EDUCAUSE
CENTER FOR APPLIED RESEARCH

IT Infrastructure in the Bring-Your-Own Everything (BYOE) Era

Research Report

January 29, 2013

Eden Dahlstrom, EDUCAUSE

Stephen diFilipo, Cecil College

The burgeoning consumer-tech market is creating new challenges for higher education IT departments.
—*Jennifer Demski,* Campus Technology

According to Gartner estimates, 515 million smartphones and 131 million tablets were sold by the end of 2012.[1] Smartphone ownership among undergraduate students increased from 55% in 2011 to 62% in 2012, and nearly twice as many undergraduate smartphone owners in 2012 than in 2011 said they use these devices for academic purposes.[2] These data confirm what is seen by IT professionals as they tour their institutions. We are living in the era where affordable, easy-to-use, and readily accessible technologies facilitate a bring-your-own everything (BYOE) standard. This "consumerization of technology" is setting a new standard in which students, faculty, and staff bring their own devices, software, apps, and cloud-based technology to create a personal computing environment. This consumerization raises understandable concerns about IT infrastructure, planning and governance, security and compliance, support strategies, teaching and learning, and fiscal considerations (see Figure 1).

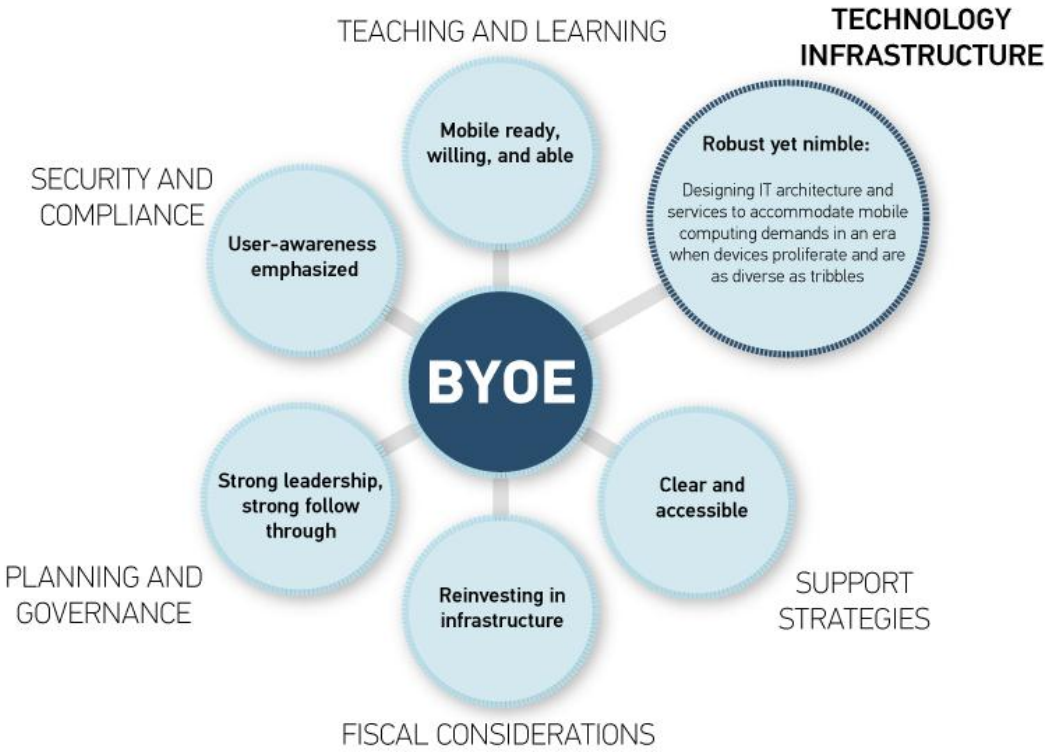

Figure 1. ECAR Framework for Studying BYOE

ECAR is addressing these issues by conducting research on how the consumerization of information technology has opened the doors to a bring-your-own-computing-environment culture and the subsequent impact and opportunities for higher education. A full ECAR report will explore each of the content areas depicted in Figure 1 in greater detail. ***This mini report provides a synopsis of the current BYOE computing environment issues that relate to IT infrastructure in higher education*** by addressing these questions:

- What are the most *important IT infrastructure issues* to higher education institutions?
- What are some *exemplary practices* to handle or manage IT infrastructure issues?
- What *strategic innovations* are here now and on the horizon for IT infrastructure because of the consumerization of IT?

These findings will be supplemented in the final ECAR report with the results of a recent ECAR survey about BYOE practices in higher education. The survey data will provide an understanding about the current state of policies, practices, and experiences of BYOE in higher education and will also provide insight about the future plans for, and implications of, BYOE.

Findings

> There are more choices for the enterprise users, and our job as the CIO is to enable those devices in...a short term...a few days and weeks. We believe that bring-your-own-device will be mainstream and in full execution in 2013.
>
> *—Oliver Bussmann, "SAP CO Explores Consumer Technologies Impacting the Enterprise at CES 2013"*

The Bussmann quote above applies to higher education as much as it does to any business or industry. In speaking with IT professionals about the consumerization of IT and BYOE, ECAR was able to identify the most important issues (infrastructure as "middleware"), exemplary practices (robust yet nimble), and strategic innovations (both present and on the horizon) for BYOE IT infrastructure. In what follows, each of these three areas is addressed. The final ECAR report will supplement this material with findings from the member-participant BYOE current practices survey.

IT Infrastructure as BYOE "Middleware"

Traditional concepts of IT infrastructure include a combination of facilities, hardware, software, and networks that exist for the purposes of supporting, controlling, monitoring, developing, testing, and delivering information technology services.[3] For BYOE, the most important aspects of IT infrastructure are the middleware components (see Figure 2).

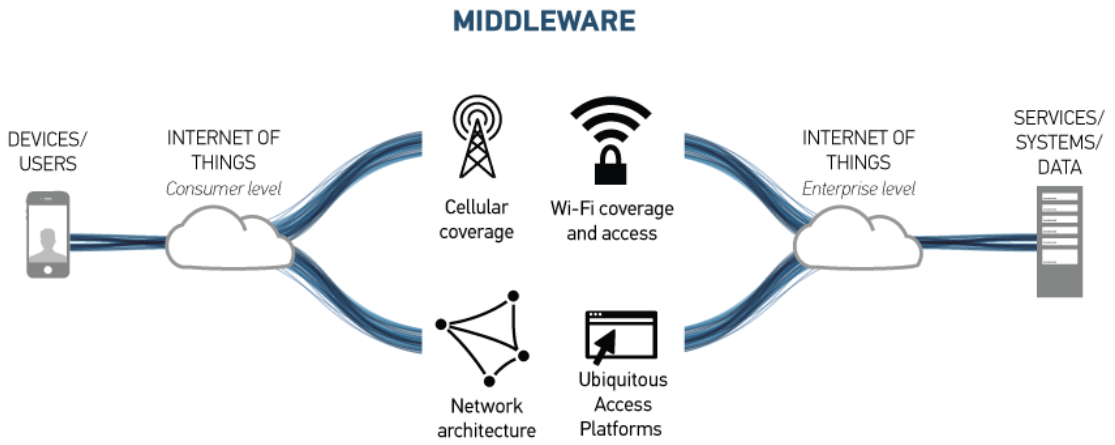

Figure 2. BYOE Middleware

These are the commodities that bridge users, their devices, and their consumer-level applications to the institution's data, services, systems, and enterprise-level applications. IT infrastructure capable of supporting an emergent BYOE-heavy environment should provide frictionless access between any device a user has and any institutionally provided or managed services, systems, data, or apps that are accessed on these devices. If the important aspects of technology infrastructure for BYOE are in this "middleware," then they are the undeniable purview of IT professionals—and an increasingly significant part of your IT framework:

- **Cellular coverage**, including campus penetration of cellular coverage from major providers
- **Wi-Fi coverage and access**, including network Wi-Fi capabilities and open public Wi-Fi versus restricted network access
- **Network architecture**, including bandwidth and Wi-Fi density ratios (i.e., devices to user)
- **Ubiquitous access platforms**, including access capabilities through device applications, browsers, virtualized desktops, identify management tools, and cloud services

Robust yet Nimble Practices

> A rock-solid network has the capability for multiple secure paths out of the environment, multiple paths through the environment, and multiple devices that can assume control for everything in [the environment] in the event that anything fails.
>
> *—John Rosebrock, University of the Incarnate Word, personal communication*

It is important to find balance between a strategically planned, robust IT infrastructure and one that can be reactive and flexible enough to accommodate new, more, or different technologies as they become available. Providing and maintaining IT infrastructure that serves a diverse array of user-provisioned and institutionally provisioned technology for students and individuals employed by the institution is a major undertaking. The phrase "robust yet nimble" characterizes the need to have an infrastructure that is strong, well-planned, large, and stable enough to accommodate BYOE needs now while preserving the ability to adapt to technology changes and growth. This is true for all aspects of IT infrastructure: hardware, software, "middleware," and facilities.

The resounding message from the ECAR interviews and focus groups of IT leaders is that the driving force behind this seemingly contradictory way of managing IT infrastructure is to do what you need to do to meet users' needs.[4] Students, faculty, and staff expect to be able access the Internet and institutionally maintained networks at any time, from any place (virtual or physical), and using the device(s) of their choice. It is easier for an IT unit to meet this expectation if, instead of constantly needing to grow the environment to accommodate more (or different) devices than anticipated, the IT unit can deploy the next round of projected upgrades or expansions to meet user expectations for frictionless access between devices and institutionally maintained services, applications, websites, or data.

What are the characteristics of a robust yet nimble technology infrastructure? For hardware and software, this primarily means investment in quality equipment or packages with a predetermined life cycle and appropriate replacement/upgrade/expansion plans. For facilities, this primarily means abandoning the model in which new demands are continually placed on campus real estate (including data centers and server farms) to accommodate growing server racks (not to mention air conditioning and electricity to accommodate the equipment). Being robust yet nimble with facilities means updating (and likely upgrading the "cloud strategy") to strike a balance between cloud and on-premise IT needs that represents fresh thinking about today's needs and the more demanding needs of tomorrow.[5] For "middleware," this means IT architecture and services have been designed—or more likely configured—to accommodate a large range of computing demands including an array of BYO devices, operating systems, browsers, and other technologies. Any sensitive data going to or through these BYOE technologies must be secure (more on this later). In addition, plans must be made for increasing necessary elements and funding for them is planned or a priority. Though the term *robust* communicates a strong, stout, and full-bodied infrastructure, it is imperative that this middle layer is transparent, if not completely invisible, to users.

Cellular Coverage

Cellular Coverage: Exemplars

What is your institution's current cell phone service coverage like, and does it meet the current demand for using mobile devices with data plans anytime, anywhere? In 2012, EDUCAUSE Core Data Service (CDS) respondents said that their outdoor areas have adequate cell phone coverage (88%), and 78% said that their buildings have adequate cell phone coverage.[6] Cellular service providers have a vested interest in providing cell phone connectivity to their customers—these are your students, faculty, and colleagues. Manifesting robust yet nimble cellular coverage for your physical grounds should include consideration of the market-driven commercial enterprise of service providers. Ensuring cellular coverage via standard towers or an array of neutral-host distributed antenna systems can be a lifeline to the campus community. In the unlikely event that a campus network goes down, cell coverage becomes an essential redundancy for keeping your campus connected. In the wake of natural disasters such as Superstorm Sandy, this redundancy can be recognized and appreciated for its true value. Relying on commercially provided services such as AT&T, Verizon, and Sprint ensures market-driven response to consumer needs and expectations.

Cellular Coverage: Innovations

The "Internet of things" is increasingly using microlocation-based services to track customers, and this is a driver for new, more, and better Wi-Fi coverage. Profiting from the rise of Wi-Fi is a contemporary business model, and this poses an interesting set of opportunities for CIOs to

leverage the population to whom they have traditionally supplied free Wi-Fi. "Cisco IBSG strongly believes that [service providers] can make money in Wi-Fi, and that many business models can create new revenue sources to justify investments in building robust Wi-Fi networks and operational capabilities."[7] An innovative way of providing better cellular service and more robust Wi-Fi could include brokering deals that provide better cellular coverage—and that include plans for improving/expanding campus Wi-Fi—that is financed by businesses profiting from the devices and services that make up the "Internet of things." Students, faculty, and staff win because they get expanded coverage access (regardless of the purpose—school, work, personal use), institutions win because the impact on human and financial resources is mitigated (or at least supplemented) by those who have commercial interests, and businesses and service providers win because they have better access to their customers.

If a university-to-business partnership for extending cellular and Wi-Fi coverage on campus is not palatable or desired, then investing in technologies that extend traditional cell towers, such as Alcatel-Lucent's Metro Cell, is an option. These repeater antenna systems are marketed as "cost-effective" and "energy-conscious." For example, the "...Alcatel-Lucent Metro Cell is a small cell solution...[that] enables mobile operators to expand coverage, increase capacity, and improve the user experience—when and where it's needed most."[8] At Cecil College, Verizon extended cellular penetration and signal strength by installing such repeater antennae, thus greatly improving persistent coverage cellular service coverage throughout campus.

Wi-Fi Coverage and Access: Exemplars

What is your institution's current Wi-Fi coverage and policy on user authentication? Does it meet the current need for anytime, anywhere access? CDS data tell us that a minority of institutions (47%) have Wi-Fi access that extends to at least half of open campus areas, and about one in three institutions (31%) have open (no authentication) wireless access.[9] An open network is appropriate for guests and most students. Evidence of need *not to authenticate* can be found in the 2012 ECAR student study—when asked about the one web-based resource undergraduates rely on most, Google is the winner.[10] Though undergraduates also cite using their mobile devices[11] to access course websites and syllabi, to use the course or learning management system, and to check their academic progress (i.e., grades), none of these institutionally controlled services, systems, and data necessitate providing direct access to mission-critical systems in a way that could compromise the systems or underlying data. Browser-based display for student interfaces resolves security issues that *can be* controlled by an institution. Providing easily accessible and abundant Wi-Fi to students is a real win. Wi-Fi accessibility standards are being set by companies like Starbucks, McDonalds, and Barnes & Noble, and students increasingly expect this same service at their college or university.

What about meeting faculty and staff expectations for Wi-Fi access? A recent study by Forrester Research about employee workplace practices "...revealed that leading activities workers access on both smartphones and tablets include accessing the employee intranet or portal and using e-mail and/or calendar applications...smartphones are primarily used to read or view documents, while tablets are more likely to be used to edit documents, access a web meeting, or perform processor-intensive activities such as analytics."[12] Given this information, an open Wi-Fi network is appropriate for most campus employees as well. If sensitive data are secure, access is based on roles and permissions, and browser-based display interfaces are used to view mission-critical system data, maintaining restricted network access becomes an

inconvenient redundancy for most users while not providing a proportionate amount of additional security.

A perfunctory approach to data security is neither recommended nor prudent, and the next ECAR mini-report on the BYOE phenomenon specifically addresses security issues, strategies, and innovations.[13] Without going into detail now, ECAR approaches BYOE security issues from the point of view that the cost of encrypting data in transit and at rest are dollars better spent addressing the crux of security concerns with BYOE. This tactic offers a comfort zone to permit network architecture that provides a free, open Wi-Fi connection outside the institutional firewall enabling access to Internet resources only. Wi-Fi is robust through a pervasive signal, and bandwidth is generous enough to substantiate continuity through the heaviest demand periods. Establishing nimble access requires leveraging browser-based solutions for all student, faculty, staff, and public resources (portal, website, LMS, library, blogs, social networks, etc.).

Wi-Fi Coverage and Access: Innovations

The Internet is arguably the single greatest invention of the 20th century. Initially its value to education was in its speed, its scope, and the rate of accessing and sharing information. It soon became a way to communicate individually and within or to groups. Separately these functions were educational game changers, and together they are the power-force behind the explosion of easy-access, low-cost (and sometimes free) education. Given that the proliferation of handheld, mobile, Internet-capable devices is making wired Internet connection passé, why is U.S. college and university Wi-Fi coverage so lean and littered with access roadblocks? Shouldn't institutions of higher education be at least as innovative as Starbucks when it comes to providing free, open, wireless access to the Internet? Starbucks' partnership with AT&T Wi-Fi Hot Spot is a model for this innovation. According to the company's website, "Starbucks offers free, one-click, unlimited Wi-Fi at all company-owned stores in the United States.... Just open a browser on your laptop or mobile device and click 'Connect.'"[14] No purchase is necessary, and there is no time limit.

Network Architecture: Exemplars

What is your institution's current capacity in terms of bandwidth? The results of an ECAR survey on bring-your-own technologies will provide benchmarking metrics for current numbers and anticipated growth in devices carried by students, faculty, and staff. A robust network is one with adequate bandwidth and Wi-Fi access that is available, scalable, and ubiquitous. Nimbleness comes from being prepared to upgrade capacity as the number of devices accessing the Internet grows.

What is your institution's current Wi-Fi density ratio? That is, how many devices are used by each user? ECAR focus group participants took the stance that there should be a culture of inclusion and that the list of excluded uses and devices should be short and available to users. The results of the ECAR survey will provide benchmarking metrics for the number of devices per user. This is imperative information for managing IP addresses**.** *Where does your institution stand on exhaustion of IPv4 addresses? Are there definitive plans in place to make the network scalable by deploying IPv6?* According to EDUCAUSE CDS data, 8% of higher education institutions had deployed IPv6 as of September 2012, and the majority of institutions that had not yet deployed it (57%) said that they are considering deploying it.[15] This indicates that managing IP addresses is heavy on the minds of IT departments. On a related matter, assessing the capacity of subnets to determine if they are large enough to support the number

of devices trying to access the Internet at any given time or place is prudent. Assessing the functionality of subnets to determine compatibility with faculty needs for classroom use is also prudent (e.g., can a faculty iPad and an Apple TV be on the same subnet?). *Can your routers actually scale highly enough to support the number of transactions going through at any given moment, and, if not, is there a plan to replace them to accommodate expanding traffic?* Robust yet nimble systems are monitored to avoid overloads and interruptions, with definitive plans for replacement, upgrades, or expansions ready for deployment.

Network Architecture: Innovations

Technology start-up companies are offering their own solutions to providing users with a robust yet nimble network connection. Connectify Dispatch, for example, is software that acts as a metaconsolidator of existing network connections. For about $50 per year, this software allows users to "...combine all of [their] Internet connections to create one super-connection!"[16] This combination could include wireless and wired networks, as well as mobile broadband sources.

Monitoring user-to-device ratios can help IT leaders plan IP address management, assess subnet capacity, and determine router scalability. User-to-device density ratios seem to be more of a philosophical network-architecture issue for many, and an innovative idea for those who have not yet considered the matter is to use a Cisco-like formula for ensuring access.[17] Predicting density ratios may be more science fiction than science to date, but data collected now can provide a baseline to help predict density ratios in the future.


Ubiquitous Access Platforms

Ubiquitous Access Platforms: Exemplars

What is your institution's practice for providing access to/through applications, browsers, virtualized desktops, and cloud-based technology? A robust yet nimble model provides user access to services with virtual sites determined behind the scenes, automatically, based on job roles and permissions. Identity management/single sign-on systems are in place and used universally for access. *To what extent does your IT shop have the opportunity for control through a mobile device management (MDM) system or for minimizing data loss through a data loss prevention (DLP) system?* Related to this are the underlying choices IT leaders have to focus on securing devices and/or securing data. The results of the ECAR survey will provide benchmarking metrics for security strategies and MDM and DLP system deployment. Furthermore, the survey will provide insight to higher education institutions' experiences with security issues stemming from BYOE experiences. A robust yet nimble IT infrastructure requires a thorough conversation about data and device security matters; the IT unit will have deployed a system for addressing the outcomes of that conversation and will be prepared to address the next round of security issues when they arise.

What is your institution's practice for providing device-agnostic browsers and applications? According to a recent Purdue University study on mobile app preferences, students say they prefer native (device-specific) mobile apps over web-based "apps" for general tasks and course-related tasks because they are faster and easier to use.[18] ECAR focus groups found support that this is true for faculty and staff experiences as well. With device and platform diversity, however, it is unrealistic to expect anything but device-neutral apps for widespread app deployment. A nimble approach to meet the demand for customized native or "native-like" apps is to investigate middleware platforms that optimize decentralized data sources and carry them through to mobile web experiences and companion native apps. The Kurogo Mobile Platform[19] is an example of "open-source Mobile Optimized Middleware" that bridges the

custom native mobile app opportunity without requiring substantial stand-alone native app investment. Following this approach could lead to a robust device-agnostic browser and app environment.

How has the consumer-driven market changed the way new operating systems are rolled out? Gone are the days where ERP readiness drove rollout schedules. Where an 18-month lag was once common between release of a new OS and institution-wide implementation, consumer-device-enabled users are driving this timeline and expect to access institutional data and support for new operating systems within a few hours of release. In this example, nimbleness is forced to the table because of user-BYOE experiences.

Ubiquitous Access Platforms: Innovations

Apple's iOS and Google's Android will continue to dominate the OS market for mobile devices, while BlackBerry 10 and Windows Phone 8 will likely battle for the third spot.[20] Four new free and open projects for Android-like operating systems were showcased at the 2013 Consumer Electronics Show—Ubuntu, Tizen, Firefox OS, and Jolla Sailfish—and time will tell if any of these newcomers will take a stronghold.[21] The message about OS is that the market is still shared broadly enough to advocate for device-agnostic access to institutionally controlled services, applications, and websites. This means that the app versus browser argument still persists, though advances in technology are blurring the lines of this argument. Presently the advantage of native apps is speed and upgradability, while the disadvantage is that they can be expensive to develop and maintain. The advantage of browser-based "apps" is that they provide device/OS-agnostic access, yet they are not as nimble as native apps and require more bandwidth to use. Expect more "mobile middleware" that bridges the user preference for stand-alone native app without requiring a substantial stand-alone native app investment.

Recommendations

Campus penetration of cellular coverage from major providers is robust yet nimble.

Assess your institution's current cellphone service and Wi-Fi coverage to determine whether they meet demand—currently and in the immediate future—through forthcoming ECAR BYOE benchmarking metrics for using mobile devices with data plans anytime, anywhere. Plan to keep up with near-term increases in wireless demand. Look for opportunities to improve campus cellular and wireless coverage by leveraging relationships between your institution's wireless user population and the industry profiting from the "Internet of things."

Explore options with cellular service providers to install repeater antennae on campus to expand/strengthen their coverage areas, where necessary. If possible, avoid leasing cellular networks from services providers, to remain one step removed from the service-provider process.

Open public Wi-Fi vs. restricted network access is robust yet nimble.

Assess your institution's current Wi-Fi coverage and policy on user authentication practices through forthcoming ECAR BYOE benchmarking metrics. Develop an implementable plan to meet the current need for anytime, anywhere access. Focus on securing institutional data rather than regulating devices so that easier access can be granted for the majority of network and Wi-Fi experiences, which do not pose a threat to sensitive or valuable information.

Leverage browser-based solutions for all student, faculty, staff, and public resources (portal, website, LMS, library, blogs, social networks, etc.).

Assess your institution's current network bandwidth capacity though ECAR BYOE benchmarking metrics. Use this information to establish a network with adequate bandwidth and Wi-Fi access. Take lessons from open Wi-Fi frontrunners, such as Starbucks, and commit to providing and maintaining a Wi-Fi service that is low-friction, abundant, reliable (in terms of availability and continuity), and scalable to ensure robust and nimble customer experiences. To ensure the integrity of data security within institutionally maintained systems, this Wi-Fi connection can run outside the institutional firewall, enabling access to Internet resources only.

Network architecture and network capabilities for bandwidth and Wi-Fi are robust yet nimble.

Assess your institution's current Wi-Fi density ratio through forthcoming ECAR BYOE benchmarking metrics—that is, how many devices are used by each user? Use this information to better manage IP addresses and deployment plans for IPv6, to determine whether subnets are large enough to support the number of devices trying to access the Internet at any given time or place, and to gauge the capacity of routers that scale enough to support the number of transactions going through at any given moment. Use data at hand for plans to avoid overloads and interruptions and create definitive plans for replacement, upgrades, or expansions ready for deployment. Be prepared to upgrade capacity as the number of devices accessing the Internet grows.

Ubiquitous access capabilities through applications, browsers, virtualized desktops, and cloud services are robust yet nimble.

Assess your institution's practice for providing access to/through applications, browsers, virtualized desktops, and cloud-based technology. Implement or improve a model that determines user access to services and virtual sites behind the scenes, automatically, based on job roles and permissions. Deploy identity management/single-sign-on systems that are used universally for access.

Seek opportunities to invest in "mobile middleware" that bridges the universal nature of mobile web with the user-functionality of native apps.

Complete the conversation about data and device security matters. If data are truly secure, a less robust MDM system and/or DLP system might be prudent, saving the institution both time and money for deployment and maintenance of such systems.

The ECAR Queue

This consumerization of information technology/BYOE research report on IT infrastructure provides a sneak preview of the work ECAR is undertaking to understand how the consumerization of IT is affecting higher education. In 2013, ECAR will produce a series of publications on this topic, and we are experimenting with opportunities to provide content throughout this research effort by releasing aspects of the study monthly. This report is the second in the series and was preceded by a summative research preview. An additional research report will focus on findings around security and compliance issues that relate to the consumerization of IT/BYOE; this will be published in late February. The complete report and

supporting materials will be released at the end of quarter one in late March. The project research hub (http://www.educause.edu/library/resources/byod-and-consumerization-it-higher-education-research-2013) will be updated as information about this project emerges.

- Technology security research report (Feb. 2013)
- Full ECAR report on higher education BYOE (Mar. 2013)
- Infographic, slide deck, and support materials (Mar. 2013)

This suite of resources will provide actionable recommendations, which can be useful in developing or refining those elements of a comprehensive BYOE strategy that are within the purview of IT leadership, as well as perspectives about BYOE issues for which IT may not be directly responsible but that IT leaders will benefit from understanding.

About the Authors

Eden Dahlstrom (edahlstrom@educause.edu) is a Senior Research Analyst with EDUCAUSE.

Stephen diFilipo (sdifilipo@gmail.com) is Vice President and Chief Information Officer at Cecil College.

Citation for This Work

Dahlstrom, Eden, and Stephen diFilipo. "IT Infrastructure in the Bring-Your-Own-Everything (BYOE) Era." Research Report. Louisville, CO: EDUCAUSE Center for Applied Research, January 29, 2013, available from http://www.educause.edu/ecar.

Notes

1. Lawrence Pingree, "Bring your Own Device (BYOD): Mobile Trends and Securing the Transaction," webinar hosted by Gartner, January 15, 2013, available from http://www.gartner.com.
2. Eden Dahlstrom, with foreword by Charles Dziuban and J.D. Walker, *ECAR Study of Undergraduate Students and Information Technology, 2012*, Research Report (Louisville, CO: EDUCAUSE Center for Applied Research, September 2012), available from http://www.educause.edu/ecar.
3. Annelies van der Veen and Jan van Bon, *Foundations of ITIL V3* (Zaltbommel, Netherlands: Van Haren Publishing, 2007).
4. EDUCAUSE Center for Applied Research (ECAR), Focus Groups, October–November 2012.
5. Bob Evans, "The Top 10 Strategic CIO Issues for 2013," *Forbes*, September 28, 2012, http://www.forbes.com/sites/oracle/2012/09/28/the-top-10-strategic-cio-issues-for-2013/.
6. The term "adequate" is self-defined by each CDS completer who answered this question (module 6, question 14); EDUCAUSE Core Data Service, 2012, http://www.educause.edu/cds.
7. William Gerhardt et al., "Profiting from the Rise of Wi-Fi: New, Innovative Business Models for Service Providers," Cisco Internet Business Solutions Group (IBSG), March 2012, http://www.cisco.com/web/about/ac79/docs/sp/SP_Wi-Fi_PoV.pdf.
8. Verizon Wireless, "Explore Innovation with Verizon," Verizon Wireless Innovation Centers CES 2013, http://innovation.verizon.com/content/vic/en/ces.html.
9. EDUCAUSE Core Data Service (CDS), 2012.
10. Dahlstrom, *ECAR Study of Undergraduate Students*.
11. In 2012, 62% of undergraduates said they own a smartphone, and two in three (67%) said they use their smartphones for academic purposes; 15% of undergraduates own a tablet, and 86% own a laptop.

12. Forrester Research, Inc., “The Expanding Role of Mobility in the Workplace,” A Custom Technology Adoption Profile Commissioned by Cisco Systems, January 2012, available from http://www.forrester.com.
13. Scheduled for release February 26, 2013.
14. From Starbucks Wireless Internet information page, http://www.starbucks.com/coffeehouse/wireless-internet.
15. EDUCAUSE Core Data Service (CDS). 2012.
16. Connectify, http://www.connectify.me.
17. Wireless LAN Design Guide for High Density Client Environments in Higher Education, http://www.cisco.com/web/strategy/docs/education/cisco_wlan_design_guide.pdf.
18. Kyle Bowen and Matthew D. Pistilli, “Student Preferences for Mobile App Usage,” Research Bulletin (Louisville, CO: EDUCAUSE Center for Applied Research, September 25, 2012), available from http://www.educause.edu/ecar.
19. The Kurogo Mobile Platform, http://kurogo.org/home/.
20. Roger Cheng, “Mobile: 10 predictions for 2013,” CNET Blog, December 27, 2012, http://news.cnet.com/8301-1035_3-57553339-94/mobile-10-predictions-for-2013/.
21. Naina Khedekar, “Which Upcoming Mobile OS Has Potential to Dethrone iOS and Android?” *Tech2*, January 17, 2013, http://tech2.in.com/features/software/which-upcoming-mobile-os-has-potential-to-dethrone-ios-and-android/698352.