



**THE  
INTERNET  
OF  
THINGS:**

# Riding the Wave in Higher Education

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Looking at the vast ocean that is modern-day computing, we can see that major developments come in waves. The arrival of mainframe computers in the 1960s generated the first wave (one computer for many people), followed in the late 1970s by personal computers in the second wave (one computer for one person). In 1988, Mark Weiser presciently observed that computers embedded into everyday objects, objects all around us, were forming the third wave—what he called *ubiquitous computing* (many computers for one person). A decade later, in 1999, Kevin Ashton put forth the ideas behind, and coined the term for, the fourth wave: *the Internet of Things*.

In this paradigm shift, Weiser's computer-embedded everyday objects—or “things”—are connected to the Internet and can communicate with users and with other devices. The guiding principle is *connection*, along with the conviction that if something *can* be connected, it *will* be connected. Indeed, in recent years, the wave appears to be rising to a crest. The plunging cost and size of processors and chipsets, the massive expansion of the IP address space, and the growing coverage of broadband networks allow virtually any object to be connected to the Internet. The computers, laptops, tablets, and smartphones that constitute the bulk of the Internet of Things (IoT) today are being joined by smartwatches, smart appliances, cars, lightbulbs, and an array of other devices that collect and transfer data, often without any human involvement. As that data is increasing and the technologies are advancing, we are moving from the early IoT of smart connections to a new phase, one of invisible integration.

Predictions for the growth of the IoT vary considerably: some experts forecast that about 20 billion devices will be connected by 2020; others put the number closer to 40 or 50 billion; and some even foresee as many as 100+ billion connected devices by that time. Regardless of the exact number of devices, spending in this market is expected to increase substantially, with the International Data Corporation (IDC) calculating that the

worldwide market for IoT solutions will reach \$7.1 trillion in four years. Clearly, the hardware, networking, software, analytics, and device/component vendors are embracing the IoT.<sup>1</sup>

What does all this mean for colleges and universities? Considering the key role being played by vendors in this market, we decided to ask some industry leaders in higher education a few questions. These experts have been looking toward and anticipating the IoT for quite some time, perhaps longer than many campus leaders and IT staff. In addition, they have valuable cross-industry insights to share with higher education. Who better to help us understand the impact of the IoT?

Below, five industry leaders give their perspectives on the IoT and new devices; the IoT benefits and campus influence; the problems solved/created by the IoT; and security, privacy, and data ownership issues. Based on their experiences with the IoT, they also share lessons learned and offer words of wisdom.

The Internet of Things is here. And it's big. Let's ride the wave.

**Note**

1. IDC, “The Internet of Things: Data from Embedded Systems Will Account for 10% of the Digital Universe by 2020,” April 2014; Gill Press, “Internet of Things by the Numbers: Market Estimates and Forecasts,” *Forbes Tech*, August 22, 2014; Gill Press, “Internet of Things (IoT) News Roundup: Onwards and Upwards to 30 Billion Connected Things,” *Forbes Tech*, September 22, 2015.

The guiding principle is *connection*, along with the conviction that if something *can* be connected, it *will* be connected.





**Itai Asseo**  
Strategic Innovation Executive  
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**The Internet of Things has evolved over many decades as wearables, RFID, BYOD, wireless devices, and more have increased in both number and usage. How do you define the IoT today?**

The *Internet of Things* is not a new term. It's been around since at least the late 1990s, but another decade or so went by before it became a mainstream term. The idea is that as computing power can be condensed into ever smaller units and devices, and as the power demand gets lower and more efficient, we can embed computing devices into anything from household items to clothing—and even into living matter.

That is the traditional view of the IoT. But as the IoT becomes more prevalent in our lives, we should be thinking about more than just the “things.” The invisible part of this equation is the engine and the processes that enable these devices to be “smart.” Most connected IoT devices can communicate simple data—for example, their location or a temperature reading of an object. But it is only *the connection of the device*

to an engine or database that puts this data in context to other information. This is where we can truly unpack the value of the IoT. For example, perhaps the reading of the location and temperature are of a package containing important biological components for a lab, and the package needs to be shipped by a certain date and stay under a certain temperature. If any of these conditions aren't met, or are predicted to be unmet, a new delivery and alerts can be dispatched automatically. The IoT is all about moving from being reactive to being proactive and even being predictive as a result of automating processes and decision making.

**What game-changing IoT devices and uses do you expect we'll be seeing on campuses within the next one to three years?**

We're already seeing some colleges and universities experiment with IoT approaches, such as adopting fitness devices to record student's health indicators or tracking temperature readings in lab equipment and sending notifications when certain conditions are met. But not all IoT solutions are going to come from extra devices, or “things.” Many students and administrators are already carrying, every day, very powerful IoT devices in the form of mobile devices. In the next three years, we'll be seeing more campuses taking advantage of the current context in which students, administrators, and instructors operate. For example, by connecting a database of students' submitted work, students' schedules, and the time of day, the institution can send reminders and alerts when they are most effective, and each message can be personally tailored to the student. In addition, by employing some elements of gamification, the institution can reward students digitally for engaging and for completing tasks on time. To truly innovate, campuses need to combine information they gather from devices and from other sources in order to analyze and predict students' academic progress and identify problem areas and risk of attrition.

**What are the most exciting academic and administrative benefits enabled by the IoT for higher education?**

As we're already seeing in other fields such as media and marketing, one of the biggest potential benefits enabled by the IoT is a 1:1 journey that is personalized and unique to each student—from the recruiting and enrollment processes, in which communication can be tailored to who students are and the decisions they make, to the orientation process and ongoing engagement. Students can get personal recommendations on relevant academic topics/courses that they perhaps hadn't considered, events that



**“The IoT is all about moving from being reactive to being proactive and even being predictive as a result of automating processes and decision making.”**

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might be of interest to them, and internship opportunities that could best suit their academic pursuits. When students' behavior indicates that they are struggling academically or personally, alerts can be sent so that administrators can reach out and act more quickly to resolve issues. In addition, students' profiles can be built over the length of their engagement with a campus, providing a better way for the institution to also assist them as alums, especially when coupled with employment activities post-academia. The truly exciting prospect of the IoT for higher education is that the more data we are able to capture about the different interactions that are happening continuously, the more we can improve practically every aspect of the institution's engagement with all parties involved. From the students' perspective, this interaction can become a significant factor when considering their options of where to spend their time and resources.

**What higher education problems could be solved quickly with the widespread deployment of IoT technology? What problems might be created?**

The IoT can help solve challenges across a wide array of topics, from logistics to administration to student life. So when designing an experience, institutional leaders should approach it first by discovering the biggest pain points. Streamlining and optimizing the utilization of facilities can help achieve financial savings (e.g., responding to weather events, automating operations). Smart devices can alert staff and providers about when to service equipment before a problem even presents itself. Smart doors, locks, and cameras can be used to monitor and control movement in different facilities. As more devices become connected, campus leaders will be able to extract much more value from the continuous stream of data and information, helping them move from a transactional relationship with students, faculty, administrators, and providers to an iterative process in which micro-decisions can be made on an ongoing basis.

**Based on your experience with the IoT, what industry best practices or lessons learned do you think are significant to, and might apply in, higher education?**

A great example of how the IoT is playing out in the real world today—an example that is applicable to higher education institutions—lies not in Silicon Valley but in Orlando, Florida. Disney World's MagicBand is a wearable device that transforms the entertainment experience into a much more personalized affair. The MagicBand allows guests to do everything from unlocking their rooms to making restaurant reservations to accessing the theme parks, and of course, to paying for anything in the resort—all simply by tapping their wrists. It's been a very successful implementation, but the main reason that the MagicBand works is that it exists in a closed environment where people enjoy having that extra bit of "magic." Whereas the same experience might come

across as intrusive in other situations, in the contained environment of Disney World it seems magical rather than creepy.

What might a MagicBand look like in higher education? For students the academic experience becomes seamless, simple, and streamlined, with easy access to fitness/recreation facilities, academic buildings, residence halls, and athletic events and with simplified attendance, library access and lending, and payment at the cafeteria, bookstore, copiers, and more. Yet the real power comes into play for administrators and faculty. By leveraging the data of students' interaction with the campus at all times, higher education institutions can become more effective and productive as a result of mashing together different data points, such as attendance and performance, and can become more proactive, even more predictive, rather than reactive.

**If you could offer a word of wisdom to higher education leaders on how to think about and apply the benefits of the IoT, what would that be?**

The IoT benefits can be huge. If higher education fails to provide students with the advances and benefits of the IoT, students will look elsewhere. The key is to design student, faculty, and administrator experience that will have the highest value for all parties involved. Some of the most obvious advantages of having a connected campus also reveal some of the challenges. With any IoT user experience, the "creepy factor" spectrum needs to be considered. Two main areas that create this spectrum are personalization and transparency. Having all the data about a user's information across different areas—to be used for personalization—brings up the risk of an experience that invades privacy and a certain personal space. That intrusiveness can be tolerated only if the value of the interaction exceeds the perceived cost of giving up some privacy. On the other end of that spectrum, a lack of personalization can lead to less engagement and to an experience that feels "cold." Similarly, providing transparency to users about what data is collected, for what reasons, and from whom is extremely important. Finding out after the fact that certain information—personal or not—has been acquired without a user's knowledge can lead to mistrust. Yet when leveraged correctly, transparency can be used to create a sense of surprise and delight. ■

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## Maggie Johnson

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**The Internet of Things has evolved over many decades as wearables, RFID, BYOD, wireless devices, and more have increased in both number and usage. How do you define the IoT today?**

At Google, we define the IoT as a network of everyday items with embedded computers that can connect directly or indirectly to the Internet. The number of devices connecting to the Internet is likely to grow exponentially over the next ten years.

**What game-changing IoT devices and uses do you expect we'll be seeing on campuses within the next one to three years?**

In addition to the enhanced educational experiences noted below, collaborative workspaces using projected or cast content can facilitate interactive group sessions for students and researchers. As these various interactions occur, massive amounts of data can be collected and processed using machine learning algorithms, which will allow for more person-

alized learning and accurate recommendations on what will further enhance a student's experience. All of these possibilities are enabled through the IoT.

**What are the most exciting academic and administrative benefits enabled by the IoT for higher education?**

The IoT is already present on most college and university campuses in the form of security cameras, temperature controls, and access to buildings, lights, power, etc. What's more interesting are potential benefits of increased connectivity that enhance teaching and learning or that provide new modes of operation. For example, ubiquitous access to computing power, high-quality online content, and social media and connections can be used to enhance the educational experience. Students can supplement their coursework with relevant video, activities, assessments, and conversations with students and faculty around the world. In addition, opportunities to do academic research on various aspects of the IoT are already under way in many higher education institutions—for example, the "living lab" at Carnegie Mellon University.<sup>1</sup>

**How will the demands of a more connected student and a more connected campus influence—positively and/or negatively—the systems, processes, and infrastructure of the current higher education landscape?**

New devices and the proliferation of smartphones and apps are generating huge amounts of data, which will continue to increase. It's no longer feasible to have that data processed in a central location. This will expand the complexity of the network and the potential for security holes—there's no such thing as a firewall with the IoT. These challenges are not unique to higher education institutions, but given the budget cuts and aging infrastructure in academia, the challenges may be more profound in that space. On the other hand, academic institutions looking for ways to conserve energy (and save money) can use energy monitoring and automation devices, allowing them to pay only for what they need instead of having to cool or heat large buildings whether or not the buildings are being used.

**Will issues of privacy and data ownership stand in the way of a fully realized IoT? What other barriers or challenges will need to be addressed?**

We believe there are three areas<sup>2</sup> that require significant investment and collaboration before an ecosystem can emerge to interconnect people, spaces, and institutions:



**“All IoT objects—such as thermostats, front door locks, and even cars—must have deeply ingrained, authority-based usage rights that carefully control access.”**



- Strong data management and identity controls must be built into the ecosystem from the start. All IoT objects—such as thermostats, front door locks, and even cars—must have deeply ingrained, authority-based usage rights that carefully control access. Users must also have control of their own data as it flows through this ecosystem. Regarding user control, in April 2016 Google added EIDs (Ephemeral Identifiers) to Eddystone, the Bluetooth low energy (BLE) beacon format we introduced last year. Since this beacon frame changes periodically, the signal is recognizable to only a controlled set of users, instead of being a public signal. We think

EIDs will enable a new set of beacon use cases where users will be able to exchange information securely and privately.<sup>3</sup>

- The current IoT landscape is made up of individual solutions, or “walled gardens,” that offer perks for customers who buy from a particular product family. If we are to learn from the development of the Internet, we know that the open ISP model provided superior services to customers. We need to find a way to do something similar for the IoT.
- Increasing the number of connected objects should not increase the screens or keyboards that we need for configuration or use. Technology should “fade into the background” via objects and services that provide real user benefit from connectivity and can be controlled through voice, gesture, or other relevant means of input. ■

#### Notes

1. Byron Spice, “CMU Leads Google Expedition to Create Technology for ‘Internet of Things,’” *CMU News*, July 9, 2015.
2. See also Vint Cerf and Max Senge, “Taking the Internet to the Next Physical Level,” *Computer* 49, no. 2 (February 2016).
3. Nirdhar Khazanie, “Growing Eddystone with Ephemeral Identifiers: A Privacy Aware and Secure Open Beacon Format,” *Google Security Blog*, April 14, 2016.

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## Bob Nilsson

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**The Internet of Things has evolved over many decades as wearables, RFID, BYOD, wireless devices, and more have increased in both number and usage. How do you define the IoT today?**

The phrase *Internet of Things* (IoT) generally refers to machine-to-machine (M2M) communications involving network-based remote sensors and actuators. Wireless sensors generate data (often “big data”), which can be stored and analyzed either on site or in the cloud. The range of smart IoT devices found in schools today includes e-books and tablets; sensors in hallways, entrances, classroom spaces, and campus vehicles; all sorts of fitness bands and wearables; virtual and augmented reality headsets; robots; video sensors; and smart displays, lights, and locks. Data from these devices can be used for simple tracking (e.g., campus shuttles, student attendance, and supplies) or for more complex monitoring (e.g., to understand student learning patterns as students progress through e-books and adaptive

learning systems). Data can also be used for control. For example, the IoT provides the means to finely tune HVAC systems to keep all rooms throughout the campus optimally comfortable at minimum expense. Airflow, air quality, temperature, humidity, and lighting can be constantly optimized in every space that can conceivably be used for learning. Finally, flexible displays provide the important benefit of easily presenting data and status information on classroom screens or personal devices like smartphones and laptops. Modular dashboards and point-and-click control software (e.g., IFTTT, <https://ifttt.com/>) can easily configure sensors and actuators to create do-it-yourself, highly optimized custom-control systems. All of these IoT examples can ultimately enhance the learning experience for students and teachers, offering improved engagement and collaboration.

**What game-changing IoT devices and uses do you expect we’ll be seeing on campuses within the next one to three years?**

I think we will see three categories of smart IoT-based breakthrough devices for the campus: remote-presence robots; virtual/augmented/mixed-reality headsets; and adaptive learning digital textbooks. The latter two in particular augur a new level of personalized learning. The adaptive learning devices can track how well individual students understand course content and can provide new content or offer supplemental teaching in various forms including video, text, experiments, or even virtual field trips.



**“The campus network is becoming a computational IoT nervous system, critical for keeping the facilities functioning and the learning environment alive.”**

**What quantity of IoT devices would you anticipate having to support for the average student?**

The number of different types of devices per student can be upward of five to ten. Starting with the smartphone, fitness tracker, tablet, laptop, and game device and adding jewelry like Ringly (<https://ringly.com/>) or Pebble (<https://www.pebble.com/>), nonportable devices like smart TVs, Wi-Fi lightbulbs, and Wi-Fi speakers for campus rooms, other small smart appliances, and a head-mounted display results in more than ten. Jon Bruner of O’Reilly Media notes how new breakthroughs in prototyping, fundraising, and manufacturing—collectively referred to as “the new hardware movement”—are opening a floodgate of Internet-ready, low-cost devices that students will want to take advantage of.<sup>1</sup> Although there is bound to be some bundling and consolidation of capabilities into single devices, the proliferation of new types of devices may more than make up for that.

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### What are the most exciting academic and administrative benefits enabled by the IoT for higher education?

One of the major academic benefits the IoT brings to higher education is a dramatically improved, higher-quality remote presence. Students who are unable to be physically present in the classroom can still experience the images, the sounds, and even the smells of the room.<sup>2</sup> Remote students can participate with the instructor and other students via remote-presence robotic devices such as Beam (<https://suitabletech.com/getbeam/>) and Double Robotics (<http://www.doublerobotics.com/>). Similarly, students no longer must be physically present in a laboratory to run science experiments. IoT devices such as TetraScience (<http://www.tetrascience.com/>) connect experiments and instruments to the Internet for control and monitoring from anywhere. PocketLab (<http://www.thepocketlab.com/>) and Lab4U (<http://lab4u.co/>) attach to smartphones to provide powerful, but still low-cost science lab instruments capable of measuring acceleration, force, angular velocity, magnetic field, pressure, altitude, and temperature. Combine these sensors with robotics and controllers, and online students are able to run, monitor, and directly participate in science experiments of all types.

A second benefit that the IoT brings to higher education is the ability to optimize the classroom learning environment. With the fine level of control and extensive sensor data available through the IoT, instructors can continuously adjust classroom conditions, which may be changed depending on the subject and the time of day. Both artificial and natural lighting intensity and even hue can be controlled. Air quality can be optimized, as can noise level. By monitoring the ambient sound level at the back of the room, instructors can be alerted if their voice becomes difficult to understand.

Student health and safety can be improved with wearables, video monitoring, and smoke, fire, and dangerous noise (e.g., gunshots) detection. Student engagement can be monitored to an extent well beyond simple automatic classroom attendance recording. The collective engagement of students in a classroom could be tracked by measuring changes in temperature, carbon dioxide, or the sounds of conversations. Students could be individually tracked via fitness bands that measure pulse rate, body temperature, and oxygen levels, and individual headbands (e.g., Muse, <http://www.choosemuse.com/>) could measure student brainwaves and pass along students' cognitive activities during class. Oral Roberts University integrated wearable technology with its physical

fitness curriculum, though it quickly discovered the risk in terms of public perception.<sup>3</sup> Because the IoT provides rich data, it becomes possible to correlate all the conditions described above with student success to optimize the classroom and campus environment.

In terms of administrative benefits, the IoT enables more efficiency and therefore lower costs in facilities management. By remotely monitoring the HVAC, lighting, and almost everything that consumes energy and resources, institutions can optimize control. All inventories can be tracked and even automatically reordered when low. Safety can be improved with remotely monitored and controlled IoT locks. Outdoor campus lighting can be constantly optimized based on ambient levels, weather conditions, local activity, and anticipated patterns. Traffic can be eased with remote tracking and analysis. The instantaneous location of campus shuttles can be displayed on Google Maps, and school parking lots can be managed with smartphone apps. In addition, some students are hoping that colleges and universities use the IoT not only to improve safety and parking but also to reduce the price of tuition.<sup>4</sup>

### How will the demands of a more connected student and a more connected campus influence—positively and/or negatively—the systems, processes, and infrastructure of the current higher education landscape?

The campus network is becoming a computational IoT nervous system, critical for keeping the facilities functioning and the learning environment alive. This nervous system thrives on solid, dependable, high-density, high-capacity, pervasive Wi-Fi. The need for wired networking at the edge is diminishing as almost all devices communicate wirelessly. The campus infrastructure must seamlessly handle roaming. IoT devices cannot disconnect and reconnect as they move about campus. Remote-presence robots become helpless without continuous Wi-Fi. Many mobile IoT devices reside inside of machines or enclosures and are inaccessible or are constantly in motion. Often the devices show up in locations where connectivity was not built in: HVAC mezzanines, closets, crawl spaces, elevators, fire staircases, and exits.

**In its definition of the Internet of Things, the *Oxford English Dictionary* notes: “If one thing can prevent the Internet of Things from transforming the way we live and work, it will be a breakdown in security.” Do you agree?**





Security is definitely a concern, but if managed properly, it is not an insurmountable challenge. By employing adequate network-access control, rigorous network policy management, and network application visibility, colleges and universities can maintain security. Policies can help restrict what can connect to what, in order to guard against rogue devices and prevent interruption of critical flows of data and control. With these measures in place, institutions will be able to ensure that device control is permitted only from authorized points and that if an outside agent tries to either control a device or extract data, alarms will sound and the breach will be shut down.

**Will issues of privacy and data ownership stand in the way of a fully realized IoT? What other barriers or challenges will need to be addressed?**

As with BYOD, schools need a clear policy regarding what is allowed on the network in terms of both devices and data. Provision needs to be made to prevent overwhelming the network with streaming data and video. Just as some campuses now restrict Wi-Fi access to gaming consoles and bandwidth-consuming apps like Netflix, special provisions or restrictions may be appropriate for streaming IoT devices.

It is important to understand who owns the data that originates from IoT devices and that travels across the campus network. IoT product vendors assert a varying level of ownership over the software, the data, and even the products that an institution has purchased. Perhaps serving as a harbinger of these data, software, and product-ownership trends, the farm machinery manufacturer John Deere has asserted that the vehicle owner “receives an implied license for the life of the vehicle to operate the vehicle” but does not actually own the vehicle. Another example concerns digital environmental control systems in campus buildings. Is the data created by these systems owned by the HVAC system manufacturer, the real estate entity that owns the building, or the school that leases the space? Do the individual employees whose presence is monitored to optimize the lighting, heating, and cooling systems have rights to that data?

Higher education institutions should prepare for the following IoT-related regulation issues:

- Protecting IoT user and data privacy<sup>5</sup>
- Preserving patent rights for new combinations and mashups of IoT devices on the campus network
- Complying with licensing restrictions involving how a campus configures IoT devices and apps

**Based on your experience with the IoT, what industry best practices or lessons learned do you think are significant to, and might apply in, higher education?**

Historically, when devices similar to those associated with the IoT have come along, they have arrived suddenly and en masse.

Think about the rapid growth of smartphones and game controllers; many IoT devices are even smaller and less expensive. IDC has projected that 200 billion devices will be capable of communication on the Internet by 2020 and estimates that 30 billion IoT devices will be connected by that time.<sup>6</sup> There have already been some IoT calamities. One example of what can happen when automated connections go awry was the trillion-dollar stock market “flash crash” in 2010.

Although the data demands of many of these devices start out lightweight, they grow as product vendors find how easy and low-cost it can be to add constant monitoring and even streaming HD



video to their devices. Since these are smart devices, they require periodic online software updates. Remember how networks seemed to go down whenever Apple released a new version of iOS? Imagine what could happen when thousands of IoT devices start requesting software updates during working hours. More consumer-grade products will also be used on the IoT. According to one recent survey, over half of education CIOs and IT managers are already evaluating consumer technology.<sup>7</sup> Higher education IT leaders need to be prepared to support the latest consumer IoT devices that are likely to show up on campus and need to be clear about which ones cannot be supported.

Effective technology roll-outs require three aspects: user training; adequate infrastructure, especially sufficient Wi-Fi coverage and bandwidth; and coordinated timing. Planning needs to be both defensive, ensuring that the IT infrastructure is ready and security concerns are met, and offensive, proactively encouraging and leading groups within and outside of the IT organization to take full advantage of the promise of the IoT. IT staff should have a solid understanding of the terminology, types of apps, and service-level agreements that will be required. To take full advantage of the IoT, however, institutions need to reach beyond the IT organization. For example, professors should understand how to incorporate the IoT into their curriculum to bring the subject matter alive, as well as to help students become comfortable with the technology, which will be an important factor in their professional lives.

## Pilot Internet of Things Projects

To set up a pilot IoT project on campus, start with something small that touches all the bases: sensors, controllers, security, data analysis, and reporting. Here are some simple ideas:

- Install IoT sensors on doors. Wi-Fi wireless door locks can pose challenges when rolled out en masse but are manageable as a pilot project tied in with other sensors, especially when limited to a few interior doors.
- Set up interior environment monitoring and control using Wi-Fi temperature and light sensors to track how well the HVAC system is performing and even how it correlates to student engagement.
- Program selected classroom or common space lighting (e.g., with Philips Hue or Hue Lux) to vary lighting over the course of the day (dimming bulbs when natural lighting is strong) and simulate clouds passing over. Track the results.
- Monitor activity at a receiving dock or movement in a lobby.
- Put Wi-Fi moisture IoT sensors in office plant pots to provide an alert when plants need watering.

**If you could offer a word of wisdom to higher education leaders on how to think about and apply the benefits of the IoT, what would that be?**

Get ahead of the flow of new IoT devices. Keep an eye on Kickstarter and Indiegogo for emerging IoT devices that may start showing up on campus, requiring campus network accommodations. Stay knowledgeable about the networking standards that may affect the IoT: IEEE 802.15.4 low-rate wireless personal area networks (LR-WPANs), IPv6 over low-power wireless personal area networks (6LoWPANs), BLE (Bluetooth Smart), and Wi-Fi HaLow. Informally or formally survey all campus departments to understand current and future IoT device use. Start planning institution-wide training. Undertake a pilot IoT project (see sidebar). Get all department heads involved in brainstorming new IoT-related educational opportunities.

Take advantage of the opportunity and responsibility to teach students how to design IoT products and systems. Incorporate new subjects in order to provide the skills that are necessary in an IoT business world, where analysis of big data from IoT sensors will take on a major role. Teach the base modules of the IoT (e.g., Arduino and Raspberry Pi). Most important, inspire creativity to apply the IoT to new businesses and concepts, and instill a vision of where the IoT can lead. ■

### Notes

1. Jon Bruner, "How the New Hardware Movement Is Even Bigger than the Internet of Things," *O'Reilly Radar*, June 4, 2015.
2. Liz Stinson, "This Magical Scent-Sending Phone Is Now Available to Order," *Wired*, June 16, 2014.
3. "Oral Roberts University Integrates Wearable Technology with Physical Fitness Curriculum for Incoming Students," *ORU News*, January 4, 2016; Stephanie McNeal, "People Are Furious at This College for Making Its Freshmen Wear Fitbits," *BuzzFeed News*, April 17, 2016.
4. Christen Palange, "3 IoT Advancements This Student Is Ready For," *Extreme Networks*, January 15, 2016.
5. Enza Iannopolo, "CIOs: Drive Internet-of-Things Strategies Forward with Effective Data Protection Practices" (Forrester Research report, May 13, 2015), includes an IoT data-protection checklist for CIOs, whereas *Internet of Things: Privacy and Security in a Connected World* (FTC Staff Report, January 2015) suggests the need for new cloud data-privacy regulations.
6. IDC, "The Internet of Things."
7. Bob Nilsson, "Here's How Innovators Stay Innovative," *Extreme Networks Blog*, March 18, 2016.

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## Chalapathy Neti

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IBM

**The Internet of Things has evolved over many decades as wearables, RFID, BYOD, wireless devices, and more have increased in both number and usage.**

**How do you define the IoT today?**

The IoT is changing everything—from the way we drive, make purchases, and obtain medical treatment, to how we get energy for our homes. Data is emanating from everywhere. IDC predicts that by 2020, there will be close to 30 billion connected devices.<sup>1</sup> Today we define the IoT not only by its ability to connect devices (vehicles, buildings, wearables, and more) to a digital network, but also by its ability to directly integrate the physical world into computer-based systems. It is how people interact with this network of things that has become most interesting as the IoT has evolved.

Within two years, the IoT will be the single greatest source of data on the planet, but nearly 90 percent of that data will be “invisible” to traditional computing systems. This

is where cognitive computing—such as IBM Watson (<http://www.ibm.com/smarterplanet/us/en/ibmwatson/>)—comes in. Cognitive computing can process massive amounts of data from a full spectrum of sources and can help businesses make sense of and act on that data. Cognitive computing is enabling businesses to take full advantage of this burgeoning resource—data—while allowing systems to learn at scale, reason with purpose, and interact with humans naturally.

Today’s IoT can fundamentally transform the way we interact with our surroundings. Because we can electronically monitor and manage a growing number of physical objects, we can now bring data-driven decision making to new heights of effectiveness. This helps businesses and people save time, be more efficient, and improve quality of life.

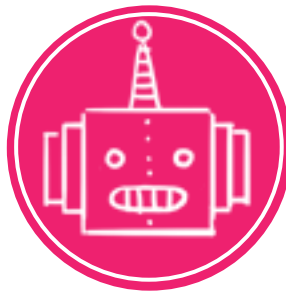
**What game-changing IoT devices and uses do you expect we’ll be seeing on campuses within the next one to three years?**

Augmented Reality (AR) devices will be the next big thing. AR is poised to transform everything from games to art to education. We’ve spent our whole lives interacting with 2D media (e.g., paper, blackboards, screens, phones), but AR forces us to rethink everything we know about human-computer interaction. AR has the potential to truly revolutionize education. No longer confined by the limitations of a physical classroom, education can become so much more than lectures and tests.

AR will offer powerful contextual, on-site learning experiences and also serendipitous exploration of the connected nature of information in the real world. Now that the technologies making AR possible are much more powerful than ever before and are compact enough to deliver AR experiences to academic venues through personal computers and mobile devices, educational approaches using AR technology are more feasible. AR can make complicated mechanisms understood via contextually enriched interaction. For example, mechanical engineering students can study a 3D model of a camshaft arrangement in conjunction with a set of actual engineering components.

**What are the most exciting academic and administrative benefits enabled by the IoT for higher education?**

As more data is captured from billions of connected devices, and as new sources of data, such as social, become available, the potential for actionable intelligence increases exponentially. This poses tremendous



**“Within two years, the IoT will be the single greatest source of data on the planet, but nearly 90 percent of that data will be invisible to traditional computing systems.”**

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opportunities for higher education. For example, it can help administrators understand their students better and help optimize the resources available to each of the students individually—everything from how crowded a classroom is to how often campus buses pass a specific location.

In addition, the IoT ingests data from a wide variety of sources inside a building—sources including sensors, meters,

and lighting, and new sources such as weather and people presence—to help building managers act on data to enable “smarter buildings.” For example, building managers can better understand which classrooms are used most often during “peak hours” and can better determine which lecture halls, residence halls, and facilities are most in need of technology upgrades.

**How will the demands of a more connected student and a more connected campus influence—positively and/or negatively—the systems, processes, and infrastructure of the current higher education landscape?**

A more connected student on a more connected campus can make a big difference to the current educational landscape. Think of mobile apps and crowdsourcing: similar to Waze, an app that recommends the most efficient driving route using real-time crowdsourced data, the process of learning consists of a series of tasks designed to get a student from competence state A to competence state B. Equipping learning facilities and students with IoT devices that monitor data, such as engagement and even emotion, can enable a more contextual, personalized, and adaptive approach to education—a Waze-like recommendation based on data pulled from many sources. Network-connected wearable sensors (NCS)—such as EEG, GPS, and VR—provide deep insights into the learner state, including how effectively he or she is learning. This can be used to provide real-time recommendations for improving learning outcomes based on similar learners’ outcomes mined through crowd-sourcing. Evidence-driven insights—such as subject mastery, productivity schedule, and motivation index—can be assessed in real time to provide students with personalized learning recommendations that span their individual learning objectives, their courses, and their overall degree program.

**What higher education problems could be solved quickly with the widespread deployment of IoT technology? What problems might be created?**

IoT technology has the potential to improve operational efficiencies, connectivity, and collaboration. Seasonal campus services, such as registration and enrollment time, are examples of how higher education institutions could benefit from IoT deployment. Understanding the flows of use of various facilities during peak periods, campus buildings can allow for a more intelligent delivery of services. The IoT helps campuses to monitor and act in real time on that infrastructure.

Energy usage and space utilization are other areas where the IoT can help solve problems. Digitization is driving a growing convergence of the real world and virtual world, enabling institutions to leverage data analytics in the development of strategies to optimize energy efficiency and space utilization. With



higher education institutions facing an ongoing challenge to reduce operating costs and get maximum use from existing space to support record numbers of students, these are serious issues that the widespread deployment of IoT technology could address.

IoT technologies, including smartphones and a Wi-Fi connection, are expected by students today, so campuses must be sure they have a quality IT and Telecom infrastructure to support that demand.

**In its definition of the Internet of Things, the Oxford English Dictionary notes: “If one thing can prevent the Internet of Things from transforming the way we live and work, it will be a breakdown in security.” Do you agree?**

Security is at the heart of IoT success. That is why, as the number and the range of IoT devices grow on campus, it will be critical to ensure that communication between devices is secure. One way that higher education institutions can reduce their security risk is to build fine-grained perimeters to protect critical assets. The data is then assigned a sensitivity value, which helps protect it.

Right now, IBM Research is developing an *Enterprise Information Security Management (EISM)* platform, which aims to semiautomatically measure the sensitivity levels of enterprise assets, including both data and non-data assets. IBM Research is conducting pilot tests with a number of real-world cases, including scanning employees’ laptops, classifying business documents, and ranking the sensitivity of servers without relying on data content. This approach has the potential to be applied to IoT devices in any type of enterprise, including educational institutions.

**Based on your experience with the IoT, what industry best practices or lessons learned do you think are significant to, and might apply in, higher education?**

Big data is arriving from multiple sources at an alarming velocity, volume, variety, and veracity. The data, by itself, does not generate any benefits: 90 percent of the data generated

today is “dark” (unusable). To derive value from it, we need to connect all the data sources with a cognitive IoT system that can analyze it.

Unlike existing computers that must be programmed, cognitive systems like IBM Watson can learn at scale, can reason with purpose, and can interact with people naturally. Cognitive systems make sense of and give purpose to the collected data. Existing computers simply can’t handle the volume and diversity of the data being generated everywhere, by everyone, every day. Cognitive systems, on the other hand, can properly utilize the data and can ensure that educational institutions are able to improve such core areas as learning experience, safety on campus, energy efficiency of buildings, and operational efficiency. But as part of utilizing IoT data, higher education institutions must ensure that the learner and the educator are fully opted in for any secondary use of the data collected from IoT devices.

**If you could offer a word of wisdom to higher education leaders on how to think about and apply the benefits of the IoT, what would that be?**

Both learning and teaching have benefited from integrating new technologies into the educational framework. However, integration by itself does not lead to a scalable, stress-free, adaptive, and personalized learning curriculum. Artificial intelligence and adaptive interactivity techniques need to be blended to achieve this. One promising approach for defining and monitoring the learning of an individual is to combine IoT and cognitive neuroscience research in the classroom of the future. The information that connected devices provide can be analyzed and, along with cognitive neuroscience, lead to deep insights into the brain’s mechanism of learning and how it is being affected in a particular setup. In an era of adaptive, connected, and artificial intelligence, the combination of cognitive neuroscience, machine learning, and psychology will thus allow us to explore the science of learning and optimize future classrooms. ■

**Note**

1. IDC, “The Internet of Things.”

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**What are the most exciting academic and administrative benefits enabled by the IoT for higher education?**

The IoT opens a range of possibilities and benefits for faculty, staff, and students. With the IoT, students are able to attend any class, at any time, from any device—providing them with greater flexibility to consume content and knowledge when and where they'd like. The IoT removes the traditional barriers to teaching and learning, providing faculty with the same flexibility to provide better learning experiences for students and allowing them to connect with experts from around the world and create robust, hybrid learning environments. The IoT also benefits administrators by helping to connect everything on campus everywhere through one secure, unified network to manage campus lighting, parking, HVAC systems, and cameras and to provide valuable data and analytics on traffic patterns, usage, and areas of resource optimization.

**How will the demands of a more connected student and a more connected campus influence—positively and/or negatively—the systems, processes, and infrastructure of the current higher education landscape?**

One of the biggest impacts of more connected students is when they come to campus with increased expectations about *experience*. Colleges and universities must reimagine the student experience, often by helping them to connect with previously unconnected systems. For example, can an institution tie a new student's location with the LMS to help the student get to his/her first class or to the right building for a study group? This requires that campus groups and departments collaborate to provide a better student experience and to ensure a solid, core infrastructure to support students' expectations and network demands. Campus leaders can look to retail stores and stadiums for ideas on how to deliver next-generation experiences.

**What higher education problems could be solved quickly with the widespread deployment of IoT technology? What problems might be created?**

The IoT presents a range of opportunities and challenges. One challenge is network security and physical safety. More connections to the Internet, with more sensors and other devices, create



**“Campuses can often be viewed like cities, and some of the greatest IoT innovations today are found in smart cities.”**



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access to the network from potential cybersecurity breaches. And physical safety can be one of the most important issues to a campus community. In fact, safety can be the reason a student might select a specific college or university. A variety of sensors, especially cameras, can now be completely integrated into a public safety system. This allows for quicker response times to an incident, making campuses safer. However, higher education institutions should also consider the policy implications of greater visibility into the lives of students and should be sure to balance privacy and safety. Including students in those policy discussions is one of the best practices that I have seen.

**Based on your experience with the IoT, what industry best practices or lessons learned do you think are significant to, and might apply in, higher education?**

Campuses can often be viewed like cities, and some of the greatest IoT innovations today are found in “smart cities.” Leaders in this space have key goals for greater economic growth, reduced road congestion, and improved access to citizen services, very similar to the objectives of many colleges and universities. To achieve those goals, they have to work across all of the city’s agencies, which can be a challenge. Often they create a new organizational structure or look to an independent third party to foster greater collaboration among different agencies. Higher education institutions can learn from leading smart city innovators: they can transform into fully connected campuses, or they can play the role of the independent third party to help enable smart city initiatives.

**If you could offer a word of wisdom to higher education leaders on how to think about and apply the benefits of the IoT, what would that be?**

The IoT can lead to breakthrough innovation and is creating entire new industries and new paradigms within existing industries. The best place to start is by having a vision of a fully connected campus to improve the experience for faculty, staff, and students.

And the best way to help students is to consider your campus to be a living lab. Engage your students to help you innovate in solving challenges and creating opportunities. Bring in industry partners who can help accelerate innovation and also foster career opportunities for students. ■

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