

Testimony before the House of Representatives Committee on Energy and Commerce

Sub-Committee on Digital Commerce and Consumer Protection (115th Congress)

Disrupter Series: Update on IOT Opportunities and Challenges

June 13, 2017 10:00 AM, 2123 Rayburn

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Chairman Latta, Ranking Member Schakowsky, and Committee members: Thank you for inviting me today to share some thoughts and insights on the opportunities and challenges in the Internet of Things (IoT). I would especially like to thank Representative Mimi Walters, who represents UC Irvine in California's 45th Congressional district for her support of UCI. For this testimony, I am representing two organizations, the University of California Irvine (UCI) and Integra Devices LLC. UCI is a world class premier public research university, the Orange County campus in the University of California system. UCI promotes IoT through research, education, outreach and tech transfer. Integra Devices is a spinout company from UCI that develops smart sensing modules for IoT, utilizing unique intellectual property for advanced manufacturing, machine learning, and energy harvesting.

My testimony describes my experiences and perspectives regarding the challenges and solutions for the Internet of Things (IoT). I shall briefly discuss three topics: (1) overview of IoT, (2) the role of the public university in leadership and stimulation of the local IoT ecosystem, (3) spinning out a startup for IoT.

This testimony comes from my direct experiences in these topics. As a professor and IoT Evangelist, I have spent many years studying IoT, working with researchers and companies to implement technology for IoT applications. As entrepreneur, I have brought technology out of the university to convert it into goods and services.

IoT promises to bring dramatic changes to the way we do things in industry, bringing large quantities of new data and insights to industrial processes, enabling us to do operations with greater productivity, efficiency, and safety than ever before. There are expected to be 50 billion connected monitoring devices deployed by 2025. Using sophisticated analysis of data from thousands of monitoring units in the industrial and civil infrastructure, we can better understand the complexities of our operations and

identify ways to improve the way we do industry. The resulting combined economic impact of IoT is predicted to be between 4-11 Trillion USD by 2025. Industry (manufacturing), transportation, and civil infrastructure (“smart cities”) are the largest impacted markets; home automation and human wearables, while significant, represent the smallest of the IoT markets. [1].

Universities such as UC Irvine have the potential to be a powerful catalyst in leading the effort towards next generation IoT. Research and development in areas such as basic sciences, information sciences, social sciences, and business lead directly to practical technologies and methodologies that can drive IoT applications, services, and products. In Orange County CA, UC Irvine provides leadership for the IoT ecosystem in OC, through research, training, public outreach, and investment. UC Irvine provides a common ground for companies, government, and the public to work together on IoT topics. Several organizations on the UCI campus are active in promoting and stimulating IoT in Orange County. These include the California Institute for Telecommunications and Information Technology (Calit2-Irvine) and the UCI Applied Innovation Institute. Calit2-Irvine works with industry and campus researchers across disciplines to convert basic research results into technology that is practical and of value to industry. UCI Applied Innovation brings campus-based inventions and entrepreneurship together with Orange County's vibrant business community to support job creation and economic growth.

My own startup company, Integra Devices, is producing IoT products based on technology that was developed at UC Irvine over the past 15 years. We produce highly integrated, wireless smart sensing devices that can be used to monitor industrial and infrastructure operations. Our sensing devices are fully self-contained (requiring no additional hardware), can be placed on machinery and infrastructure, and can analyze activity in real time, extracting the key features of the signal to send to the cloud. Moreover, our devices learn the patterns of machinery, and within a few hours can identify the natural state of machinery and report when it deviates from “normal” behavior, providing key information for

predictive maintenance and operations. Many of our devices can run under “zero power” conditions, meaning that they do not need to be cabled and do not need to have batteries replaced. Most of the research leading to these products was done at UC Irvine. Some of current development is funded by the National Science Foundation. Integra Devices has benefitted greatly from research performed at the University and continues to partner with UCI and other public institutions to develop new IoT technologies and applications, and train the next generation of IoT leaders.

Having worked in both public academia and the private sector, I am convinced that a strong public-private partnership will stimulate the next generation of technologies, business practices, applications, services, and small companies for IoT, ensuring that the US retains leadership in IoT over the coming years. IoT is probably the most significant tech market of the 21st century and it is one that the U.S. can lead, if we commit to doing so.

[1] Market predictions are taken from this source: “Unlocking the potential of the Internet of Things”. By James Manyika, Michael Chui, Peter Bisson, Jonathan Woetzel, Richard Dobbs, Jacques Bughin, and Dan Aharon, McKinsey Global Institute Report, June 2015. <http://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/the-internet-of-things-the-value-of-digitizing-the-physical-world>

I. The promise and technology challenges of IoT

IoT is the rapidly growing trend to monitor our physical world using installed electronic computing devices that send their data to the internet for analysis and tracking. In 2013 the Global Standards Initiative on Internet of Things (IoT-GSI) defined the IoT as “a global infrastructure for the information

society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.”

Data collected from installed devices can be used to perform sophisticated analysis or modeling, resulting in smart operational or business practices that bring value to stakeholders. Analysis of data will drive decisions for predictive maintenance, operations optimization, improved efficiency, and greater safety. All of these improvements to current practices promise to bring significant economic benefit, with estimates ranging between 4-11 Trillion USD by 2025 [1].

A typical IoT architecture consists of three main sectors: the “edge”, telecommunications “backbone”, and “cloud”. All of these represent opportunities for new businesses, products, and services. At the physical edge are small electronic units consisting primarily of sensors (and in some cases, actuators) that monitor physical things. These edge devices quantify information about the things they monitor, then send this data to the internet via wired or wireless infrastructure (the backbone). The data is transported across the telecommunications backbone to server farms, often referred to as the cloud. Here the data is analyzed to determine correlations, build models, provide visualizations, and produce recommended improvements or changes to machinery or operations.

In the first generation of IoT (the next five years), most of the data will travel one way, primarily starting from the sensors in the edge devices and ending at the cloud. Results from cloud analysis will be used to modify operations or business practices, but will rarely be used for real-time control of machinery or operations. As IoT matures, some data will flow back to provide guidance to machinery, and eventually may even be used to provide remote control of some operations. For example, today’s smart cars can report car sensor data and GPS coordinates to a remote cloud service. As cars continue to develop, the cloud will send data back to the cars to improve their function, such as recommending driving routes, identifying nearest gas stations, or setting alarms for maintenance. Ultimately, smart cars may be

directed from the cloud in their operations, including driving and optimal use of vehicle resources. The final scenario, where machines are controlled by the cloud, will take significant time to develop and face significant resistance from decision makers and consumers. Security and integrity of data is one of the greatest concerns the public has for IoT, and decision-makers are reluctant to allow cloud control of critical or dangerous operations. Nevertheless, the value for IoT, even in its simplest, first generation form, is already dramatically large.

All three components of the IoT architecture (edge, backbone, and cloud) will benefit from and drive developments in technology and business practices. Edge devices must be produced at low cost, small size, with a high degree of integration. This is driving the microelectronics industry to develop advanced manufacturing processes that can build everything in a simple small module, including transducers, electronics, memory, computing, power, and telemetry. The industry is tackling this through a technology called “heterogeneous integration” which promises to produce “system in a package,” allowing for next generation IoT edge products. Other developments for IoT edge products include advanced algorithms for sensors and low power techniques for driving sensors and telemetry.

The telecommunications backbone must likewise upgrade and develop technology to support the wide variety of data and the exponential increase in traffic that will result from IoT. IoT is one of the drivers of “5G”, the emerging wireless standard that promises to increase wireless bandwidth by more than 100 times current capability. Communications technology will rely more and more on wireless connectivity over cabled (copper or optical). This is especially true in developing regions, which do not have sufficient infrastructure to support cabled systems such as fiber, but which can support wireless backhaul much more easily.

Cloud offerings will develop very powerful, yet easy to use, software products for analyzing and reporting on large, complex datasets. Ways to integrate data harvesting and analytics into conventional

enterprise systems must be developed, as well as ways to share data. In addition, cloud services will need to educate an entire generation about advanced analytics and how to understand it.

There are many market verticals for IoT, and different analysts. Most analysts identify the following markets: Manufacturing, Smart cities, Transportation, Environment, Retail, Health, and Home/Office. In general, by 2025, the largest sector is manufacturing (1.4-4.6 T USD), followed by Cities (0.9-1.7 T), Transportation (0.8-1.6 T), Retail (0.4-1.1 T), Health (0.2-1.6 T) and Home/Office (0.3-0.5 T) [1].

The IoT movement faces multiple challenges overall, in addition to specific challenges within each component. Challenges to adoption include high cost of entry, large barrier to implementation, and unclear value proposition to end users. Concerns about security, privacy and information integrity are also major concerns.

II. The leadership role of the university in the IoT ecosystem

IoT will drive the development of new business paradigms and new technologies; this is both an opportunity and a challenge. Because it is new, IoT brings a number of inherent challenges to adoption, especially for small innovative companies wishing to bring new IoT products or services to markets.

Public entities such as research universities have the opportunity to accelerate economic activity in IoT. I point to UC Irvine (UCI) as a specific example of a California public university that is helping to stimulate the local IoT ecosystem in Orange County, CA.

UCI engages in four key activities that serve to stimulate Orange County's IoT ecosystem: (1) Research and development, (2) Education and training, (3) Public outreach, and (4) Business/investment promotion. These efforts demonstrate UCI's commitment to economic development in Southern California and leadership in IoT.

Research and development. UCI provides advanced research in areas related to IoT through its many schools and institutes on campus. Research is performed in the schools of engineering, information and computer science, physical sciences, biological sciences, social sciences, medicine, business, etc. Much of this research provides key findings or technologies that have immediate impact to companies developing products and services for IoT. The university actively engages in cross-disciplinary research activity, which is of critical importance to emerging IoT applications and technologies, and difficult to do in the commercial sector, especially for small companies. UCI is a member university of the DoE's Enable Clean Energy Smart Manufacturing Innovation Institute (CESMII) which promotes smart manufacturing to become the driving, sustainable engine that delivers real-time business improvements in U.S. manufacturing. Calit2-Irvine's R&D efforts are advancing IoT and mixed reality technologies to empower the "smart connected worker" to transform and increase the value of America's manufacturing labor force. UCI actively patents much of its research and these inventions are made available to local companies and entrepreneurs. As a wellspring of advanced research and technology, the university plays a powerful role in providing the raw materials needed for IoT companies.

Education and training. As a premier educational institution, UCI partners with local industry to educate the next generation of innovators and leaders for Southern California. UCI leads the nation in providing students a pathway to success, regardless of their backgrounds or financial status. The New York Times' College Access Index rates UCI first among U.S. universities based on UCI's commitment to economic diversity, doing the most to helping students achieve the "American Dream". UCI is a Hispanic-serving institution (one-quarter of undergraduates identify as Latino), as well as an Asian American and Native American Pacific Islander-serving institution, demonstrating UCI's ongoing dedication to access, diversity, and excellence. In addition, UCI provides numerous training and educational programs for working professionals in the areas of technology, engineering, and business to help prepare the workforce for IoT opportunities.

Public outreach. UCI is committed to working with the Southern California community in building IoT opportunities. UCI organizes numerous workshops, conferences, panels, and symposia to bring Southern California innovators together, stimulating new ideas, new relationships, and new ventures. In addition, the California Institute for Telecommunications and Information Technology (Calit2-Irvine), which is located on the UCI campus, helps bring disparate interdisciplinary activities and companies to IoT challenges, provides significant services in assisting local companies to learn more about IoT, connect with other IoT companies, or prototype new IoT technologies.

Business and investment promotion. UCI assists in the creation of new business entities to drive the IoT economy. Several institutes on the UCI campus are actively involved in assisting young companies, especially UCI spinouts, to attract people, resources, and funding. Calit2-Irvine, UCI's Applied Innovation Institute, and the Beall Center of Innovation all provide significant mentoring and incubation programs for companies. Several resources are available on campus to encourage students to participate in new ventures, including the UCI ANEntrepreneur Center. UCI works with many local incubators, industry trade groups, and investor groups to assist in building an innovation-friendly ecosystem for IoT startups. One example acceleration program is the Wayfinder program, part of the Institute for Applied Innovation. Wayfinder is a program for UCI-affiliated startups that is designed to accelerate venture development by providing teams with space, strategic guidance, and other valuable support resources. Several IoT startups have recently spun out of UCI, including Integra Devices (smart edge devices and 5G systems), Flyspan (drone fleet management), FunBand (IoT for child safety), and HyperSight (IoT for sales and marketing). UCI is aggressive in bringing its significant patent portfolio to the public, and provides startup-friendly terms for licensing these properties.

III. Integra Devices, a UCI spinout that develops smart edge products

My own startup company, Integra Devices, spun out of UCI about 18 months ago. Integra Devices is currently leveraging three major innovations that were developed at UC Irvine: (1) advanced manufacturing techniques for building highly integrated, smart sensor modules, (2) machine learning algorithms that can determine the key features of sensor signals and learn the time varying pattern of those signals, and (3) low to zero power sensor technologies, enabling the production of remote sensors that require no power cables and no batteries.

Integra Devices builds self-contained, smart edge monitoring devices that can be installed on machinery or infrastructure in industrial, civil, transportation, and environmental applications. These devices use on-board artificial intelligence (machine learning) to learn the “normal” patterns of the machinery that they are monitoring. The edge devices report the key features of the patterns to the cloud for further analysis or monitoring, instead of transmitting raw data. By performing this analysis at the edge, Integra enables deployment of sensing systems that have dramatically lower bandwidths over conventional sensors and can readily scale to hundreds or thousands of monitors in a single application. In addition, some of Integra’s sensing modules can be installed without then need for power cables or batteries since they use techniques to monitor and transmit data that don’t require on-board power. One such “zero power” technology, dynamic energy harvesting, is currently being developed under funding by the National Science Foundation.

Integra Devices was founded by a UCI professor and two tech industry veterans who live in Orange County. The startup company has exclusively licensed two key patents from the University with many more in the pipeline. The company has grown to a team of 10 people, employs former UCI students, and trains UCI student interns. We build highly integrated micro-electronic products using proprietary manufacturing techniques that we share with our US-based manufacturing partners, bringing advanced manufacturing to the U.S. We are working closely with a number of key strategic partners (large

companies) who view our technology as highly innovative and having high value. Integra Devices is a perfect example of how a high risk, highly innovative company can be launched with the support and partnership of the university and as a result of the U.S. government investment in advanced research.

Having worked in both public academia and the private sector, I am convinced that a strong public-private partnership is needed to stimulate the next generation of technologies, business practices, applications, services, and small companies for IoT, ensuring that the U.S. retains leadership in IoT over the coming years. I have worked with colleagues, business leaders, government agencies, and entrepreneurs in the technology industry in Europe, Asia and the Americas; the significant degree of cooperation between our public institutions and universities is the envy of the world, and widely recognized as one of our key advantages for bringing innovative technologies, practices and enterprises to market. IoT is probably the most significant tech market of the 21st century and it is one that the U.S. can lead, if we commit to doing so.