

The Internet of Things

Scenario

Andre, Kim, and Bryant are a study team in Dr. Kumar's course "Siting Urban Public Projects." In their first assignment, they will research four potential building sites for an extension of the local community center that will house a daycare and an after-school program. Some children in the target demographic have special medical, social, or learning requirements. Each team's report should name one site as a potential frontrunner, explain that choice, and offer recommendations for further study. The students name the four sites A, B, C, and D, and decide on a rating system from which they will add or deduct points, depending on what they find.

Kim starts with a city website where the maps are updated in real time from traffic sensors, parking lot monitors, toll booth sensors, and data from electronic signs. She finds that site A, near a high school, frequently has traffic snarls at 3:00 in the afternoon, which is about the time students arrive for the after-school program.

Meanwhile, Bryant finds city security cameras that show real-time views of sites A and D—a definite plus for security. At site B, he sees the traffic cam is trained on a small substation next door to the site. Only a fence separates the station from where children would play. He also checks streetlight sensors to see what time of day streetlights come on during all times of the year. Sites where all the lights consistently turn on the latest presumably have the greatest exposure to the sun and will offer children more natural light.

Because many of the children have health issues, Dave is checking air quality data from sensors placed by the local weather service. Site C, situated near a wild green space, is unusually high in plant allergens. Dave also checks water quality, and finds city water monitors show no readings at any of the sites that would suggest safety concerns. The student team builds a table that shows how many points they added or subtracted for each finding. They are confident they can easily defend Site D as their frontrunner based on traffic, security, and safety data.

1 What is it?

The Internet of Things (IoT) describes a state in which vast numbers of objects are interconnected over the Internet and can collect data and transmit and receive information. The IoT is not a new concept, but the current expansion of connected devices is a major step toward that vision. The IoT has its roots in industrial production, where machine-to-machine communication enabled the manufacture of complex items, but it is now expanding in the commercial realm, where small monitoring devices allow such things as ovens, cars, garage doors, and the human heart-beat to be checked from a computing device. Certain devices already record a broad range of human endeavor, from the wearable that measures gym activity and posts it online to the security camera that can be accessed on a phone. This new phase of the IoT is fueled by the recent availability of inexpensive, low-power sensors and transmitters, emerging standards, ubiquitous Wi-Fi, and the increased use of Bluetooth. The result is an intensely connected and data-rich environment.

2 How does it work?

The IoT is made possible by low-voltage, low-cost components and sensors that can be added to appliances, streetlights, doorways, desks, cars, e-textbooks, and other objects, all of which send data to a managing application. Apple's iBeacon, for example, is a Bluetooth component that transmits constantly to iOS devices. When in close proximity to a "beacon" of this type, smartphones and tablets can perform certain actions, such as providing data for retail check-out. With the right applications, iBeacons could take attendance, allow phone-enabled library check-out, or pinpoint a student's location in the library on an iPhone map for other study-group members. Another Bluetooth component, Broadcom's WICED Sense, is being offered to developers, particularly for the creation of wearables. Featuring a gyroscope, accelerometer, compass, barometer, and thermometer, the device's low cost and small size make it suitable for many applications.

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3 Who's doing it?

The **Secure Internet of Things Project** brings together researchers from **Stanford University, the University of Michigan, and the University of California, Berkeley**, to explore questions raised by the IoT, such as how to ensure security in an environment of pervasive sensing and analytics systems and how to protect and integrate existing data amid the vast data streams relayed from items in the physical world. An engineering course at Stanford used IoT data from building systems and environmental sensors to help students understand the interaction of the many variables in predicting and measuring energy use. In another project, **Internet2 and Innova UEV** will provide electric cars to four universities, each of which will use the cars' sensor data for research into sustainability, such as reducing the campus carbon footprint and exploring public transportation, and for other research areas including investigating commercial implications, gamification, and real-time data sharing.

4 Why is it significant?

By interconnecting all kinds of objects and systems, **the IoT could open new avenues of research and learning**. Eventually, the IoT could integrate campus infrastructure—connecting physical buildings and their contents, such as classrooms, learning spaces, resident halls, and administrative areas with the communication and utility systems that support them—to enable continuous regulation of heat and light, for example. The IoT could facilitate new kinds of assignments that explore the kinds of knowledge available from data when so many objects are linked. Students could build inexpensive IoT devices that allow them to conduct research that might previously only have been feasible at large labs.

5 What are the downsides?

The data-rich environment engendered by so many devices sending information (with or without permission) **raises serious concerns about privacy, security, and data ownership**, and these issues involve new policy questions. Data from cell towers and GPS satellites, for example, can be used to track movement patterns. An environment where an individual's phone, tablet, and wearables generate and transmit constant data streams could provide hackers with reference points to identify individuals. Hackers who use the IoT to gain control of items in classrooms or homes pose new kinds of threats. Because IoT devices employ multiple OS options and database protocols, the issue of standards is a significant

concern for developers and consumers, and the risk of balkanization will need to be addressed. Finally, some worry that the IoT will encourage passivity, resulting in a greater inclination to be consumers rather than creators.

6 Where is it going?

The IoT remains nascent, and because of that, it's likely that **many of the uses of the IoT—in general and for higher education specifically—won't be known until users start imagining the possibilities and developing applications**. The number of items that can include a sensor is nearly limitless, and the more data are collected, the greater the need to find new ways to discover and catalog that information. The expanding IoT will drive demand for data visualization that can clarify and present bulky data coherently. Even then, users might need to develop new kinds of data literacy to understand and control our streams of data. The challenge for students and faculty will be to explore what the IoT affords and imagine ways to take advantage of it for teaching and learning. In disciplines ranging from engineering to agriculture, environmental science, and others, the IoT promises extraordinary opportunities.

7 What are the implications for teaching and learning?

The IoT offers great potential for immersive learning experiences. The increasingly connected network of devices and data streams could coordinate campus physical spaces, integrating information from sensors embedded in objects including library resources, whiteboard writing surfaces, game boards, and robots. The components that collect and relay data are being used in makerspaces, laboratories, and projects undertaken by students and faculty. Off campus, students can visit historical locations or study urban environments where information is transmitted from nearby sensors. Tagged plant markers in a public herb garden, for example, could send data to a student's phone, relating common and scientific names, date of planting, culinary uses, medicinal uses, mature size, and country of origin. Student profiles could be mapped to the physical campus, such as classrooms, labs, libraries, and gyms, and wearable devices could ensure that students are granted appropriate access. Library data could note entrance and exit times, patterns of use, and which books were opened. E-texts could record how much time is spent in textbook study. All such data could be accessed by the LMS or various other applications for use in analytics for faculty and students.