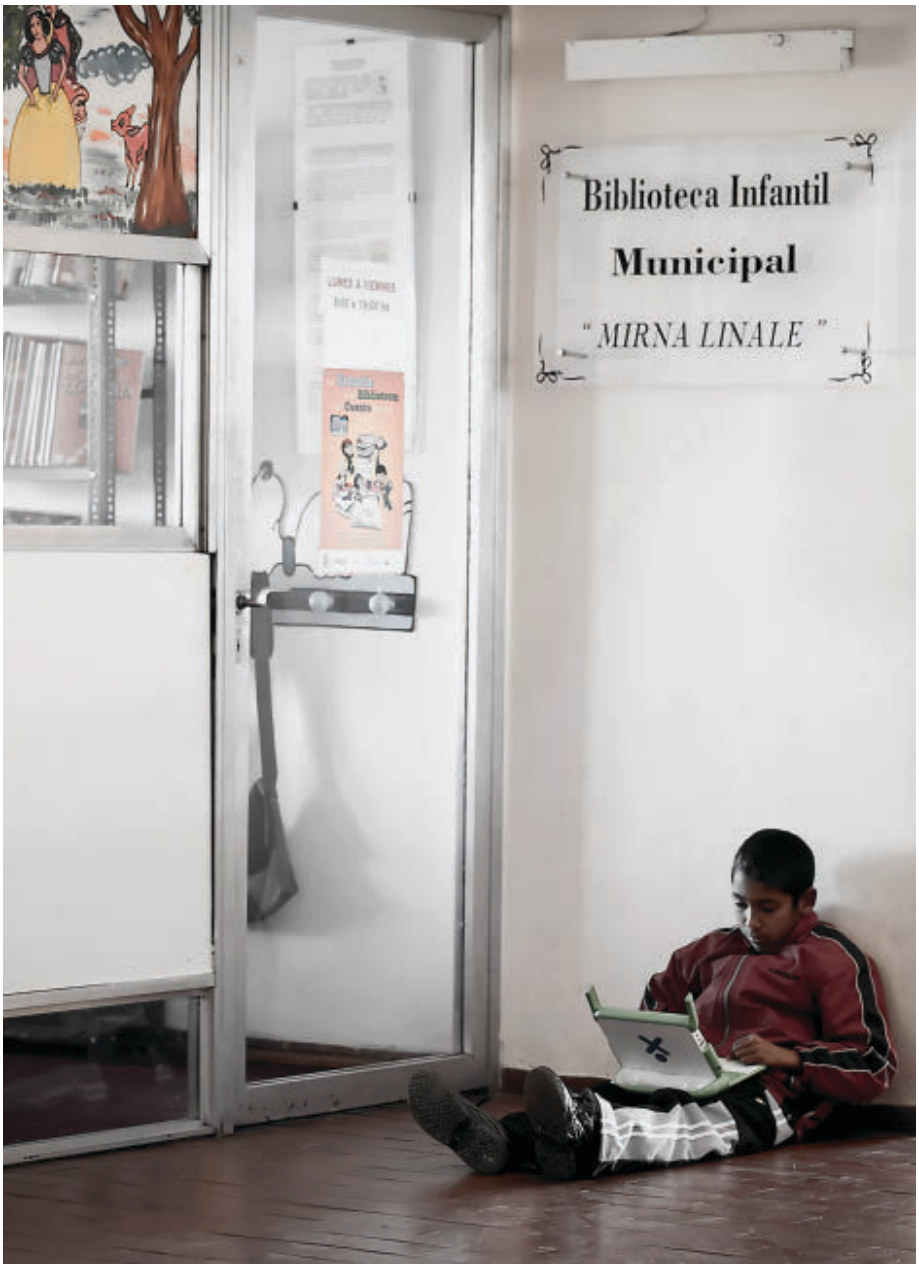

IMAGE BY GONZALO G. USETA / FLICKR

We developed the case study in order to answer the following question: *What was the evolution of the aggregate demand for Internet access in the Plan Ceibal network between 2011 and 2015, and what is the projection for 2016 to 2019?*

Plan Ceibal is facing a turning point focused on diversifying the tools and metrics it uses to analyze learning regardless of where it takes place.

Design. This case study includes the universe of *urban* schools in the primary and secondary education systems. This includes 1,535 facilities, each with its own wireless LAN covering every classroom [9].

The variables we tracked were *download internet traffic*, *upload internet traffic*, and *simultaneous connections*. These variables were collected via a network monitoring system hourly every day since 2011 and stored in Plan Ceibal's database. We took a sample of each variable at *busy hour* [10] to conduct our analysis.

The number of potential users is

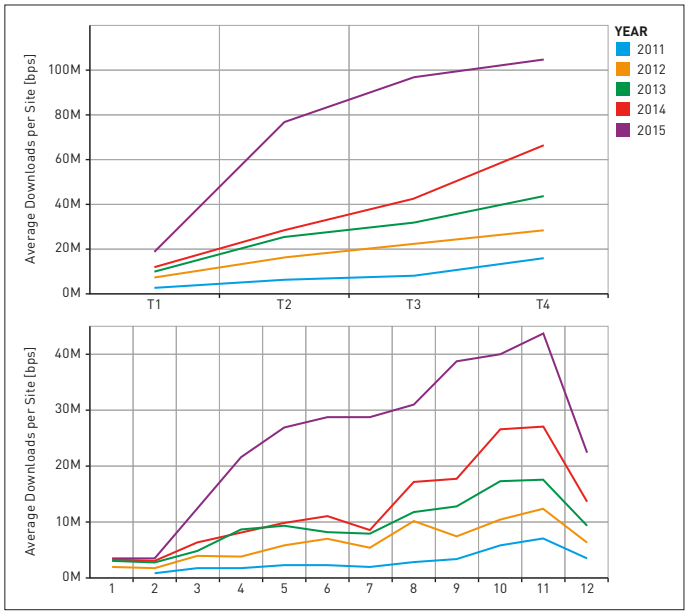

Figure 1. Pattern analysis graphs.

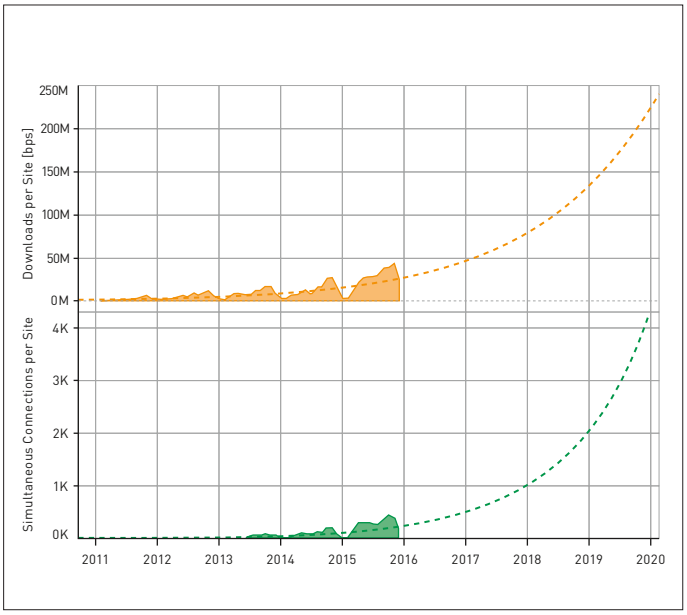

Figure 2. Series analysis graphs.

625,000. Our records indicate that during busy hour there were 120,000 simultaneous connections [11] throughout Plan Ceibal's network.

Analysis. The *pattern analysis* focuses on regularities, cycles, and seasonal effects, as shown in Figure 1. We present two charts; the first one, aggregated in quarters, shows a consistent increase in demand of traffic from quarter to quarter. In the second chart, the aggregation is by month, showing a dramatic decrease during summer break (December to February), and a moderate decrease during winter break (July).

The *series analysis*, shown in Figure 2, focuses on evolution, trends, and projections. The analysis of traffic and connections per school was calculated (i.e., ratio between download and upload traffic, ratio between download traffic and simultaneous connections, average traffic per student).

The relationship between demand of the network (traffic and connections) and demand of infrastructure is included in the analysis. This information illustrates the requirements that the network supply (Plan Ceibal) has to consider when planning the evolution of the demand.

Figure 3 illustrates the evolution of demand and capacity of Internet bandwidth. Demand has increased about four times in the past two years, whereas capacity has almost doubled in the same period.

Preliminary results. Here we summarize some of our early findings from this on-going research.

Global Plan Ceibal Internet access. Plan Ceibal's Internet download traffic has grown 13 times between 2011 and 2015. CISCO VNI reported that global Internet download traffic has grown five times in the same period. In other words, Plan Ceibal's Internet use has grown about 2.5 times faster than the global Internet.

Download and upload traffic per center. Download traffic has doubled every 18 months during the period between 2011 and 2015 (average annual growth rate of 68 percent), while upload traffic also doubled every 16 months in the same period (average annual growth rate of 82 percent).

Simultaneous connections per center. Simultaneous connections per site have doubled every 12 months between 2011 and 2015 (average annual growth rate of 105 percent).

Plan Ceibal has a number of stakeholders who can be considered end users: educators and students, but also parents.

Download/upload traffic per center. The download/upload ratio has been 11 to 1 on average between 2011 and 2015.

Demand and supply. The ratio between download bandwidth demand and the installed capacity (supply) was 40 percent in 2015 and is growing at a 12 percent average rate annually. The Wi-Fi capacity grew at a 57 percent average rate between 2011 and 2015, whereas Wi-Fi demand (connections growth) grew at an 88 percent average rate. Projections suggest a global saturation of the Plan Ceibal Wi-Fi connections by the end of 2019.

CONCLUSION AND FUTURE WORK

Today's growing professionalization of the educational technology sector in Uruguay demands the creation of novel forms of organizing and analyzing the use of Internet services. Here we aimed to categorize critical dimensions that Plan Ceibal needs to consider when implementing future global monitoring systems. Both access and use were considered among the key variables to examine how the network is being used. We also described a case study illustrating data between 2011 and 2015.

Plan Ceibal has a number of different stakeholders who can be considered end users: educators and students, but also parents. Having an end-user-oriented global monitoring

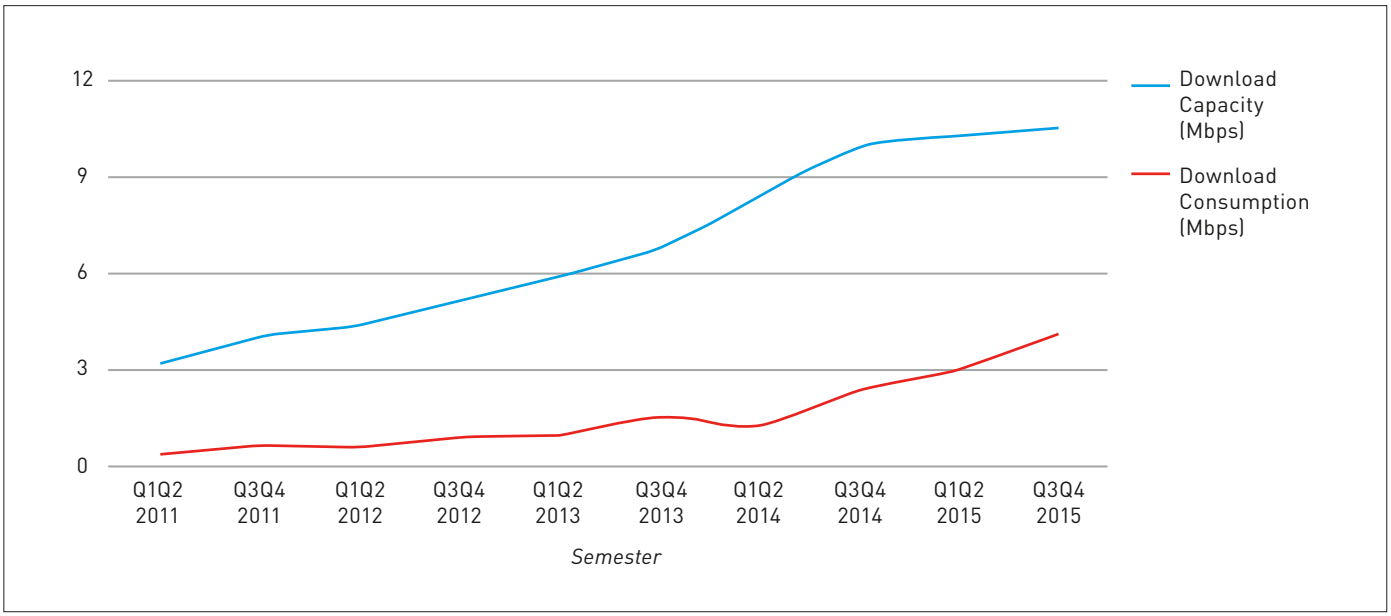

Figure 3. Demand and capacity graph.

system could help educators understand how and where learners spend their time online and what tools are the most popular among learners. Also, it can benefit students and parents by identifying their online preferences, enabling them to make more informed decisions regarding time and effort optimization, and if needed, self-regulation.

Possible queries that could be explored: Is Plan Ceibal's ecosystem moving from being driven by *supply* to being driven by *demand* in terms of hardware and software? Can users be considered more content consumers than content creators? What are the differences between software provided by Plan Ceibal and popular external software?

The insight from the rest of the variables will enable Plan Ceibal to gain a more comprehensive understanding of how the network is used and to improve its decision-making process and policies, not only with respect to IT infrastructure but also in terms of device (1:1 model) and application strategies, as well as future innovations.

Finally, the whole approach is intended to consider privacy and ethics by design [12]. Ethical reflection and privacy analysis are taking place early on in the design and development process in order to ensure the whole system will achieve human considerations, not just technical ones.

Endnotes

1. World Bank. International Comparison Program database. Database updated on July 7, 2016.
2. Bailon, M. et al. How can Plan Ceibal land into the age of big data? *Proc. of Fourth International Conference on Data Analytics*, 2015; www.slideshare.net/cristobalcobo/how-can-plan-ceibal-land-into-the-age-of-big-data
3. Caribe, C.E. para A.L. y el. La nueva revolución digital: de la Internet del consumo a la Internet de la producción, 2015; http://www.cepal.org/es/publicaciones/38604-la-nueva-revolucion-digital-la-internet-consumo-la-internet-la-produccion
4. Information provided by International Telecommunication Union, World Telecommunication/ICT Development Report and database: http://data.worldbank.org/indicator/IT.NET.BBND.P2?view=map
5. Mateu, M. *Plan Ceibal 2020: Future Scenarios of Technology and Education*. Unpublished master's thesis. Universidad de la República, Facultad de Ingeniería, Uruguay.
6. The amount of download/upload traffic that carries a connection to the network in average.
7. See the European Learning Analytics Community Exchange (LACE): www.laceproject.eu/lace/
8. See the 1st International Workshop "New Metrics for Evaluation: Towards innovation in learning" organized by Ceibal Foundation in Uruguay in April 2016: www.fundacionceibal.edu.uy/en/news/1st-international-workshop-new-metrics-evaluation-towards-innovation-learning-edumetricas
9. For a comprehensive understanding of Plan Ceibal's network architecture visit (spanish) http://blogs.ceibal.edu.uy/tecnologia/redceibal/
10. *Busy hour* means statistically the hour of the day the network registers greatest use in terms of traffic and connections.
11. Up to two connections per user are allowed in the network.
12. Drachsler, H., Greller, W., Griffiths, D., Hoel, T., and Kickmeier-Rust, M. Is privacy a show-stopper for learning analytics? A review of current issues and their solutions. *Learning Analytics Review 6* (Jan. 2016); http://www.laceproject.eu/learning-analytics-review/privacy-show-stopper/ http://www.laceproject.eu/learning-analytics-review/privacy-show-stopper/

Cristóbal Cobo is director of the Center for Research at the Ceibal Foundation in Uruguay and associate researcher at the Oxford Internet Institute, University of Oxford. He has over 10 years' experience coordinating research on innovation, open knowledge initiatives, and the future of learning in more than 20 countries.
→ ccobo@fundacionceibal.edu.uy

Matías Mateu is a telecom engineer and technical manager at Plan Ceibal. He has led the implementation of infrastructure and new technologies in the Uruguayan Education System for nine years. He also co-leads Plan Ceibal's strategy to develop big data analytics and prospective processes of #edtech.
→ mmateu@ceibal.edu.uy

DOI: 10.1145/2998387

Computing Reviews

Connect with our Community of Reviewers

"I like CR because it covers the full spectrum of computing research, beyond the comfort zone of one's specialty. I always look forward to the next Editor's Pick to get a new perspective."

- Alessandro Berni

Association for Computing Machinery

ThinkLoud

www.computingreviews.com