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BOUNDLESS COLLABORATION.

COMMUNITY

CONNECTED RESEARCH.   ACCELERATED DISCOVERY.

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SMART CAMPUSES AND THE INTERNET OF THINGS

PRESENTED BY: Florence D. Hudson, SVP and Chief Innovation Officer, Internet2

Internet2 Smart Campus initiative was developed based on use cases from three member-led innovation working groups established in 2015 from a member survey requesting input on focus areas for open collaborative innovation

E2E Trust & Security (E2ET&S)

- **TIPPSS for IoT – Trust, Identity, Privacy, Protection, Safety, Security**
- NSF EAGER Cybersecurity Transition to Practice Acceleration
- SDP (Software Defined Perimeter), Network Segmentation for IoT

Distributed Big Data & Analytics (DBDA)

- **Health & Life Sciences / Genomics**
- **Smart Campuses & Cities**
- **NSF Big Data Hub Collaboration**
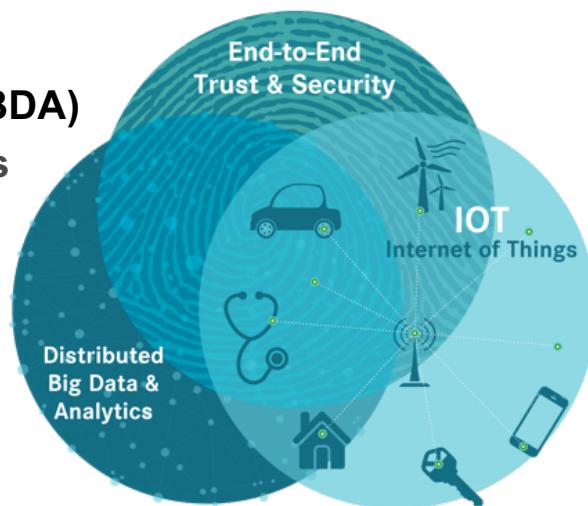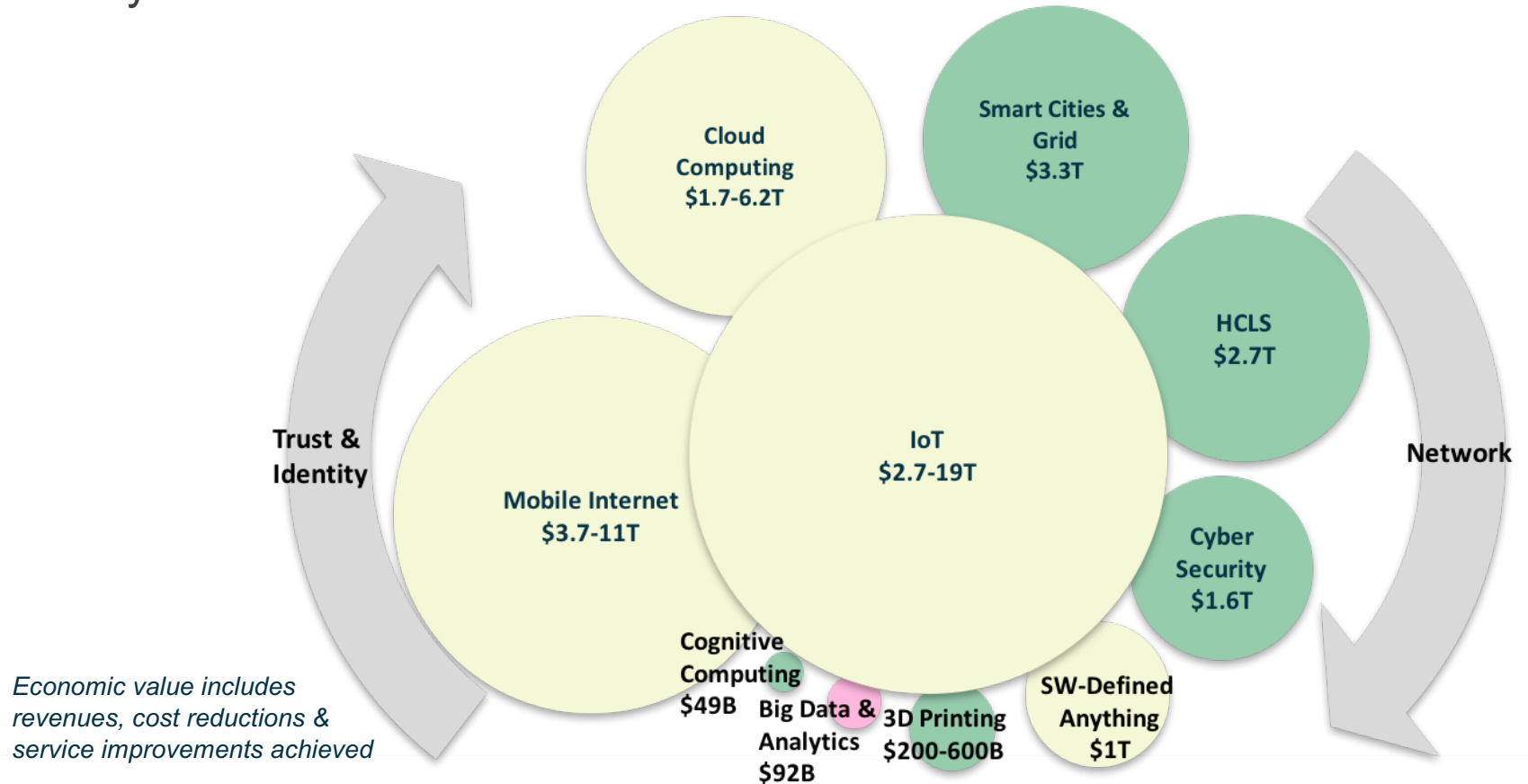
Internet of Things (IoT)

- **IoT Sandbox**
- **Smart Campuses & Cities**
- **Smart Grid Testbed**

End-to-End Trust & Security

IOT Internet of Things

Distributed Big Data & Analytics

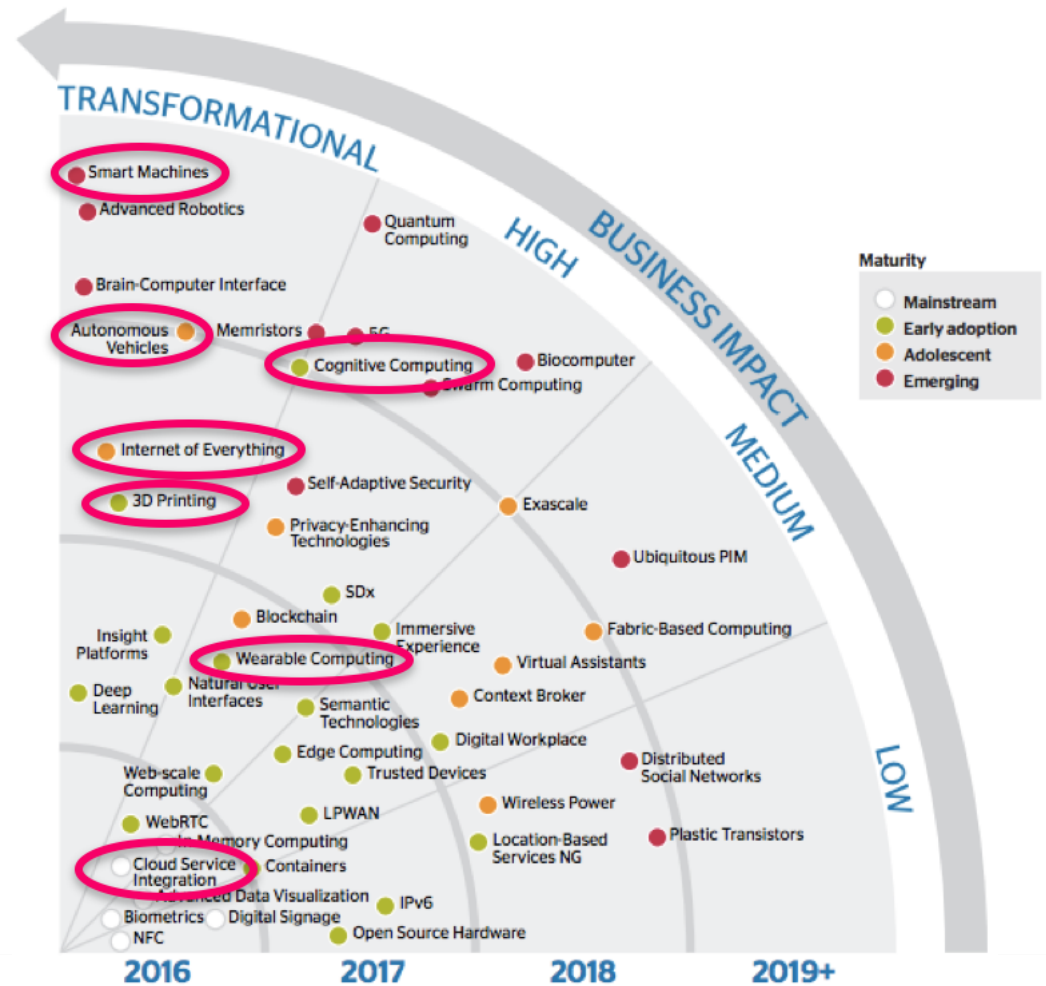Key:
Smart Campuses & Cities oriented

The Internet of Things could represent $19T in economic value by 2025, a significant component of key ICT trends for Research & Education and Smart Communities.

Cloud Computing
$1.7-6.2T

Smart Cities & Grid
$3.3T

HCLS
$2.7T

Trust & Identity

IoT
$2.7-19T

Network

Mobile Internet
$3.7-11T

Cyber Security
$1.6T

Cognitive Computing
$49B

Big Data & Analytics
$92B

3D Printing
$200-600B

SW-Defined Anything
$1T

Economic value includes revenues, cost reductions & service improvements achieved

Supporting technologies for key ICT trends are already having significant business impact, with IoT applications & devices at the top of the transformation curve.
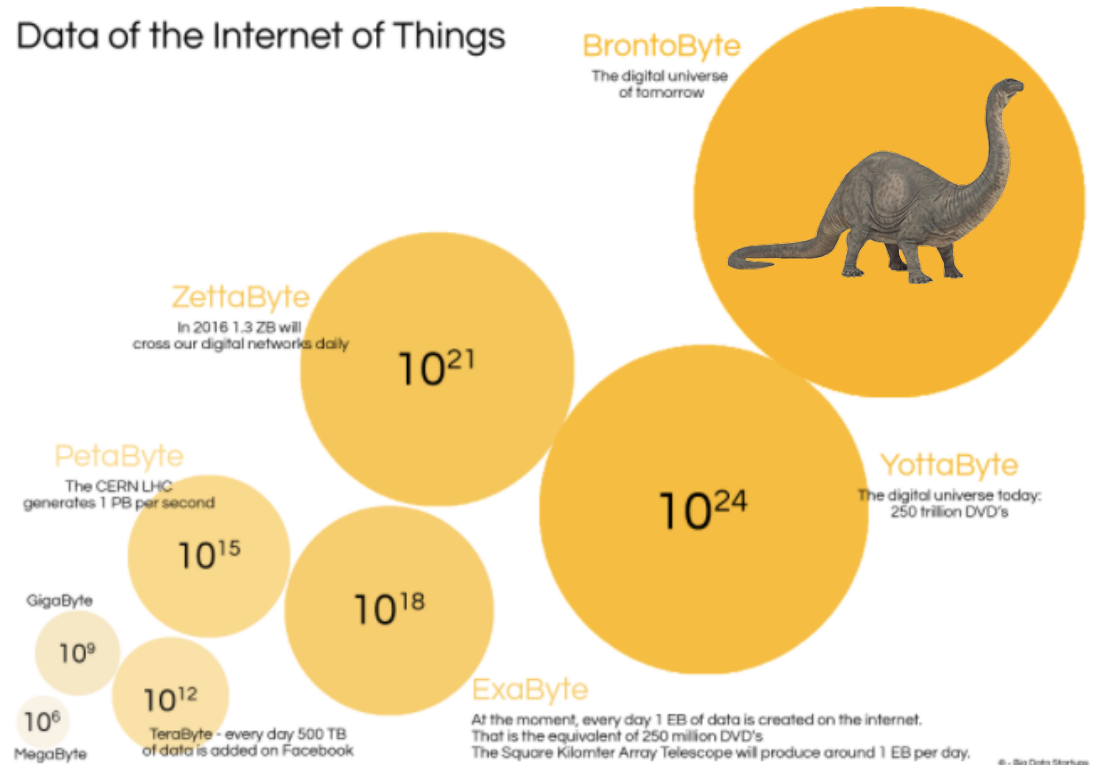

TRANSFORMATIONAL
HIGH
BUSINESS IMPACT
MEDIUM
LOW

Maturity
- ○ Mainstream
- ● Early adoption
- ● Adolescent
- ● Emerging

- Smart Machines
- Advanced Robotics
- Quantum Computing
- Brain-Computer Interface
- Autonomous Vehicles
- Memristors
- 5G
- Cognitive Computing
- Biocomputer
- Swarm Computing
- Internet of Everything
- Self-Adaptive Security
- Exascale
- 3D Printing
- Privacy-Enhancing Technologies
- Ubiquitous PIM
- SDx
- Blockchain
- Immersive Experience
- Fabric-Based Computing
- Insight Platforms
- Wearable Computing
- Virtual Assistants
- Natural User Interfaces
- Context Broker
- Deep Learning
- Semantic Technologies
- Digital Workplace
- Edge Computing
- Distributed Social Networks
- Web-scale Computing
- Trusted Devices
- WebRTC
- LPWAN
- Wireless Power
- In-Memory Computing
- Location-Based Services NG
- Plastic Transistors
- Cloud Service Integration
- Containers
- Advanced Data Visualization
- IPv6
- Biometrics
- Digital Signage
- NFC
- Open Source Hardware

2016　2017　2018　2019+

The Internet of Things will generate the majority of new data on the back of explosive device growth.

IoT installed base, global market, billions

Year	Value
2015	15.41
2016	17.68
2017	20.35
2018	23.14
2019	26.66
2020	30.73
2021	35.82
2022	42.62
2023	51.11
2024	62.12
2025	75.44

Sources: What's The Big Data 2015; Datafloq 2016; GlobalSources 2016

Data of the Internet of Things

MegaByte 10^6

GigaByte 10^9

TeraByte 10^{12} — every day 500 TB of data is added on Facebook

PetaByte 10^{15} — The CERN LHC generates 1 PB per second

ExaByte 10^{18} — At the moment, every day 1 EB of data is created on the internet. That is the equivalent of 250 million DVD's. The Square Kilomter Array Telescope will produce around 1 EB per day.

ZettaByte 10^{21} — In 2016 1.3 ZB will cross our digital networks daily

YottaByte 10^{24} — The digital universe today: 250 trillion DVD's

BrontoByte — The digital universe of tomorrow

© - Big Data Startups

Sources: What's The Big Data 2015; Datafloq 2016; GlobalSources 2016

IoT risk and security awareness is increasing… and highlighting the need for security research and development.
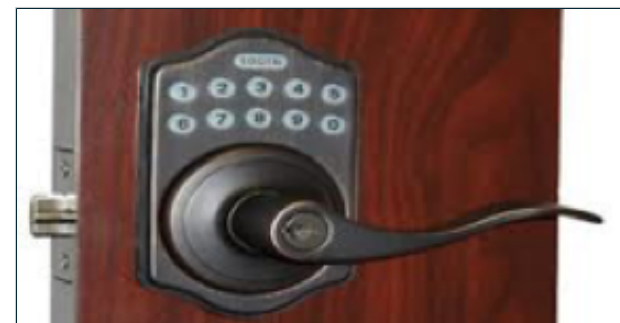

Vehicle Hacking
http://bit.ly/jeephackwired
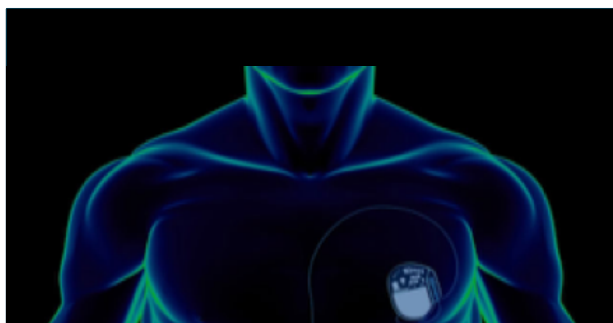
Healthcare Device Hacking
http://bit.ly/jnjinsulinpump
http://bit.ly/medtronicinsulinpump

Smart Home Devices Hacking Other Devices
http://bit.ly/hackedhomedevices

Internet2 Smart Campus Initiative is led be a Smart Campus CIO Advisory Council including thought leaders who are executing smart campus strategies.

- Kickoff meeting with Smart Campus CIO Advisory Council at Internet2 Global Summit, May 2016

- Share best practices and recommendations to deploy Smart Campus capabilities

- Commissioned IoT Systems Risk Management Task Force

- Microsoft and Internet2 co-convened first annual Campus Connections Summit, Feb 2017, 140+ university "CIO + 1" attendees from around the world

Research & Education activities are growing in Smart Campus / Communities, IoT, end-to-end trust & security, big data & analytics, Smart Grid.

ASU ARIZONA STATE UNIVERSITY
Smart Campus operations & data analytics research

Colorado State University
Advanced Networking / Cybersecurity Research

LEHIGH UNIVERSITY
Smart Grid research

NC STATE UNIVERSITY
Smart Grid research network testbed

THE UNIVERSITY of WISCONSIN MADISON / MARSHALL UNIVERSITY
IoT Lab for Research and Pedagogy

Stanford University
Smart transportation / IoT ethics research

Rensselaer
Smart Grid research

A&M
Smart Grid research and data sharing

PRINCETON UNIVERSITY
IoT Security, Privacy & Ethics

UMBC AN HONORS UNIVERSITY IN MARYLAND
Trust, Identity, Protection, Privacy, Safety, Security

W UNIVERSITY of WASHINGTON
IoT Systems Risk Management & Security

VirginiaTech 1872
Smart Campus operations, trust and security

Grey - IoT research and pedagogy
Blue - IoT Smart grid research
Orange - IoT security, privacy, ethics

ASU Smart Campus Journey began with a Smart Stadium

Gen 1: Game Day Experience

- Infrastructure upgrade
  - WiFi
  - DAS
- Real Time Parking
- Sensor Packs
- A smarter sound game
- Upgraded mobile app

Gen 2: Stadium Suite

- Water flow sensors
- Alexa skillset
- Sentiment analysis
- Indoor wayfinding
- AWS Dash

IT INFRASTRUCTURE
- 265,000 ft of cat 6 cabling
- 93,000 ft of fiber optic cabling
- 22 telecom rooms

CELLULAR NETWORK
- 162 remote nodes installed
- 230 DAS antennas added
- 50,000 ft of DAS coax
- 18,000 ft DAS fiber

WIRELESS CONNECTIVITY
- 430+ access points installed
- 80 access switches installed

TECHNOLOGY ENHANCEMENTS

USER EXPERIENCE

WIRELESS DEPLOYMENT
- Access points deployed on all 3 levels and field
- 802.11n and 802.11ac networks available
- User and vendor access available in all areas

WI-FI
- 8,100+ unique clients per game
- 72,000+ user sessions
- Over 600 gigabytes of data transferred per game

ROADMAP
- Integrated environmental sensors
- Mobility related services
- Customized Alerting
- Directions/Optimization

STADIUM VISION
- 100+ video displays installed
- Provides customizable video and graphics to fans

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Gen 3: Scaling to a Smart Campus

- Smart Fleet
    - Vehicle/Golf Cart Reservation tracking
- Smart Classroom
    - Automated attendance tracking
- Smart Assistant
    - Building out Alexa skillset
    - Integrating other information sources

ASU Smart Culture

Academic, Government & Private Partnerships

Project Wing partners with Virginia Tech to test delivery by unmanned aircraft

Project Wing will be conducting research flights with Virginia Tech's Mid-Atlantic Aviation Partnership to explore food delivery by unmanned aerial vehicles. They will gather data on these operations to share with the Federal Aviation Administration as a step towards safely integrating deliveries by unmanned aircraft into everyday life.

The Virginia Tech Mid-Atlantic Aviation Partnership and X's Project Wing will conduct research flights this fall at Virginia Tech, delivering food using unmanned aerial vehicles.

http://vtnews.vt.edu/articles/2016/09/ictas-maapprojectwing.html

IoT Research & Education at Stanford University – Autonomous Vehicles and Ethics

http://bit.ly/autonomousvehiclesethics

eMailBox

Emergency notification

Smart Trash can

Voice Control

Food Temperature Control

Pet Care

Smart Parking

Class Attendance

Security System

Remote door control

Water leak Detection

Light Control

Washing Machine scheduler

Music streaming

Smart Campus
Internet of Things
Class Projects

MARSHALL UNIVERSITY

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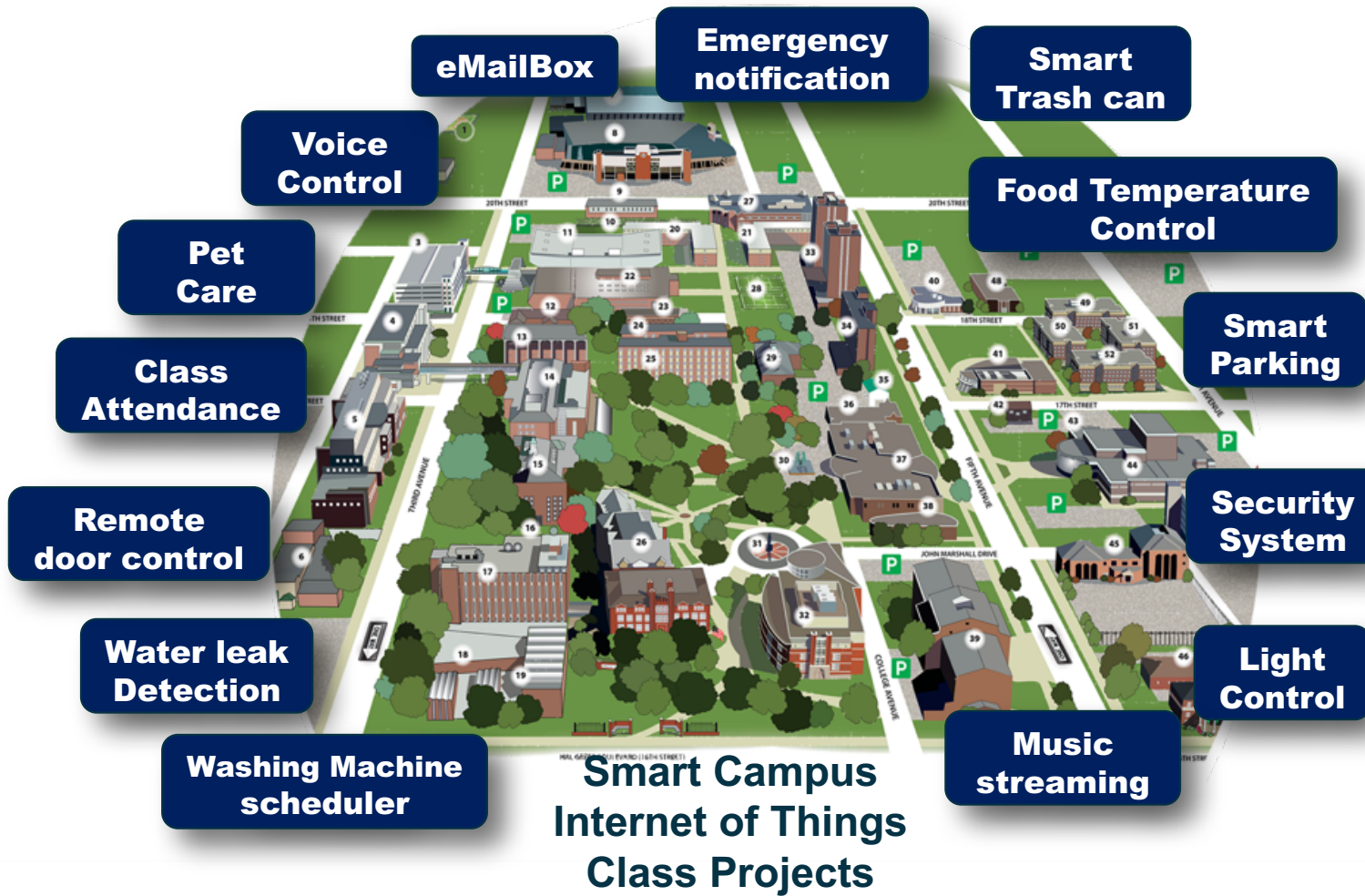
IoT will have an impact in higher education and K-12.

What impact do you anticipate from the Internet of Things?

46% Major Impact Within 2 Years

33% Minor or Delayed Impact

What concerns and drawbacks do you see to the technology?

1. Security
2. May be expensive
3. Privacy
4. Lack of interoperability among different smart technologies
5. Distractions
6. May be hard to manage
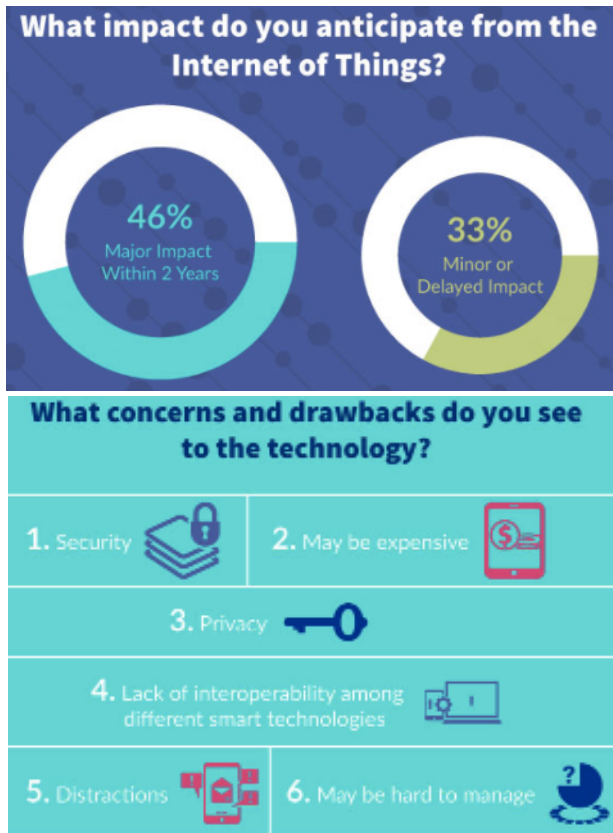
What are the benefits of smart school technology?

1. Increases student engagement
2. Takes advantage of mobile learning
3. Enables a more personalized education
4. Eases the learning process for students
5. Improves efficiency or reduces costs
6. Improves measurement of student success
7. Helps teach creativity
8. Provides a safer learning environment
9. Enhances control and responsiveness

Top 10 Currently-Implemented Smart Technologies

1. Interactive whiteboards
2. Cameras and video
3. Tablets and eBooks
4. Student ID cards
5. 3-D printers
6. Smart HVAC system
7. Electric lighting/maintenance
8. Temperature sensors
9. Attendance tracking
10. Wireless doorlocks

*N=612 IT Managers;
K-12 (65%) & Higher Ed (35%)*

Cybersecurity is required for IoT, Smart Cities, and Smart Grid to be successful.

The Growing Cyberattack Surface

3.0B | 4.0B
More users
3.0 billion in 2015
4.0 billion in 2019

3.3B | 5.9B
More smartphone connections
3.3 billion in 2015
5.9 billion in 2020

8.8ZB | 44.0ZB
More data
8.8 zettabytes in 2015
44.0 zettabytes in 2020

16.3B | 24.4B
More IP-connected devices
16.3 billion in 2015
24.4 billion in 2019

72.4 EB | 168.0 EB
More network traffic
72.4 exabytes per month in IP traffic in 2015
168.0 exabytes per month in IP traffic in 2019

Cybersecurity grabbing headlines, increasingly important with more connected IoT devices.
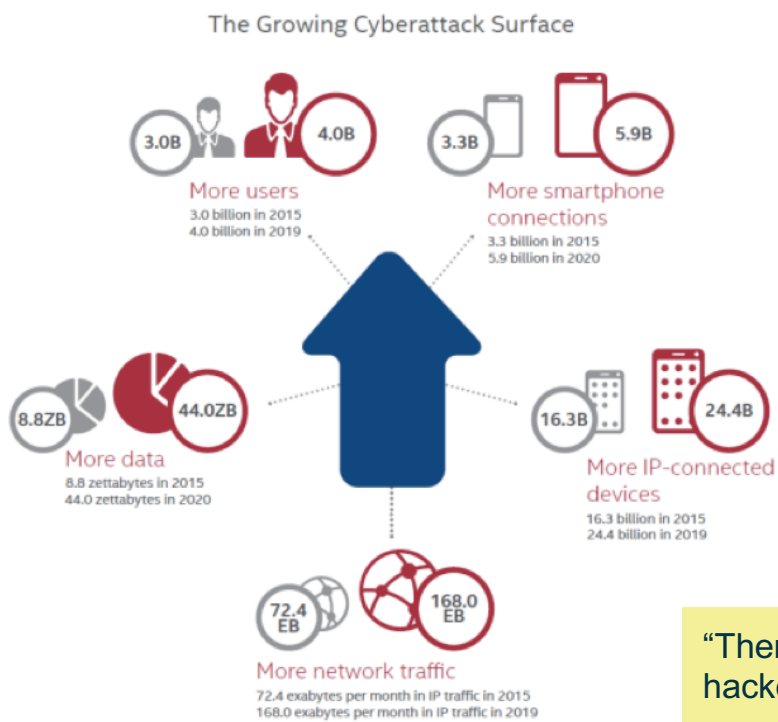
- Distributed Denial of Service (DDoS) attacks increasingly more potent and frequent

- Key areas for innovation: detection, response, defense, prediction, prevention

- Multiple aspects of risk: data, physical, and financial

- Critical applications of IoT require TIPPSS: **Trust, Identity, Privacy, Protection, Safety, and Security**

"There are two kinds of big companies in the US. There are those who've been hacked, and those who don't know they've been hacked."

— *FBI Director, James Corney*

Addressing TIPPSS for IoT is essential to achieving safe, secure, scalable future smart city and campus architectures.

- **Trust**: Allow only designated people/services device access

- **Identity**: Validate identity of people, services, or "things"

- **Privacy:** Device, personal, sensitive data is kept private

- **Protection:** Device users protected from harm

- **Safety**: Safety of devices, infrastructure and people

- **Security**: Maintaining security of data, devices, people, etc.
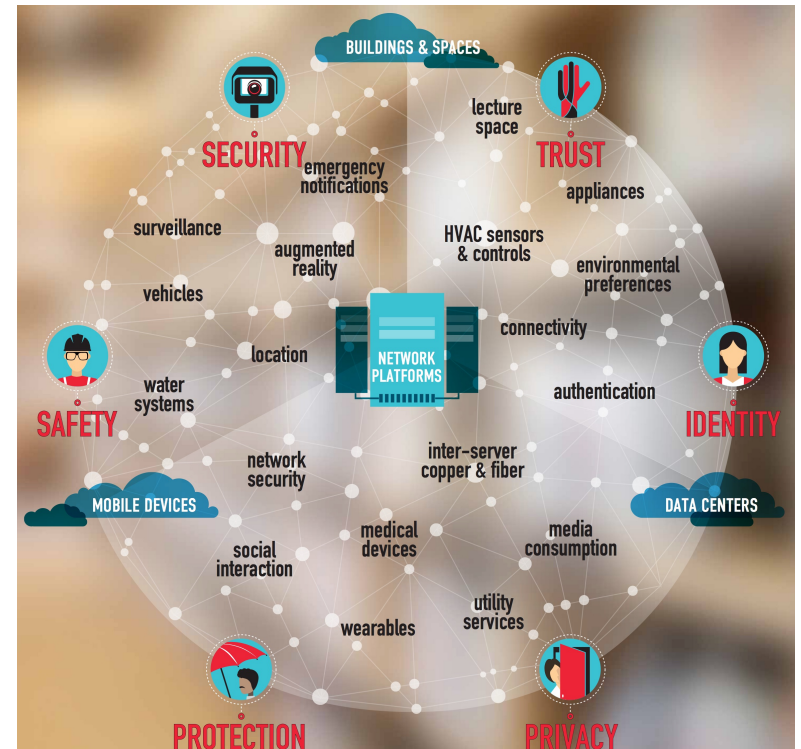
Flo's Top Concerns: TIPPSS in an interconnected IoT world.

Top concerns:

- Connected vehicles
- Connected healthcare devices

Protection needed regarding:

- Physical health and safety risk
- Financial risk
- Reputational harm
- Loss of privacy
- Data theft
- Hack in / Hack out risks

How The Internet Of Things Is The Perfect Target For DDoS Attacks And Data Breaches

14 January 2017, 12:00 pm EST By Athena Chan Tech Times

COMPUTERWORLD FROM IDG

NEWS

DDoS attack on Dyn came from 100,000 infected devices

TechRepublic. SEARCH — CXO Cloud Big Data Security Innovation More ⌄ Newsletters Forums Resource Library Tech

SECURITY

49% of businesses fell victim to cyber ransom attacks in 2016

Ransom is the top motivation behind cyber attacks, according to a report from Radware, and IT professionals are most concerned about data loss. Here's what you need to know.

By Alison DeNisco | January 10, 2017, 3:00 AM PST

Xconomy Xperience Tech + Life | EXOME Biotech + Health | Our Regions | Tech Channels | Meet the Xconomists | Our Events

Cybersecurity in 2017: Goal, Illusion, or Oxymoron?

Internet2 IoT Systems Risk Management Task Force: Recommends Initial Exposure Benchmarking/ Baselining via Shodan & Censys.io tools.

How to Find IoT Devices Connected to Your Campus Network

Why is this important?

IoT devices on our campus networks may be vulnerable to malware and increase the risk for information security and privacy compromises. Yet, many of these devices show up on campus without the knowledge of central IT. So how can we find those devices that put us at risk? The Internet2 IoT Systems Risk Management Task Force found two tools, Censys and Shodan, to be easy enough for non-security experts to use to find IoT devices.

Types of Devices/ Vulnerabilities
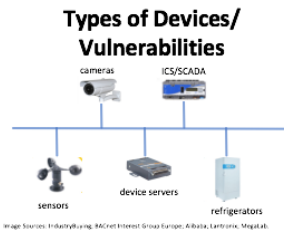
Bashlite and Mirai malware have created botnets that carried out DDoS attacks on DYN, OVH, and an unnamed US university. Other potential vulnerabilities include:

- Devices with weak or hardcoded passwords: IP cameras, light sensors, refrigerators
- Devices that connect through known high risk ports such as Telnet/port 23 using TCP/IP (no encryption): printers, cameras, device servers
- Devices that connect to components of building automation systems: SCADA and ICS components

Tools: Shodan and Censys

Shodan and Censys are search engines that find servers and other devices connected to the Internet that use Internet protocols specifically associated with industrial control systems and, increasingly, IoT devices & systems. They retrieve metadata about the devices such as geographic location, operating system, device name and serial number.

Join Us

Interested in joining the Internet2 Collaborative Innovation Community and IoT Working Group? Contact the Internet2 Chief Innovation Office at CINO@Internet2.edu

Reports

Both tools let you download reports in a variety of formats, like JSON, CSV, XML. You can also generate reports and have them emailed to you using Shodan.
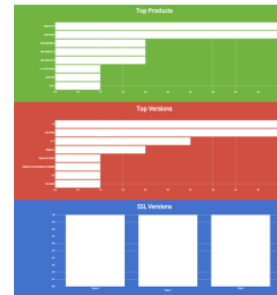
WARNING: Consult your CISO office before sharing results and reports with external audiences.

What results mean

So you found IoT devices on your network connected to the Internet but does that mean they pose a risk?

- Is this a device that should be on a network segment behind a firewall? Is there a reason it is publicly available?
- Is it a device that enables remote access to configure key systems like building power or other operational technology?
- Could it be used as a jump point for bad actors?
- Is it a device on a watch list for password default or one that uses a protocol with known vulnerabilities, like Telnet?

If you find devices that meet some of these criteria, you may want to notify both device owners and your CISO office.

How to get started

WARNING: Consult your CISO office before proceeding since prior notice and authorization may be required.

Anyone can run basic searches in Shodan and Censys for free, although advanced searching and reporting features may have a cost. Create accounts at:

shodan.io
censys.io

Try searches with IoT keywords, such as "camera." Also, Shodan has a specific filter for finding Industrial Control System devices: the ics category and Censys syntax includes the "scada" tag for Supervisory control and data acquisition components of industrial control systems.
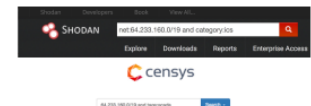
Arizona State University's Vision for a Connected Campus

A comprehensive connected campus blends both IoT-driven insights and digital engagement capabilities to deliver a leading higher education experience across university stakeholders.

Smart Campus

Implementing IoT technologies across multiple layers of the campus environment to help inform university decision making and improve the day-to-day life of students, faculty, administrators, and alumni

Digital Student

Delivering world-class on campus and digital experiences by looking at services from the outside-in putting students, faculty, administrators and alumni at the heart of design

Connected Campus

- Space & Sustainability
- Safety & Security
- Student Success
- Collaboration & Learning
- Mobile Payment
- Transport
- Athletics & Entertainment
- Businesses and Alumni
- Staff
- Faculty
- Students

Student
- Higher Student Retention
- Higher Student to Teacher Ratio
- Higher Student Engagement

Faculty
- Higher Student Interaction
- Early Detection of Disengagement
- More Personalized Attention

Administration
- Better Resource Utilization
- Secured & Safe Infrastructure
- Automated and Continuous Process Improvement
- New Revenue Streams

accenture
High performance. Delivered.

Microsoft

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February 2017 Microsoft Campus Connections Summit participants identified initiatives to further the Smart Campus journey.

- **Safety & Security**
  - Cybersecurity Learning Hub
  - Digital Literacy
- **Energy & Sustainability**
  - Campus as a Living Lab Breaking Cultural Barriers
  - Achieving Carbon Neutrality SCOPE ME
- **Success & Data Analytics**
  - The Agile University
  - Global Talent Profile
  - MentorBot Personal Tutor for Student Success
- **Collaborative Research**
 - Research Portal "1 Portal for All"

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Survey finds that U.S. university students are comfortable sharing personal data with universities, but want an improved college experience in return.
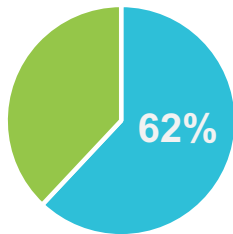
98%
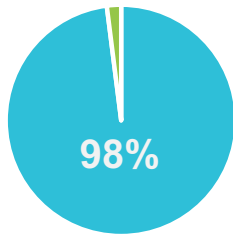
98% want school to use personal information to improve academic processes
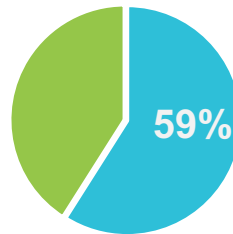
95%
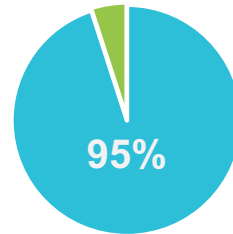
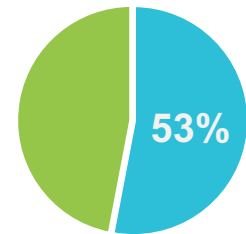95% expect the personal data shared to improve college experience, student life

82%
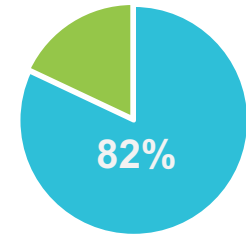
82% think personal data shared now will transform future college experiences

62%

62% want school to track graduation requirements & progress

59%

59% want school to use personal data to help select, register for classes

53%

53% want school to use data for scheduling academic advising sessions

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Future smart communities will be an interconnected "system of systems" to improve efficiency, safety, quality of life, energy use, & environment.

Mesh Networks

V2V, V2I, V2H, V2P

Smart Grid / MicroGrid

Smarter Transportation

Smart Homes/ Buildings

Industrial M2M

Connected Healthcare

Safety

Connected Citizens

What can we enable if we think across the system of systems?
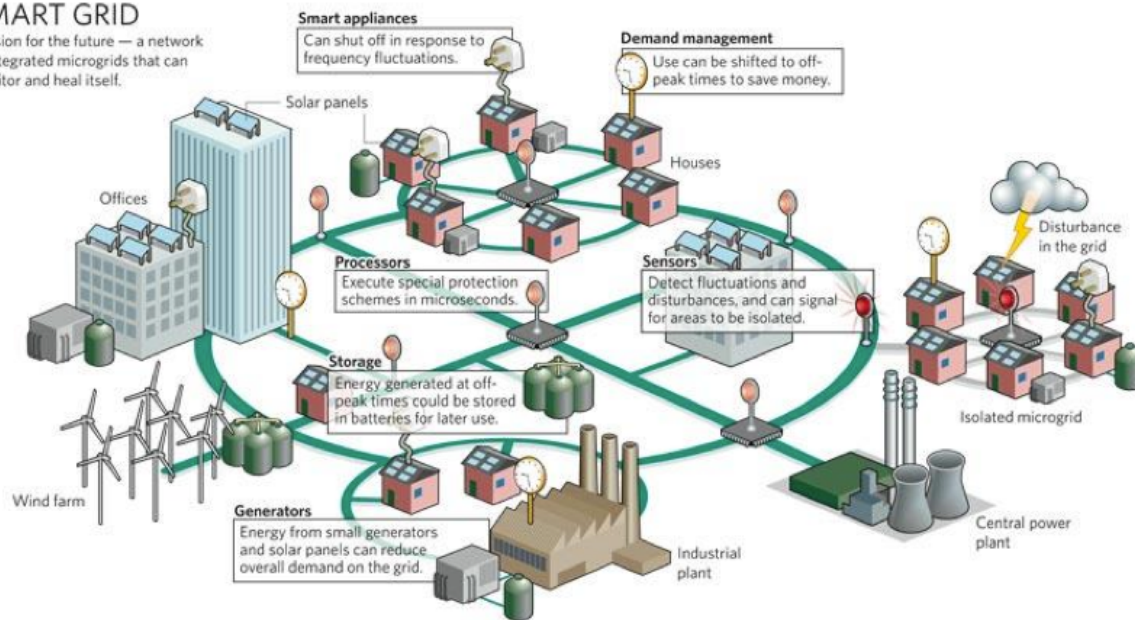
Smart Grids are a key step in the development of Smart Cities/ Campuses, and require end-to-end trust and security.

SMART GRID
A vision for the future — a network of integrated microgrids that can monitor and heal itself.

Offices

Solar panels

Smart appliances
Can shut off in response to frequency fluctuations.

Demand management
Use can be shifted to off-peak times to save money.

Houses

Disturbance in the grid

Processors
Execute special protection schemes in microseconds.

Sensors
Detect fluctuations and disturbances, and can signal for areas to be isolated.

Storage
Energy generated at off-peak times could be stored in batteries for later use.

Isolated microgrid

Wind farm

Generators
Energy from small generators and solar panels can reduce overall demand on the grid.

Industrial plant

Central power plant

Smart Grid value is transformational and positively impacts

- Transmission optimization
- Renewables integration
- Distribution automation
- Advanced metering infrastructure
- Analytics
- Cybersecurity

Universities & Regional Networks are leveraging the Internet2 Network for Smart Grid testbeds

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Sources: TERC; GreenTech Media 2013

Mobile Internet is an enabler of IoT, Smart Cities/Campuses, and Healthcare transformation.

## Internet-enabled portable devices are now a way of life

- By 2020, 4 Internet-Connected devices for every human
- Mobile computing devices, high-speed wireless connectivity, and applications
- Healthcare could benefit the most from Mobile Internet
- Consider a Connected Healthcare scenario:
    - http://bit.ly/asperationalhealthcare

Healthcare Leads Mobile Internet Potential in 2025

Payments $0.3T

Retail $0.4T

Public Sector $0.5T

Education $1T

Worker Productivity $1.7T

Health Care $2.1T

Connecting People to a Healthy Future (2012)

Glucose level — Weekly Trend

108 mg/dl

Sources: Business Insider 2016; McKinsey 2013

Healthcare & Life Sciences advances – like Telemedicine – are enabled by broadband connectivity and IoT.
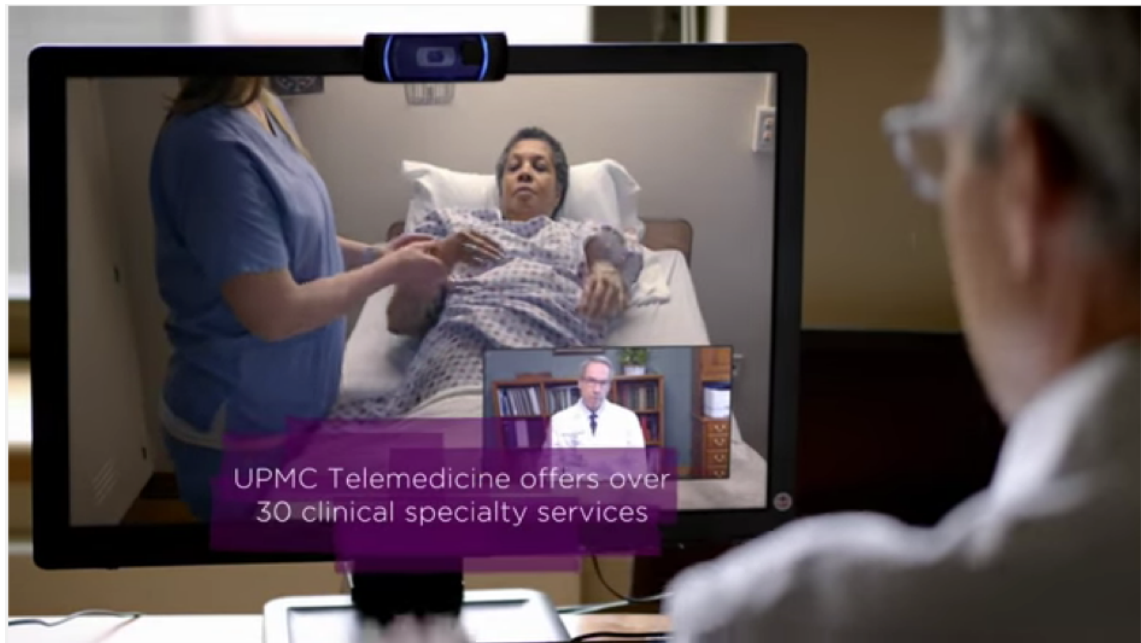
University of Pittsburgh Medical Center Telemedicine
http://bit.ly/upmctelemedicine

Source: Frost & Sullivan 2016

Internet2 Smart Campus Initiative Next Steps

- **Increase** IoT systems risk awareness using Shodan & Censys.io, demos at Global Summit 2017 in Washington, D.C. April 23-26

- **Share** IoT Systems Vendor Management Document at Global Summit 2017

- **Planning Workshop** with Princeton University Center for Information Technology Policy (CITP) on TIPPSS and Ethics in Campus IoT Networks, 2017

- **Create** thought leadership on TIPPSS for IoT for smart & connected campus/communities

  - **Whitepaper collaborations:** Enterprise IoT Internet2-ITANA (IT Architects iN Academia) Collaboration and Internet2 Chief Innovation Office Program Advisory Group led whitepaper

- **Participate** in new community initiatives and collaborations toward a Smart Campus

Opportunities for the Research & Education Community.

- **Develop curricula & labs to build the technical & business leaders of the future economy**
  - TIPPSS, IoT, Precision Medicine, Smart Campus/Cities/Grids, new business models, technologies
- **Create technology innovation through research and testbed programs**
  - Testbeds leveraging Internet2, international & regional networks: Smart Campus/Smart City/Smart Grid
  - Collaborative research and Innovations for device, chip, app, network, architecture, security …
- **Develop new models for improved operation & sustainability of a campus, city, community**
  - IoT to measure, monitor, model, and manage campus / city / community / health / safety operations
  - Cross-functional collaboration for improved outcomes, e.g., IT / facilities / administration / students
- **Internet2 and its members can guide health & life sciences to the next frontier**
  - Enable leverage of various data sets for precision medicine
  - Connect across multiple new technologies for strategic areas/use cases
- **Higher education and K-12 opportunities to leverage innovations for R&E**
  - Advanced networking, Trust & identity, Innovation communities, cloud services
  - Leverage current innovations, enable collaborative research for future innovations

Questions & Answers…

Thank You

fhudson@Internet2.edu
@FloInternet2