Princeton University: Framing Up the Internet of Things (IoT)

Current Uses
Future Predictions

> *Oh the Things you can find,*
> *if you don't stay behind!*
>
> **- Dr. Seuss**

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Focus on the Person, not the Technology…

"I am convinced that if we are to get on the right side of the world revolution, we as a nation must undergo a radical revolution of values. We must rapidly begin to shift from a "**thing-oriented**" society to a "**person-centered**" society.

When machines and computers, profit motives and property rights are considered more important than people, the giant triplets of racism, materialism, and militarism are incapable of being conquered."

Martin Luther King, Jr.

April 4, 1967

WoW Presentation INF-4140

Architecting the Future Infrastructure for the Cognitive Era

In the cognitive era, IT leaders are the **architects of the future,** architects of ideas, architects of '**we can do anything.**'

Framing IOT at Princeton

- Many IoT devices are operating on campus but there is no established framework for IoT going forward

- IoT will transform nearly **ALL** business processes and some teaching and research processes over the next five to ten years

BRANDING
Labels Matter! Why Call This "IoT"?

1. All 'things' considered …
2. Any 'thing' goes
3. Crazy Little 'thing' called _____
4. Every-thing but the kitchen sink
5. First 'things' first
6. In the grand scheme of things
7. In the thick of things
8. Age Don't Mean a Thing
9. Things that make ya go hrmmm
10. Best thing since sliced bread
11. Things aren't what they used to be

BRANDING

JINGLE

I'd like to teach the world … some 'thing'

Princeton Campus

- Princeton Campus Plan (2017-2026)
  - Expansion
  - Sustainability
  - Seamless Wireless
  - Parking
  - Electric Vehicles & Autonomous Vehicles
  - Drone Deliveries
- IT and OT Have Become Fundamental to Campus Planning

Princeton Network Statistics 2016

- Hosts
  - Total hosts: 79,300+
  - Wireless devices: 32,873
    (12-15K concurrent wireless each day)
  - Student hosts: 27,477

- Wireless ~ 6900 Wireless Access Points

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Princeton – IoT Security

- IoT - found where you least expect them
  - And they will eventually be everywhere
  - Hackers WILL try to use them (and will most likely be successful)
- Companies lack any incentives to building in security in IoT
- Where is the data? Who owns it? Who can see it?
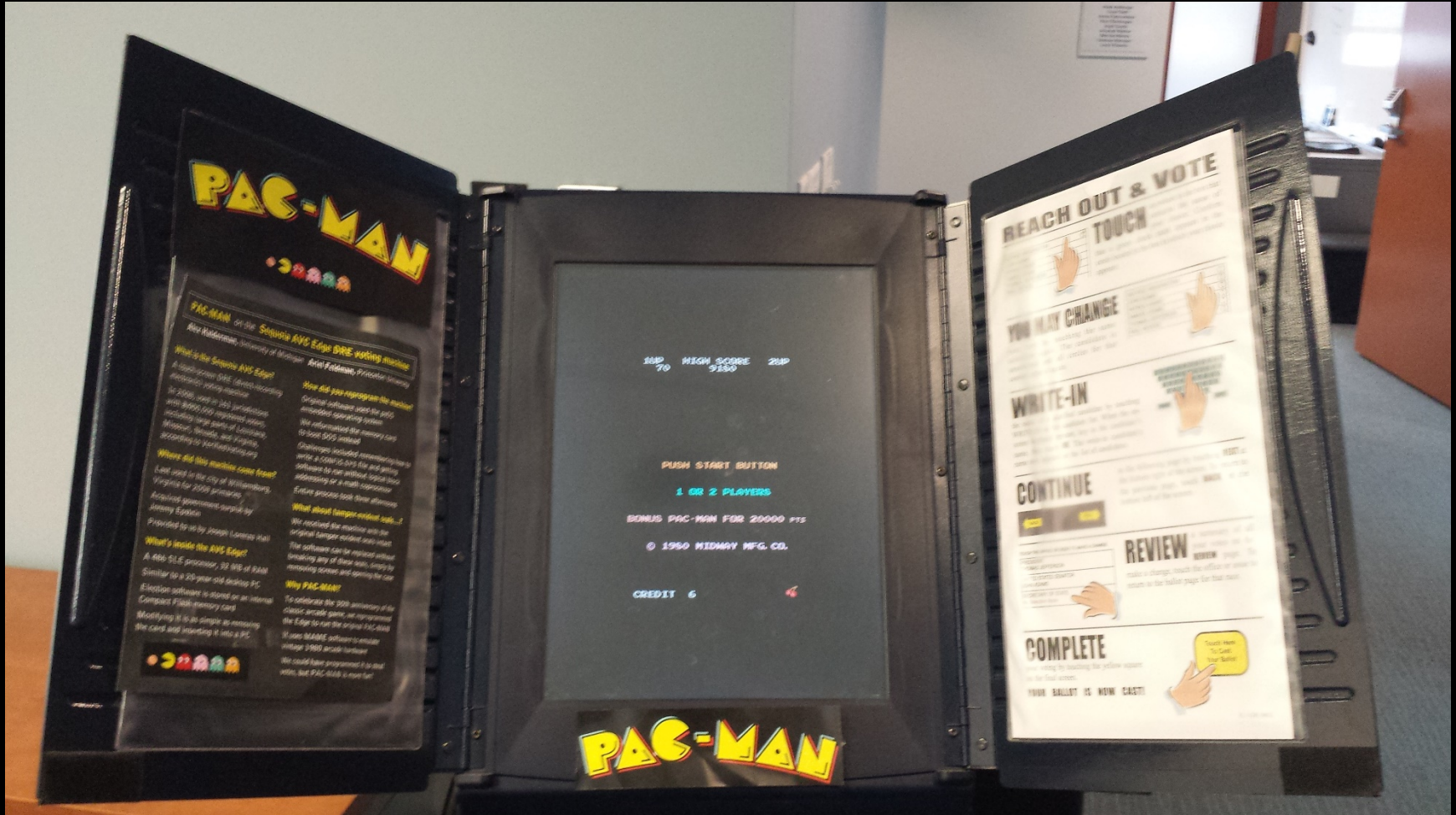
Princeton Some Public Safety Stats (Person in the Loop)

- DPS Alarm System Acknowledgements
  - 110,000/yr Doors/Panic/Fire
- DPS Phone Calls For Service (approx)
  - 2,000/yr Campus 911/BL/BLT
  - 2,500/yr Off-Campus 911
- Digital Radio System Processes
  - 4,900 transmissions/day

Princeton Assets

Are These IoT ????????

Princeton – Infrastructure Devices (35K)

Fire Alarm/Suppression Systems

Emergency Communications Systems/Networks:
Campus Radio System(s)
Blue Light Campus Towers
Panic Buttons
E911 infrastructure

CDN/PPN Wired Networks

Building Exit Signage and Lighting

Building Management Control System

Door Access Systems

Power generation/distribution and backup power to other critical systems

Life Sustaining Equipment

Audio Alert Systems

Environmental Health Systems

University Data Center Facilities

Life Safety Systems

Security Systems used to Protect University Personnel/Students

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Power Generation

GE LM-1600 Gas Turbine
(15 MW Capable)

Solar Panel Field
(4.5 MW Capable)

Princeton University Fire Truck

University Employee Fire Fighter Volunteers
(Truck Located at Site Protection Bldg)

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Emergency Comms - Radio

Steam Tunnels

HPCRC Data Center

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Princeton Connectivity

- 1984   Phones; No Internet

- 2016   Smart Phones; Client/Server

                              Network Architecture

- 2026   Internet of Things /

              Cognitive Internet)

Princeton IoT Opportunities

- Residence
- Food & Water
- Health (and Health Services)
- Transportation
- Communication
- Learning
- Research

Princeton Student Life

- Residence
- Food & Water
- Health (and Health Services)
- Transportation
- Communication
- Learning
- Research

Princeton URLs of Interest

- https://www.princeton.edu/strategicplan/ Princeton Strategic Plan

- https://campusplan.princeton.edu/ 10 year Campus Plan)

- https://tiger-energy.appspot.com/home (Energy)

- https://blogs.princeton.edu/mudd/ (This Week in Princeton History (Mudd Library)

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Predicting the Future

WHO DO YOU BELIEVE ????????

WoW Presentation IOT-1527
Self Powered IoT

Internet of Things – Trillion of Sensors only scalable with Energy Harvesting Wireless Nodes
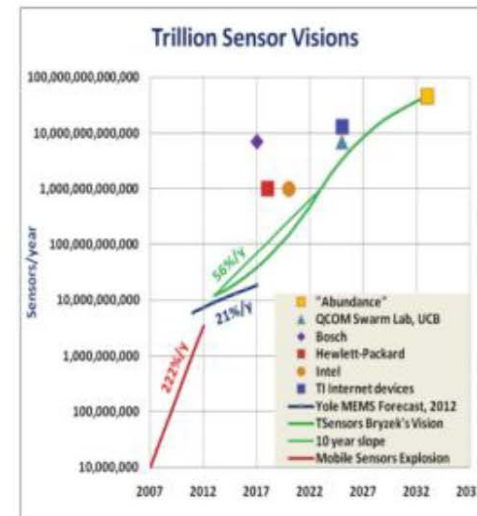
EnOcean
Self-powered IoT

30B

permanently connected things by 2020

Source: Gartner, 2014.

50T

connected sensors by 2032

Source: TSensor Summit Oct 2013

Trillion Sensor Visions

- "Abundance"
- QCOM Swarm Lab, UCB
- Bosch
- Hewlett-Packard
- Intel
- TI Internet devices
- Yole MEMS Forecast, 2012
- TSensors Bryzek's Vision
- 10 year slope
- Mobile Sensors Explosion

How are we going to power and connect 50 Trillion Sensors ???

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WoW Presentation IOT-1527
Self Powered IoT

WoW Presentation IOT-4036
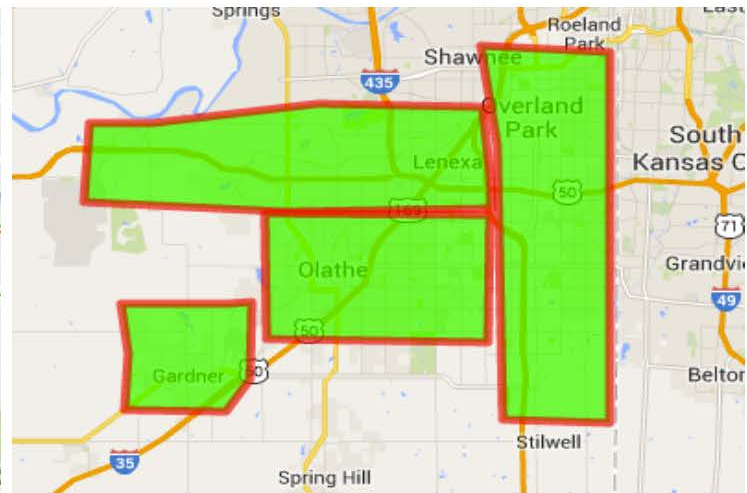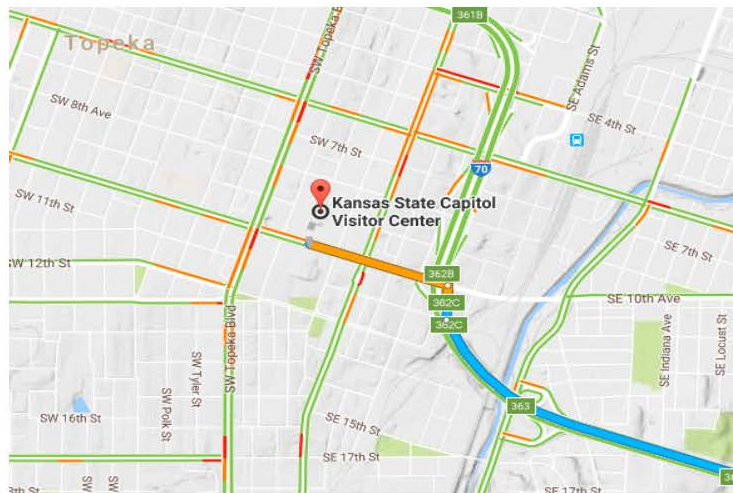## Cognitive Solutions for IoT ("CIoT")

IoT Requires Highly Optimized Spatial and Temporal Data Processing

Many IoT applications have a spatial component to them

- Vehicles, cell phones, even pets…

In these cases both location and time is important

- Show me the vehicles that have passed by location X in the last hour
- Where has my car been over the last few hours?

Other IoT Insights (Princeton)

- Communications energy per byte is 1000x greater than the compute energy per instruction
- Crypto on cheap IoT devices – More advanced processor adds insignificant power and cost compared with wireless communications so no reason not to use them
- "Differential Privacy" - Databases
- "PAN-Privacy" – Dynamic/Streaming Data

Summing Up

- IoT Already on Campus
- Network Refresh Presents Fortuitous Opportunity
- All on Campus will be Stakeholders
- Use Cases will Drive Investments

Thank You

CITP – PAC-MAN VOTING MACHINE

PAC-MAN

PAC-MAN on the **Sequoia AVC Edge DRE voting machine**

Alex Halderman, University of Michigan   **Ariel Feldman,** Princeton University

What is the Sequoia AVC Edge?

A touch-screen DRE (direct-recording electronic) voting machine

In 2008, used in 161 jurisdictions with 8,900,000 registered voters, including large parts of Louisiana, Missouri, Nevada, and Virginia, according to VerifiedVoting.org

Where did this machine come from?

Last used in the city of Williamsburg, Virginia for 2008 primaries

Acquired government-surplus by Jeremy Epstein

Provided to us by Joseph Lorenzo Hall

What's inside the AVC Edge?

A 486 SLE processor, 32 MB of RAM

Similar to a 20-year-old desktop PC

Election software is stored on an internal Compact Flash memory card

Modifying it is as simple as removing the card and inserting it into a PC

How did you reprogram the machine?

Original software used the psOS embedded operating system

We reformatted the memory card to boot DOS instead

Challenges included remembering how to write a CONFIG.SYS file and getting software to run without logical block addressing or a math coprocessor

Entire process took three afternoons

What about tamper-evident seals…?

We received the machine with the original tamper-evident seals intact

The software can be replaced without breaking any of these seals, simply by removing screws and opening the case

Why PAC-MAN?

To celebrate the 30th anniversary of the classic arcade game, we reprogrammed the Edge to run the original PAC-MAN

It uses MAME software to emulate vintage 1980 arcade hardware

We could have programmed it to steal votes, but PAC-MAN is more fun!

REACH OUT & VOTE

TOUCH anywhere in the box that contains the name of your choice. Confirm that a green check mark appears in the circle located in the box in which your choice appears.

YOU MAY CHANGE your vote by touching the same selection again. The candidate is unselected and all circles for that contest appear again.

WRITE-IN the name of a qualified candidate by touching WRITE-IN on the candidate list. When the on-screen keyboard appears, key in the candidate's name, then touch OK. The write-in candidate's name now appears on the list of candidates.

CONTINUE to the following page by touching NEXT at the bottom right of the screen. To return to the previous page, touch BACK at the bottom left of the screen.

REVIEW a summary of all your votes on the REVIEW page. To make a change, touch the office or issue to return to the ballot page for that race.