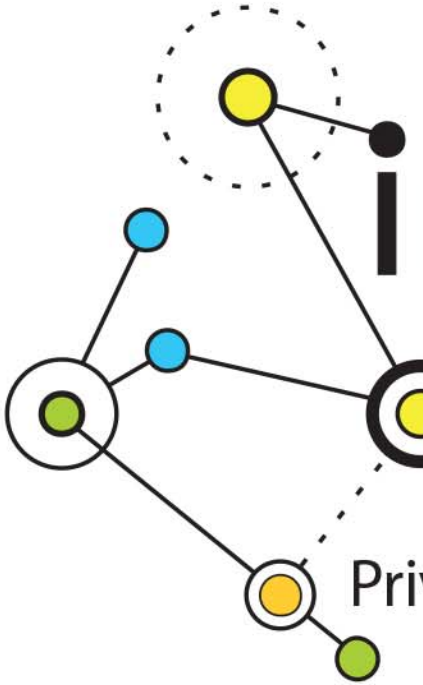
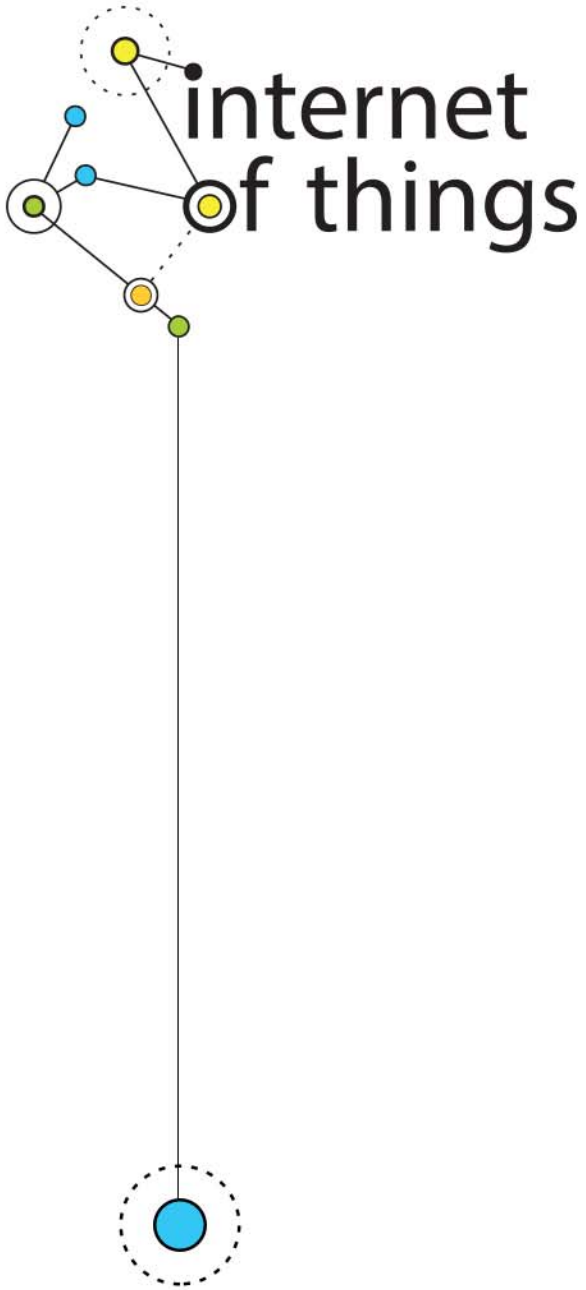


internet of things

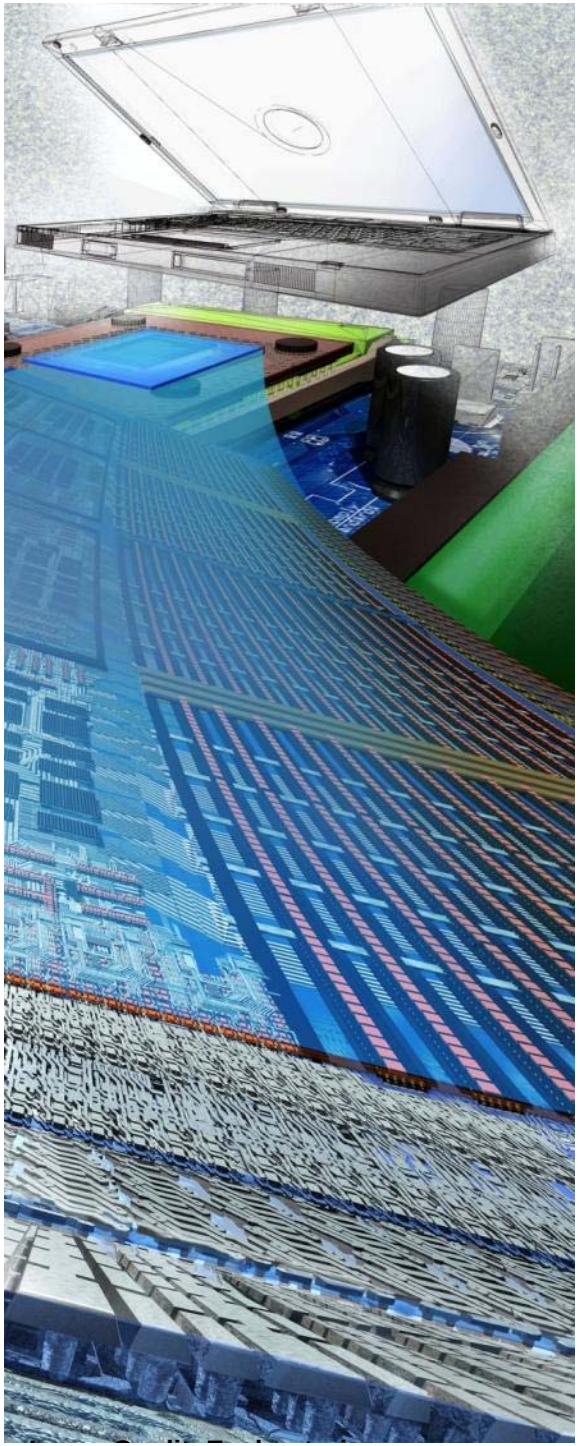
Privacy & Security in a Connected World



Welcome

Opening Remarks

FTC Chairwoman Edith Ramirez



The Internet of Things

Keith Marzullo
Division of Computer and Network Systems
Directorate for Computer & Information Science & Engineering
National Science Foundation

Just out!

IT'S ALL CONNECTED

PRETTY SOON, EVEN YOUR TROUSERS
WILL HAVE THEIR OWN TWITTER ACCOUNT

Paul Ford, Hemispheres 11/13, pp 66-68.

Origins

- *Ubiquitous computing, pervasive computing* (late 1980s)
- *Distributed sensor networks* (late 1990s)
- *Internet of Things* (mid 2000s)
- *Cyber-Physical Systems* (mid 2000s)

National Priorities

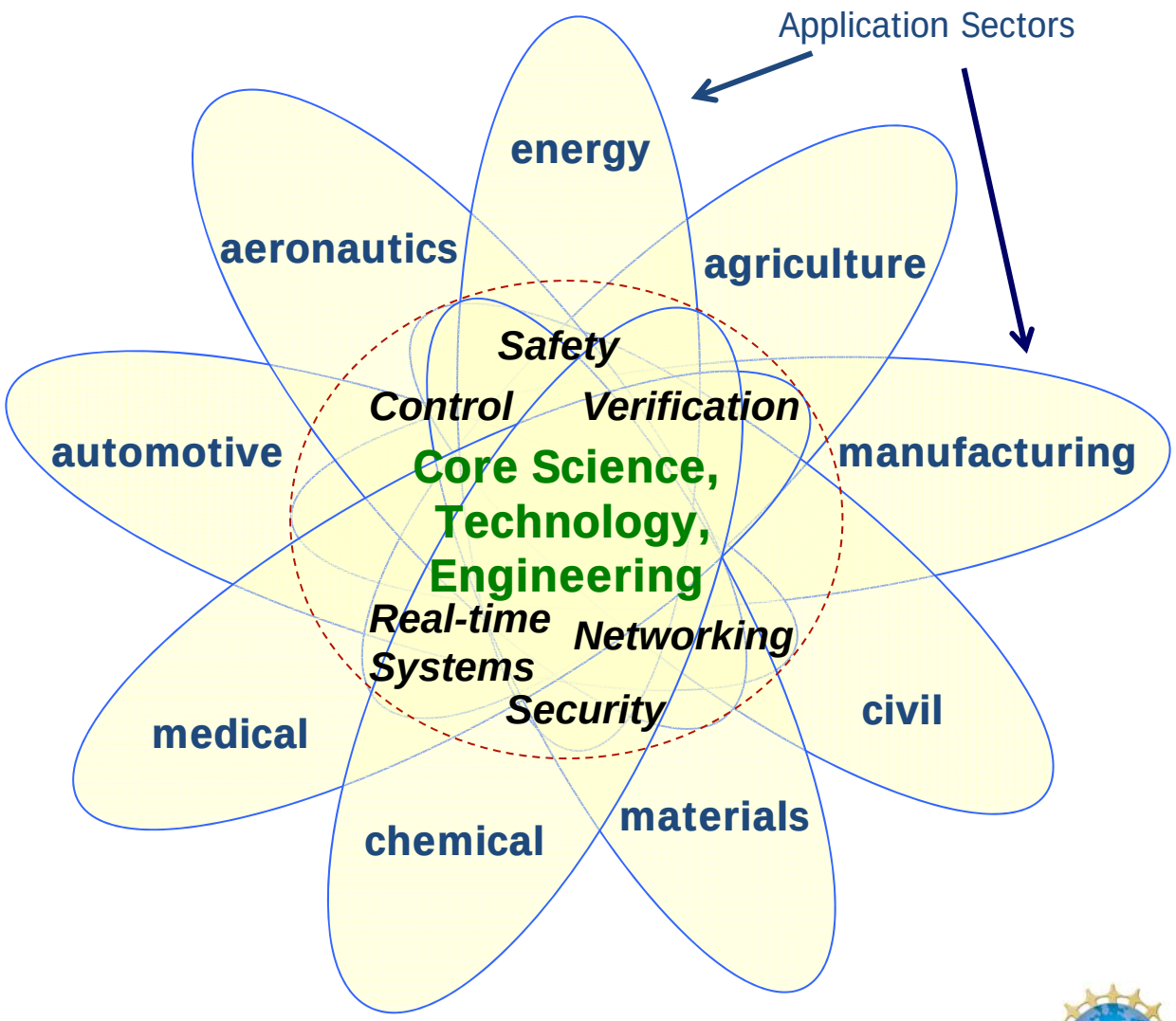
National Priorities and Challenges are outlined in several government reports…

Transportation	▪ Faster and safer aircraft ▪ Improved use of airspace ▪ Safer, more efficient cars	
Energy and Industrial Automation	▪ Homes and offices that are more energy efficient and cheaper to operate ▪ Distributed micro-generation for the grid	
Healthcare and Biomedical	▪ Increased use of effective in-home care ▪ More capable devices for diagnosis ▪ New internal and external prosthetics	
Critical Infrastructure	▪ More reliable power grid ▪ Highways that allow denser traffic with increased safety	

…Highlighting **networked information systems connected to our physical world**.

Goals of NSF's CPS program

- Abstract from sectors to more general principles
- Apply these to problems in new sectors
- Build a new CPS community
- Encourage other communities to join



Goals

- Overcome complex technical challenges of systems that interface cyber with physical
- *Design for certifiability* of dependable control
- Discover principles for bridging control, communications, real-time systems, safety, security
- Define next generation system architectures and assurance technology including formal methods and computational frameworks for the design and implementation of reliable, robust, safe, scalable, secure, stable, and certifiably dependable systems
- Enable societal acceptance and reliance – CPS people can bet their lives upon
- Integrate CPS research and education to prepare the next generation of practitioners

Some projects

- Networked embedded sensor-rich systems
- Foundations of reliable cyber-physical systems
- Advanced transportation systems
- Environmental monitoring

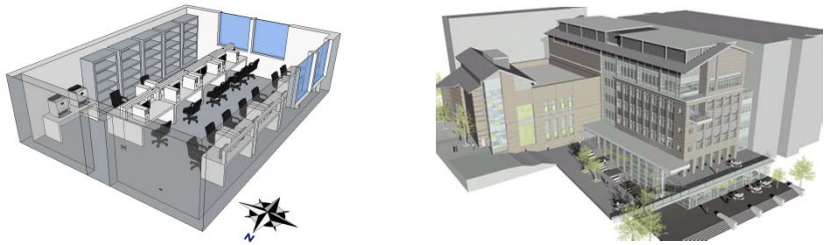
Networked Embedded Sensor-Rich Systems (ActionWebs)

- Researchers: Claire Tomlin, Edward Lee, S. Shankar Sastry, David Culler (Berkeley); Hamsa Balakrishnan (MIT)

- ActionWebs: Networked embedded sensor-rich systems that are taskable for coordination of multiple decision-makers.

Energy Efficient Buildings

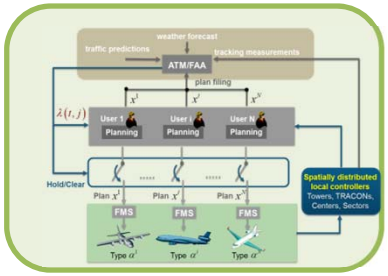
Berkeley Retrofitted and Inexpensive HVAC Testbed for Energy Efficiency (BRITE) [1]



- Learning-based model predictive control (MPC) [2] compensates for occupancy
- Heating load computed using only temperature sensor
- Significant energy savings on multiple testbeds
- Framework for demand-response
- Pricing for noncooperative differential games applied to energy efficient building control

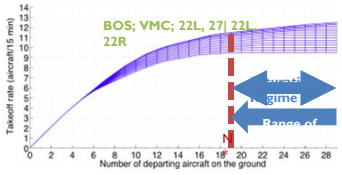
Energy Efficient Air Transportation Systems

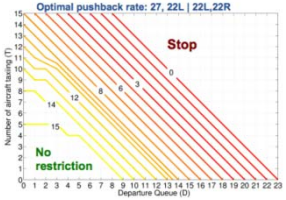
NextGen Air Transportation as Sensing and ActionWeb of Aircraft



- From verbal information sharing to "sensing and action web" in the sky
- Hierarchical structure with interacting layers

Surface Congestion Management [3]





- Departure runway throughput "saturated" when pushback N greater than N*
- Control pushbacks for runway utilization

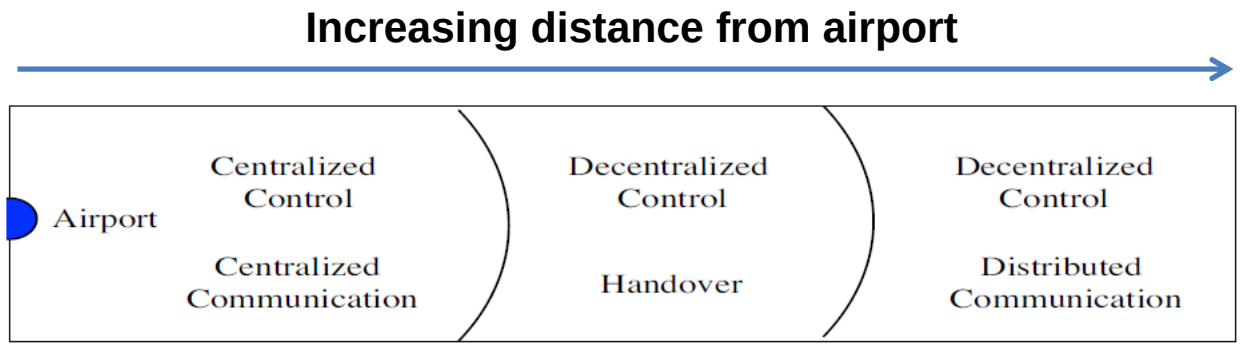
Foundations Of Resilient Cyber-physical Systems (FORCES)

Foundational Principals

- Resilient Control (RC)
  - Threat assessment & detection
  - Fault-tolerant networked control
  - Real-time / predictive response
  - Fundamental limits of defenses
- Economic Incentives (EI)
  - Incentive Theory for resilience
  - Mechanisms to align Nash allocations with social optima
  - Interdependent risk assessment
  - Insurance & risk redistribution

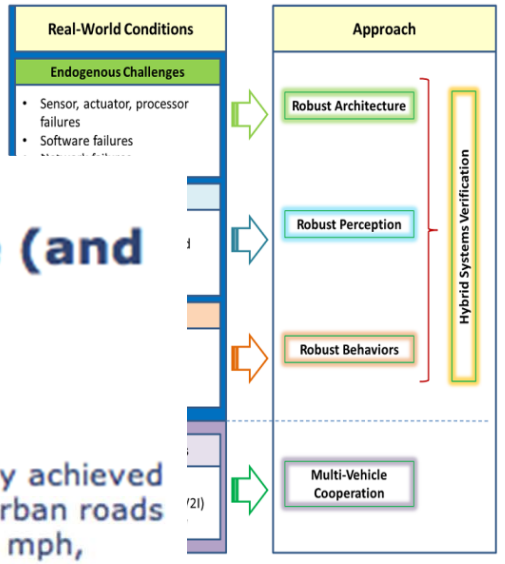
National Airspace Operations

- Data: Airport Operations, aircraft trajectories, weather
- Airport: Algorithms for ATC choice modeling, scheduling, congestion control, resource re-allocation
- Airspace: Methods for surveillance (conformance monitoring, threat detection), sectorization, re-routing
- Next-gen security & reliability



Advanced Transportation Systems

- Raj Rajkumar, Ed Clarke, John Dolan, Sicuan Gao, Paul Ribski, David Wettergreen, Paolo Zuliana at Carnegie Mellon University
- Societal and economic impact



- News From the Field

CMU autonomous Cadillac goes the distance (and obeys the speed limit)

September 4, 2013

Carnegie Mellon University's autonomous Cadillac SRX recently achieved a milestone: It drove itself on a 33 mile trip along dense suburban roads and two interstate highways. Maximum vehicle speed was 65 mph, completely within the speed limit. Passengers included U.S. House Transportation and Infrastructure Committee Chairman Bill Shuster and Pennsylvania Department of Transportation Secretary Barry Schoch. Full Story

Source
Carnegie Mellon University

Environmental Monitoring (Intelligent River®)

see entire clip at http://www.clemson.edu/public/psatv/env/intelligent-river-overview.html

Security and Privacy

- Semantic security monitoring for industrial control systems
- Reprogramming a pacemaker
- Reprogramming a modern car
- Security and privacy in vehicular systems
- Secure and private telerobotics

Semantic Security Monitoring for Industrial Control Systems (ICS)

- Robin Sommer (Berkeley) and Adam Slagell & Ravishankar Iyer (Illinois)

- ICS are critical resources, connecting to water, gas, and power distribution networks, building automation, etc.
- Lacking in security
  - Often legacy hardware that is hard to protect, not built with security in mind
  - Capable of being driven into an unsafe state *without exhibiting any obvious red flags*
- Classic intrusion detection systems are not appropriate, as attacks are rare and often unknown
- A novel approach for detecting malicious actions
  - Developing models of what we should be seeing and employing anomaly detection

Reprogramming a Pacemaker

- Kevin Fu (U Mass-Amherst; now at U Michigan)

	Commercial programmer	Software radio eavesdropper	Software radio programmer	Primary risk
Determine whether patient has an ICD	✔	✔	✔	Privacy
Determine what kind of ICD patient has	✔	✔	✔	Privacy
Determine ID (serial #) of ICD	✔	✔	✔	Privacy
Obtain private telemetry data from ICD	✔	✔	✔	Privacy
Obtain private information about patient history	✔	✔	✔	Privacy

HOME SECTIONS SEARCH NEW YORK POST

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DEN STYLE PETS WEDDINGS

NEWS

Cheney feared terrorists would 'hack' pacemaker

By Bob Fredericks October 19, 2013 | 4:11am

ur pacemaker be hacked?

Reprogramming Automobiles

Tadayoshi Kohno & Shwetak Patel (U Washington) and
Stefan Savage & Ingolf Krueger (UCSD)

Vulnerabilit Class	Cost
Direct physic	ow
Indirect phys	Medium
	Medium-High
	ow
	ow
Short-range wireless	ow-Medium
	ow-Medium
Long-range wireless	Medium-High
	Medium-High

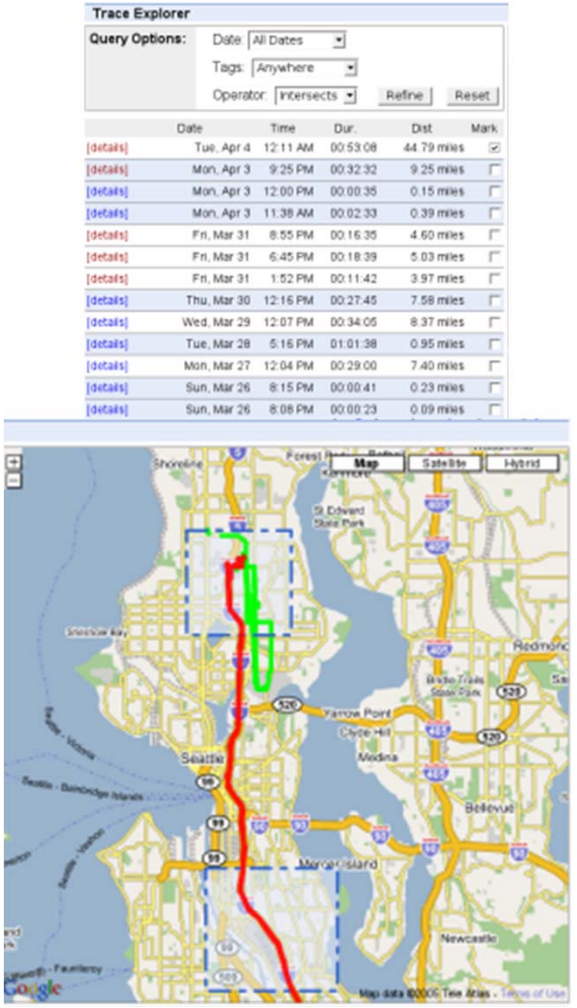
Figure 6. Displaying an arbitrary message and a false speedometer reading on the Driver Information Center. Note that the car is in Park.

Figure *car.* Colors indicate rough grouping of ECUs by function.

Security and Privacy in Vehicular Cyber-Physical Systems

- Hari Balakrishnan, Samuel Madden, Daniela Rus (MIT)

- Mobile applications process position data from individual devices and input this information into the transportation infrastructure
  - Traffic monitoring, usage- or congestion-based road pricing, “pay-as-you-go” insurance, etc.
- Clear benefits, but potential privacy issues:
  - GPS monitoring of cars as they drive, surveillance cameras, and toll transponders)
  - Can be linked to the movement of individuals, so aggregate data can violate individual’s location privacy
- An effort to compute aggregate statistics over location data with provable guarantees on location privacy



http://cartel.csail.mit.edu/

Secure Telerobotics

- Howard Jay Chizeck & Tadayoshi Kohno (U Washington)

- Telerobotics have human operators interacting with robots through a computer network
  - Ex: remote battlefield surgery by robot
- How can malicious activities against the robot be prevented (and corrected)?
- Project adapts and extends security methods to these systems
  - Remote navigation and control of robotic systems
  - Real-time verification of operator's requests vs. robot's actions
  - Timely, reliable detection of discrepancies that suggest spoofed operator movements

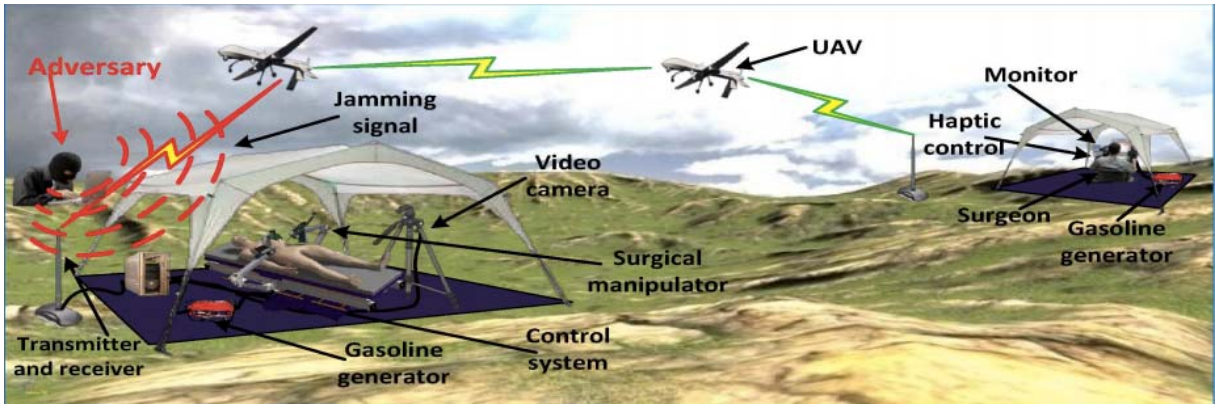


Image from T.Bonaci. H. J. Chizeck. Surgical Telerobotics Meets Information Security. RSS 2012 Workshop on Algorithmic Frontiers in Medical Robotics: Manipulation in Uncertain, Deformable, Heterogeneous Environments, Sydney, Australia, July 2012

IoT summary

- 25 years old in the research community
- technology advances (RFID, "smart dust", cellular communications, ...) have made IoT affordable
- advances in control, verification, and "big data" are leading to commercial opportunities
- security and privacy are real issues

Trust and Context in a Connected World

FTC Internet of Things Workshop
November 19, 2013

M-H. Carolyn Nguyen, Ph.D.
Director, Technology Policy Group

Microsoft

Agenda

- Impact of the Internet of Things on individuals
- Why is context relevant?
- How do individuals define contexts?
- Building a context-aware system
- Policy considerations

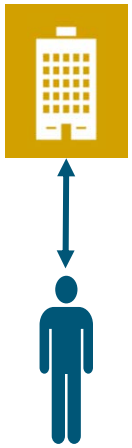
Evolution of a Data-Driven Ecosystem

- Sharing of personal data with another person
- Data *actively* provided

Explicit permission

Permission unclear

Evolution of a Data-Driven Ecosystem

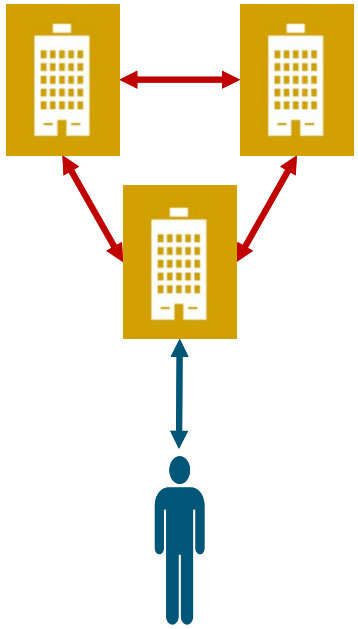


- Sharing of personal data with an entity
- Data ***actively*** provided

Explicit permission

Permission unclear

Evolution of a Data-Driven Ecosystem

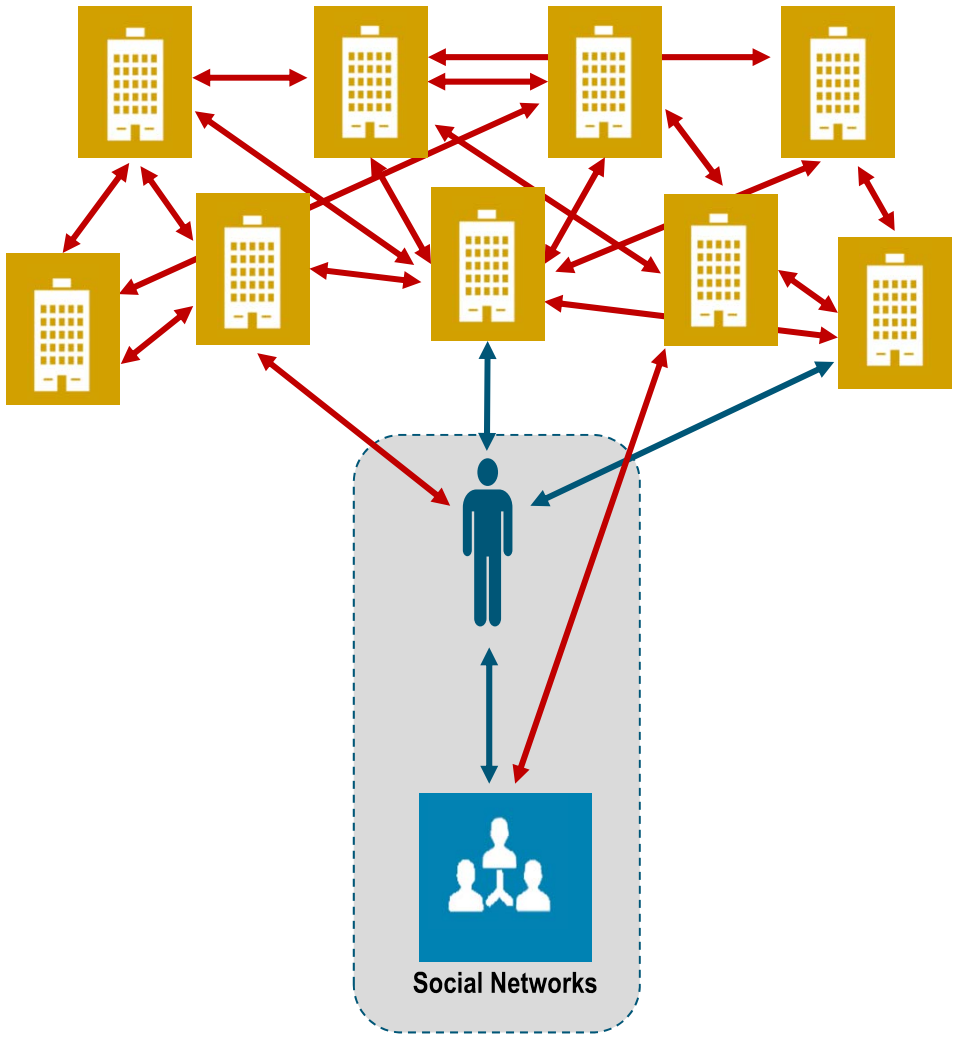


- Third-party sharing of personal data
- Data *actively* provided and *passively* generated

Explicit permission

Permission unclear

Evolution of a Data-Driven Ecosystem

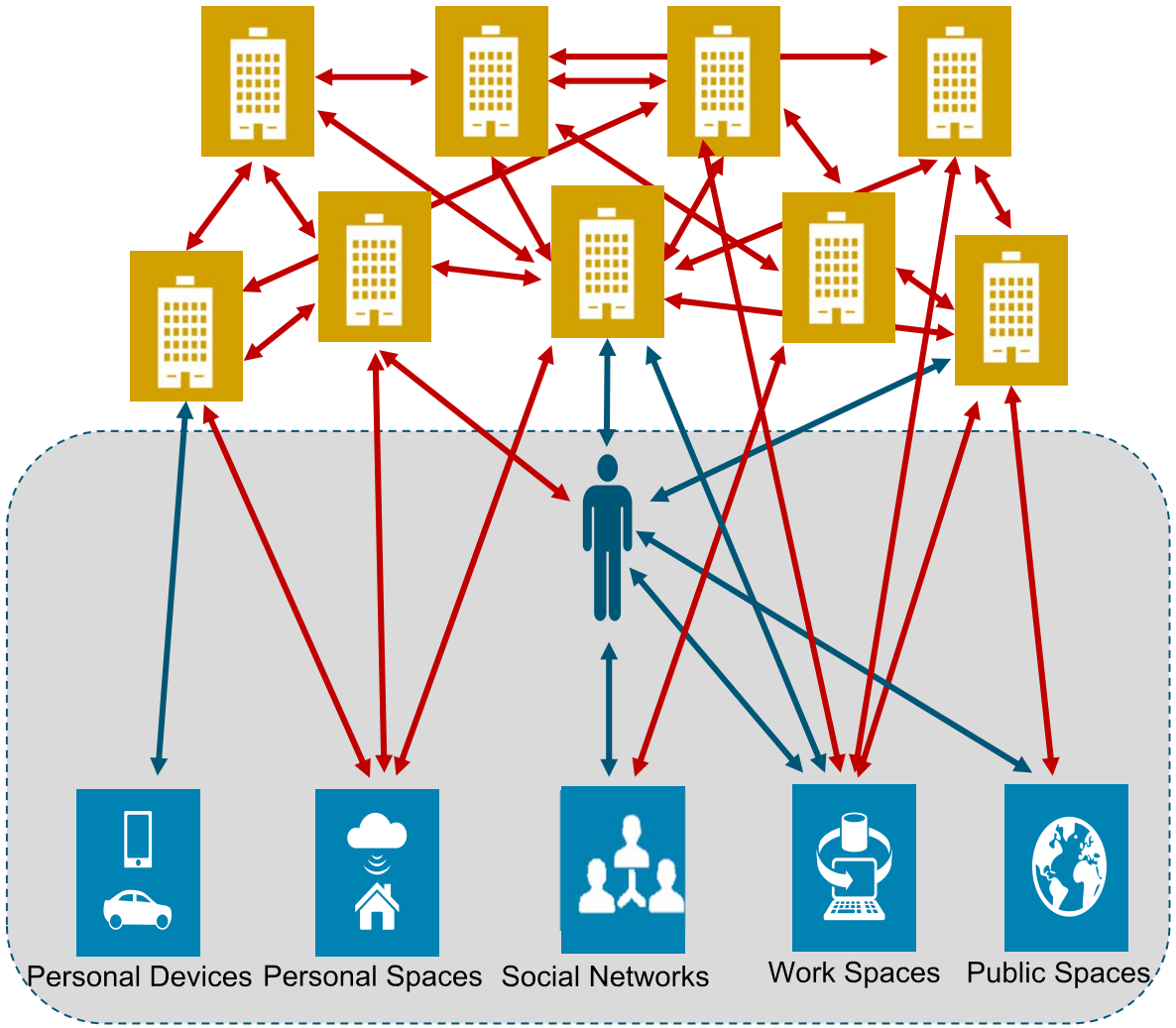


- Third-party sharing of personal data in a connected world
- Data *actively* provided, and *passively* collected and generated

Explicit permission

Permission unclear

Evolution of a Data-Driven Ecosystem



- Sharing of data "related to me" in an Internet of Things world
- Data primarily *passively* collected and generated

Explicit permission

Permission unclear

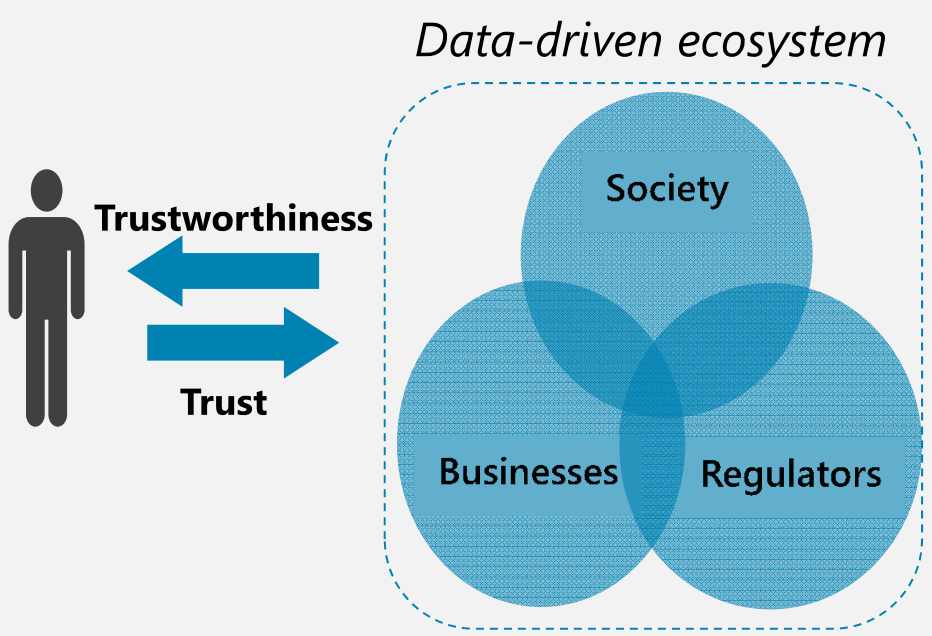
A Crisis of Trust in Data Use

Today

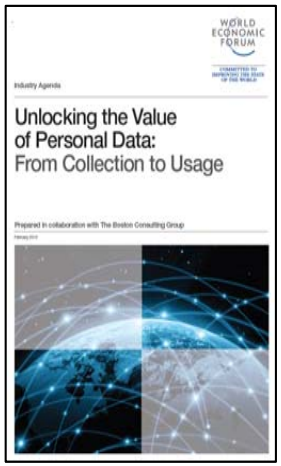
Asymmetry of power between businesses and individuals

Tomorrow

A trustworthy user-centered data ecosystem

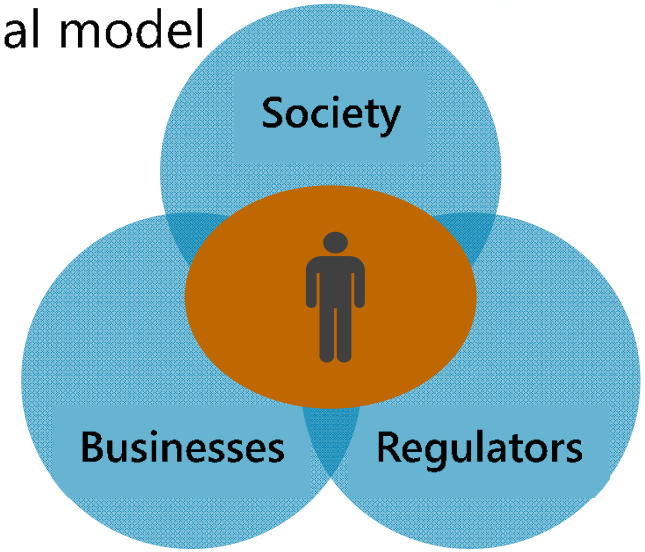


Trust and Context in a User-Centered Data Ecosystem



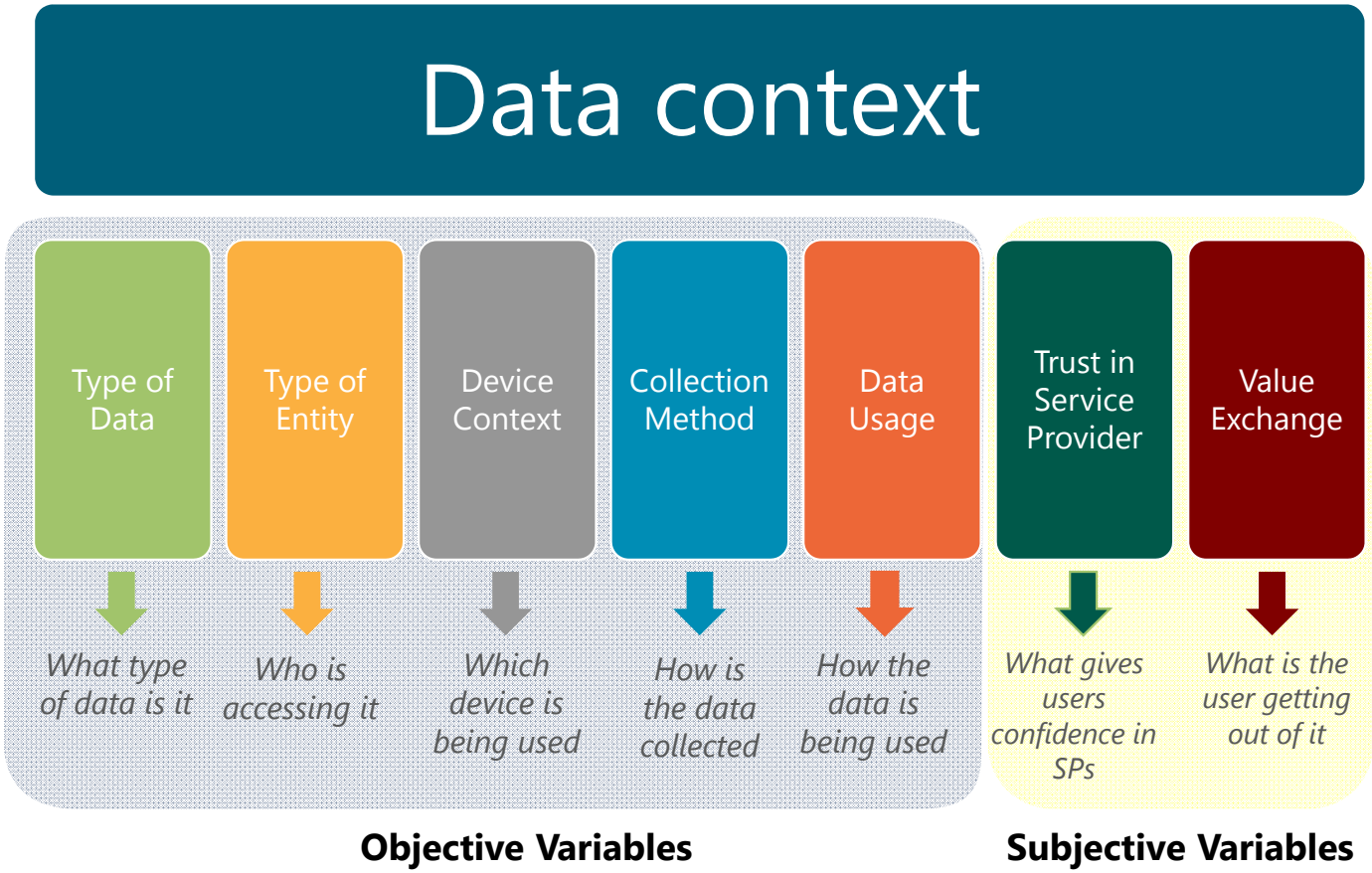
- New approach to personal data is needed
- Shift to governing data usage
- Engage and empower individuals
- Context is key
- Respect for context
- Integrate technology as part of the solution
- Demonstrate usage-based contextual model

☛ *Context-aware data use is essential to a sustainable user-centered data ecosystem*



How Individuals Define Data Context

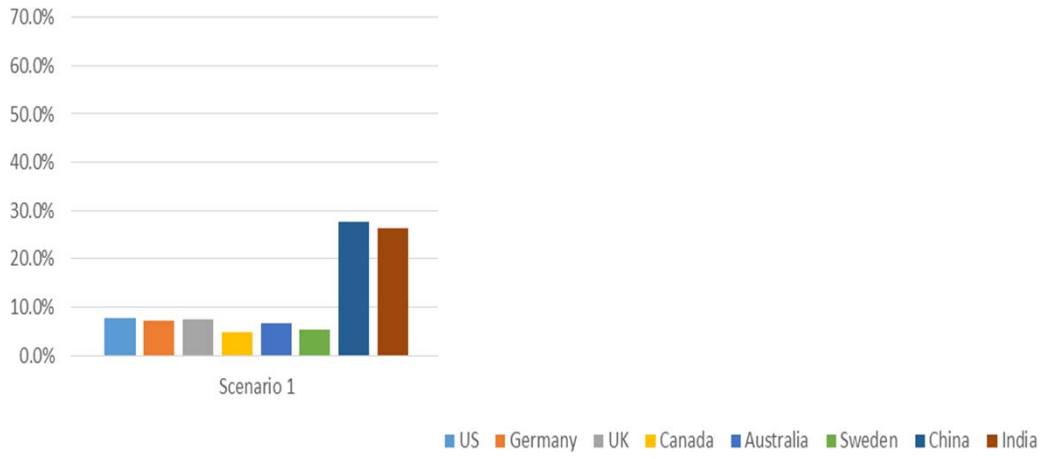
Qualitative research identified 7 key variables that impact user sensitivities to their data use.



Qualitative methodology: 8 focus groups, 26 individual interviews, 4 countries (Canada, China, Germany, US)
Quantitative methodology: 9,600 online surveys, 8 countries (Australia, Canada, China, Germany, India, Sweden, UK, US)

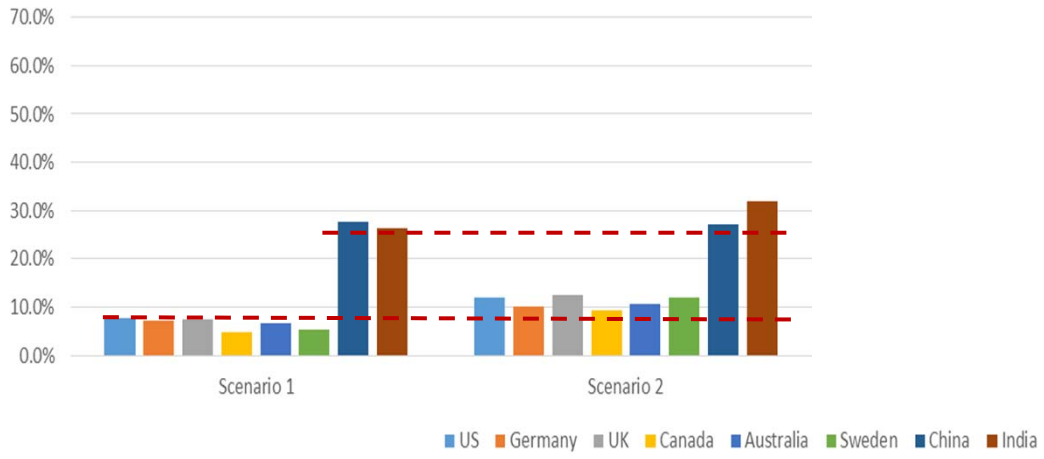
Example: Location Data Collected From a Mobile Device

Context Variable	Scenario 1:
Type of Data	Current location
Type of Entity	A service provider
Device Context	Mobile device
Collection Method	Passively collected
Data Usage	
Trust	
Value Exchange	



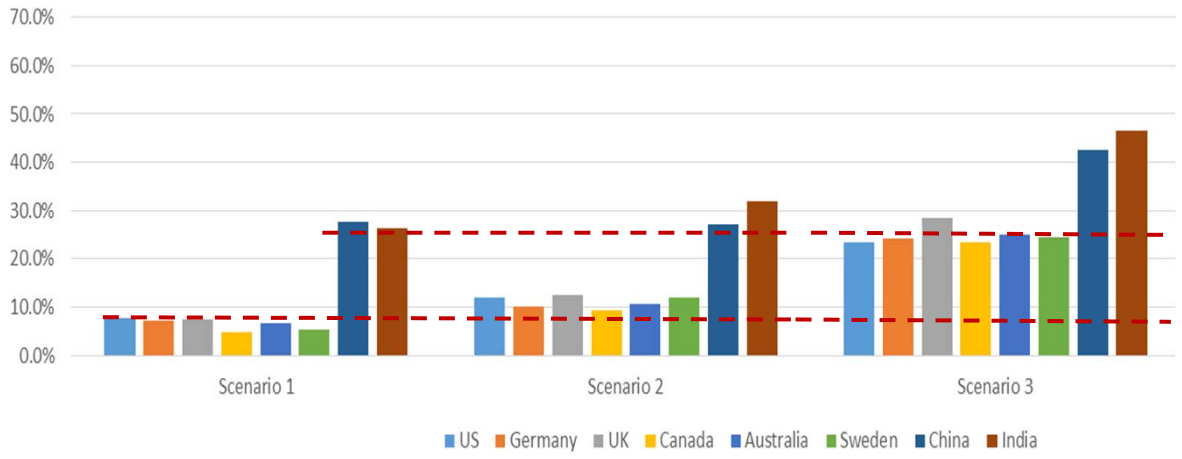
Example: Location Data Collected From a Mobile Device

Context Variable	Scenario 1:	Scenario 2:
Type of Data	Current location	
Type of Entity	A service provider	
Device Context	Mobile device	
Collection Method	Passively collected	
Data Usage	Make automatic decision for me →	
Trust	Is unfamiliar to me	
Value Exchange	No benefit to me	



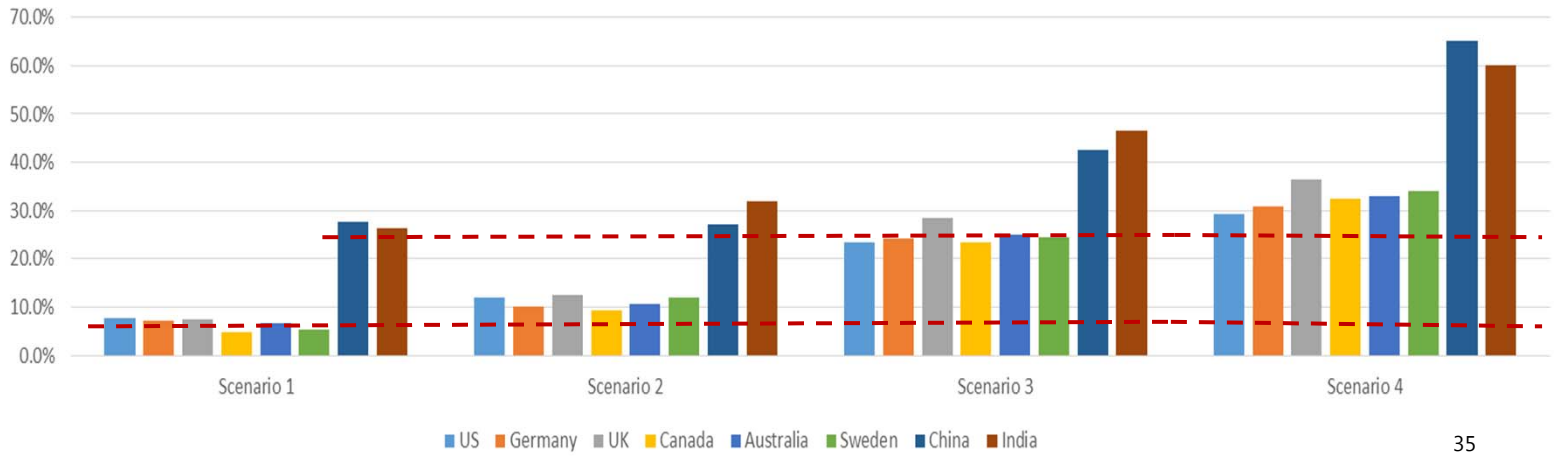
Example: Location Data Collected From a Mobile Device

Context Variable	Scenario 1:	Scenario 2:	Scenario 3:
Type of Data	Current location		
Type of Entity	A service provider		
Device Context	Mobile device		
Collection Method	Passively collected		
Data Usage	Make automatic decision for me	Personalize my choices	
Trust	Is unfamiliar to me →		
Value Exchange	No benefit to me		

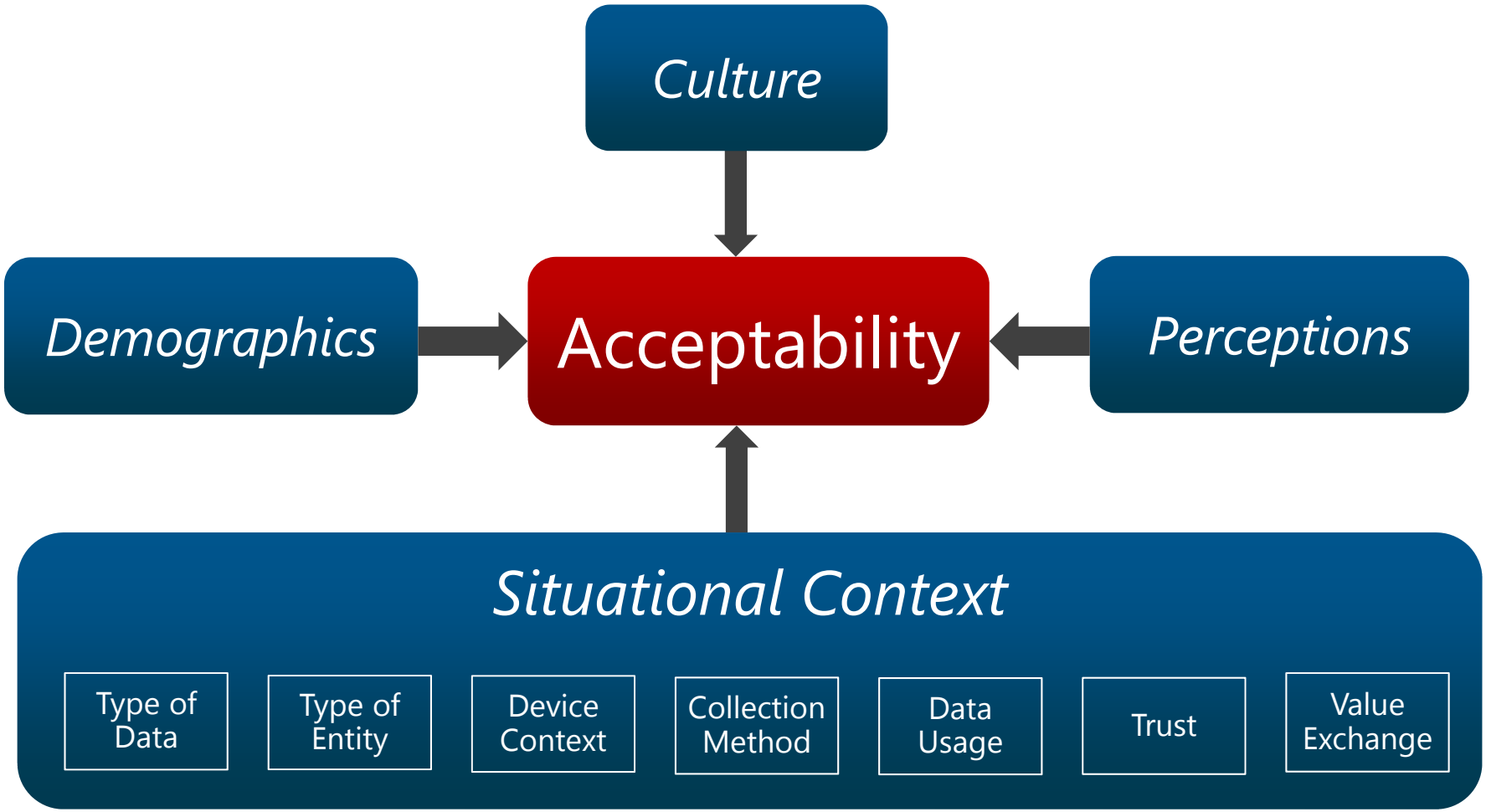


Example: Location Data Collected From a Mobile Device

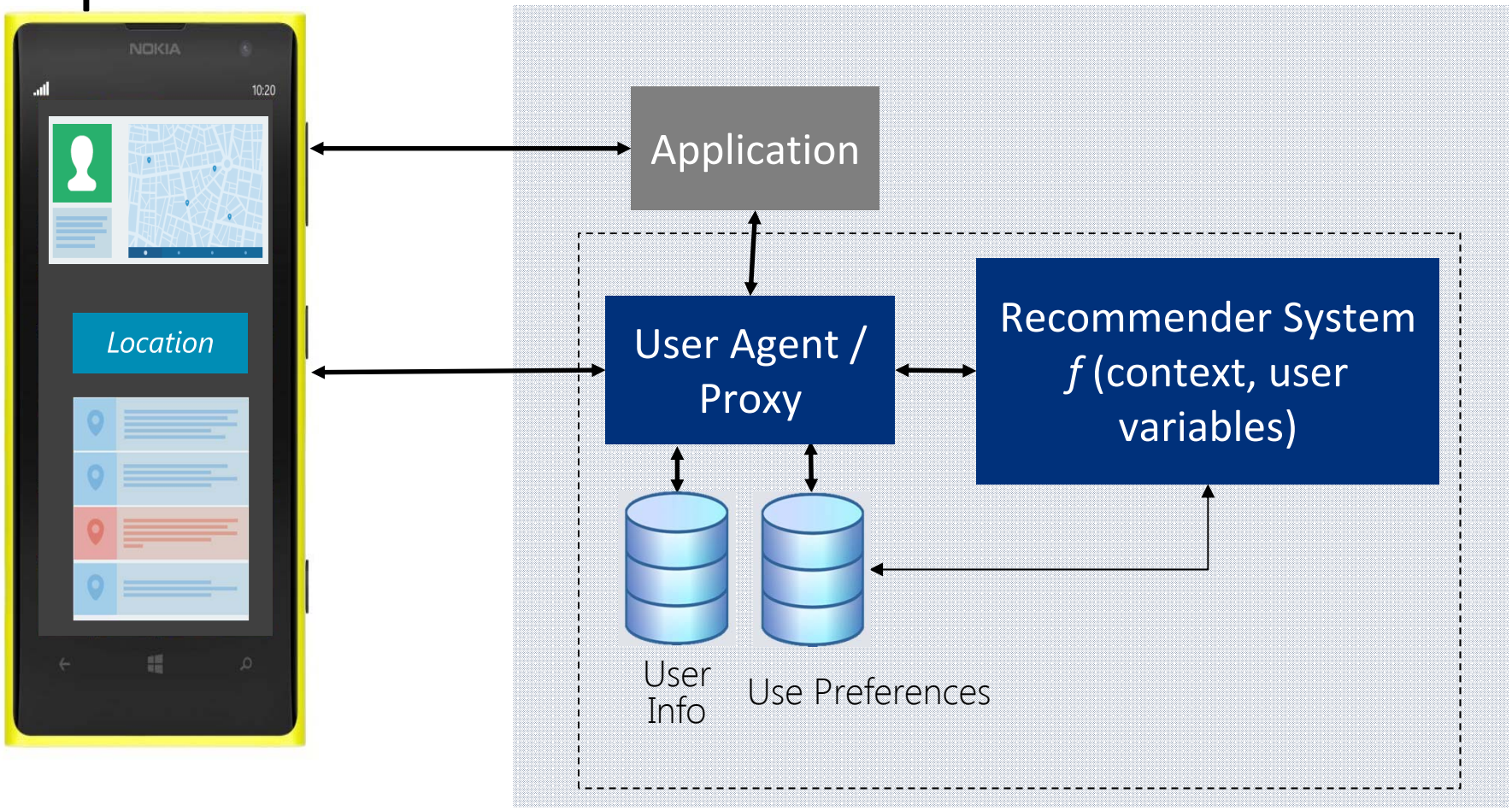
Context Variable	Scenario 1:	Scenario 2:	Scenario 3:	Scenario 4:
Type of Data	Current location			
Type of Entity	A service provider			
Device Context	Mobile device			
Collection Method	Passively collected			
Data Usage	Make automatic decision for me	Personalize my choices		
Trust	Is unfamiliar to me		Is well-known to me	
Value Exchange	No benefit to me →			



Building a Context-Aware System

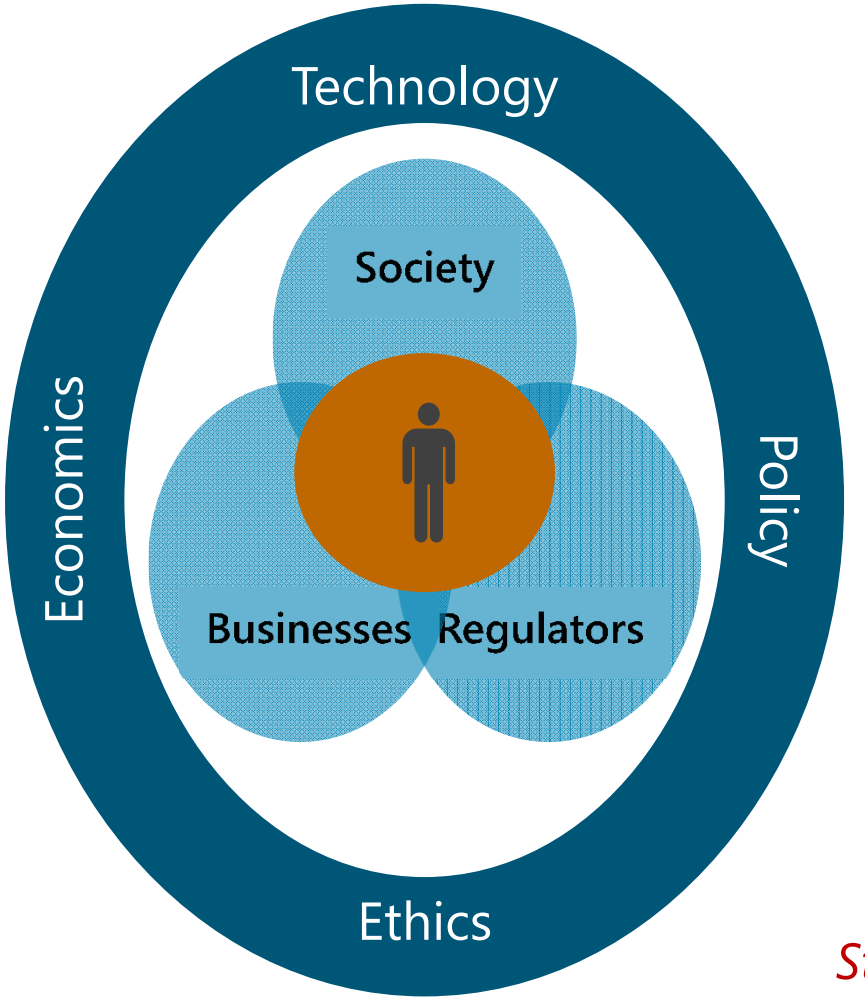


Context-Aware and Personalized User Experience



Recommender system can be used by service providers to enable a personalized UX, or by users to assist in context-sensitive data settings

Policy Considerations



- A connected world raises the need for new, use-based approaches to data governance
- Context-aware data use is essential to creating a sustainable ecosystem
- Technology can facilitate context-aware data use, empowering individuals while enabling alternative policy approaches
- Need to develop an evidence base for informed policy-making

Still much more work to understand what drives user context and how to create trust … this is only a beginning

Thank you

M-H. Carolyn Nguyen
cnguyen@microsoft.com

Panel 1: The Smart Home

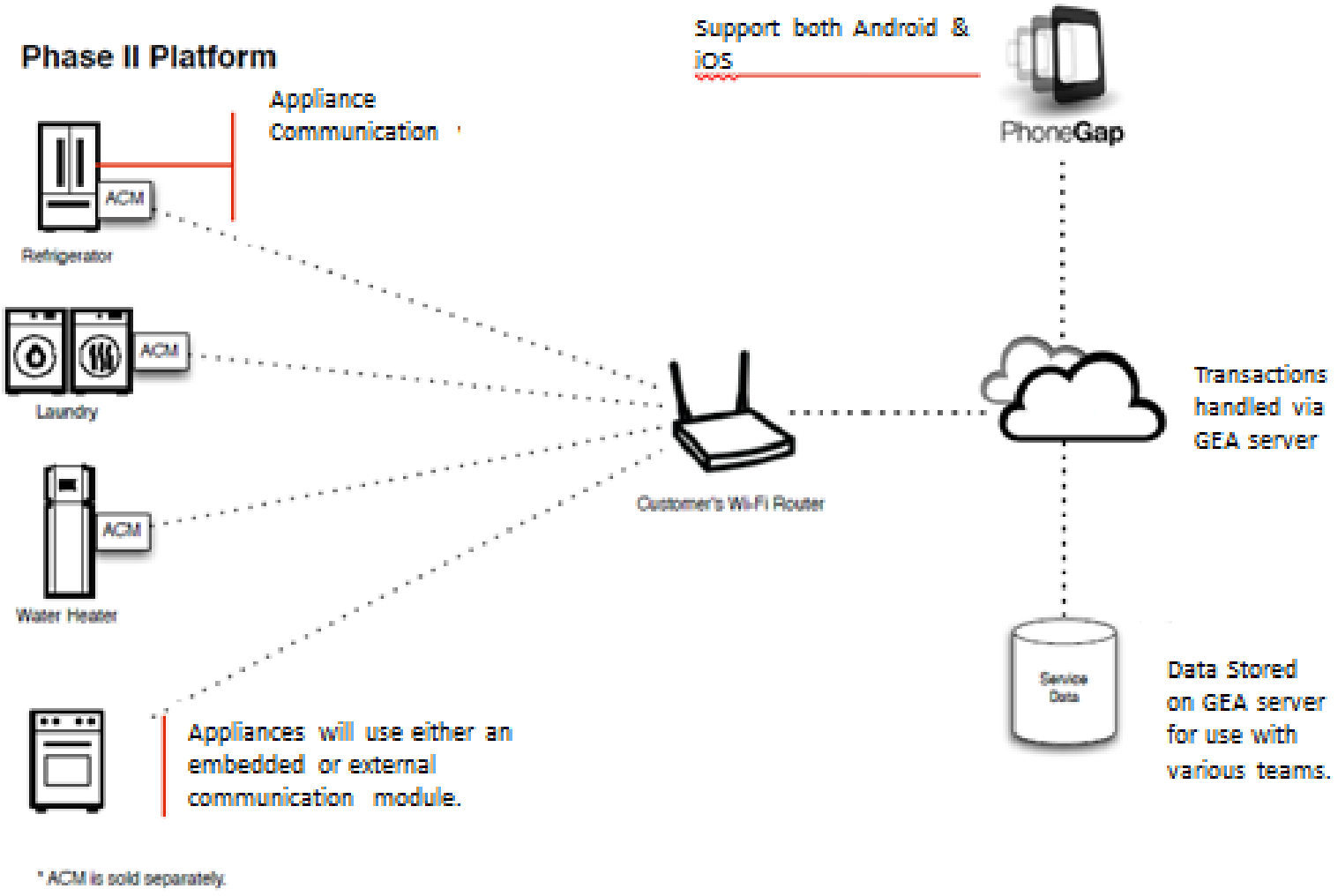
- **Michael Beyerle,** GE Appliances
- **Jeff Hagins,** SmartThings
- **Craig Heffner**, Tactical Network Solutions
- **Eric Lightner**, Department of Energy
- **Lee Tien**, Electronic Frontier Foundation

internet of things

Connecting with your Appliances

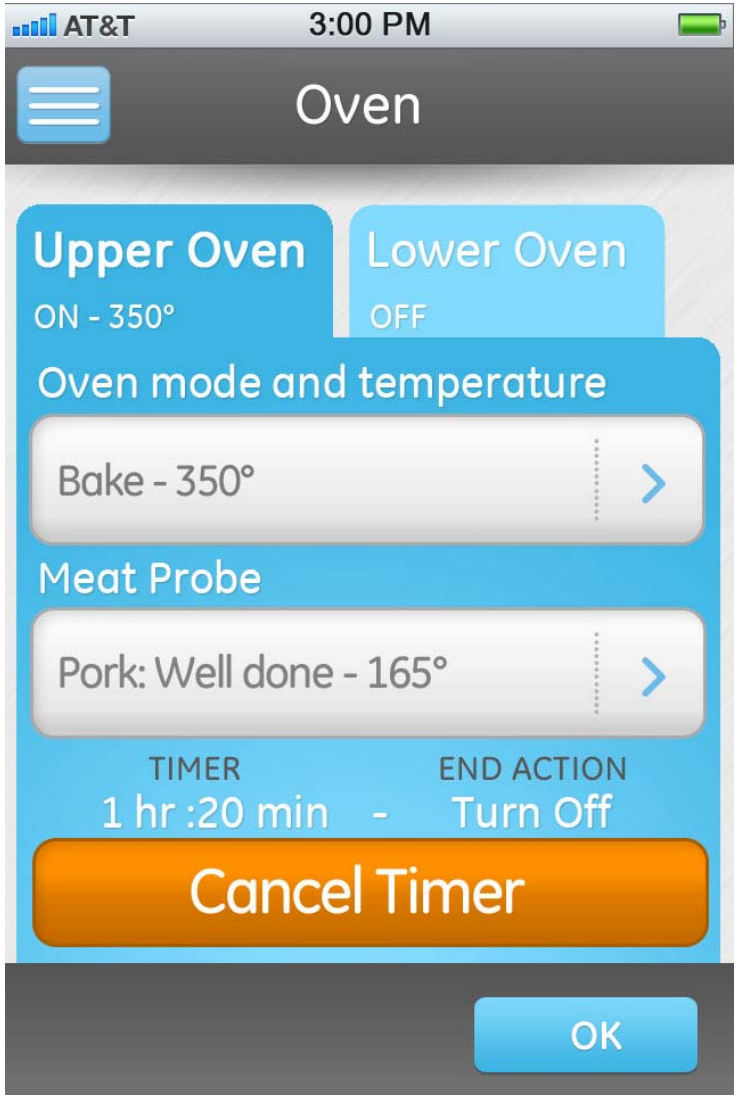
Mike Beyerle
GE Appliances

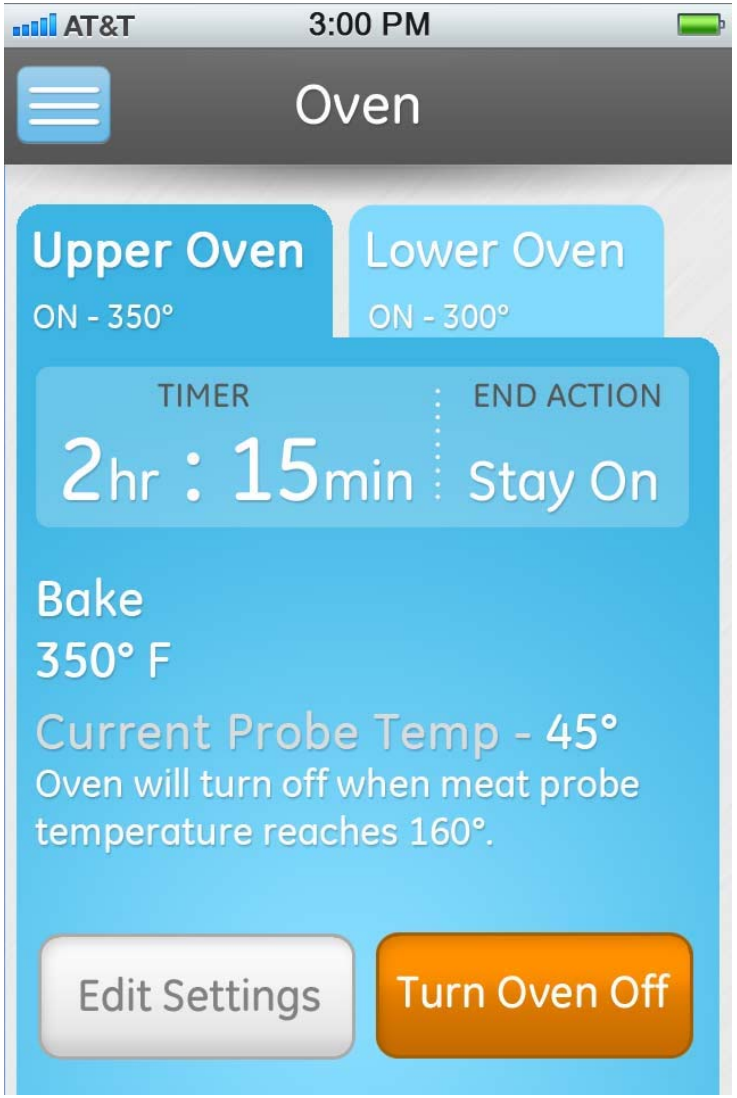
Connected Platform



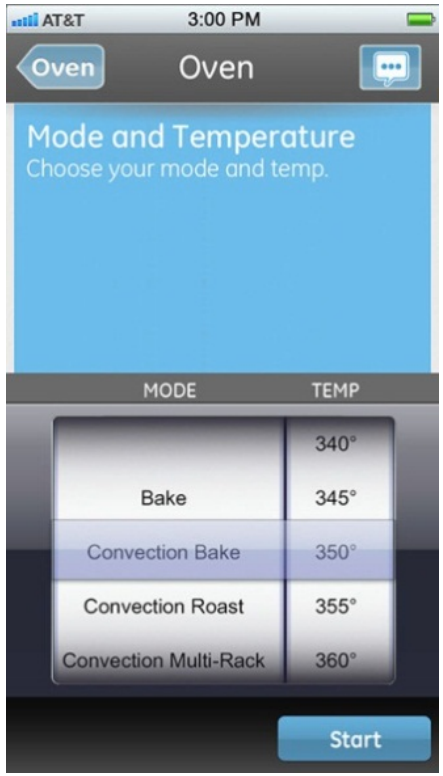
imagination at work

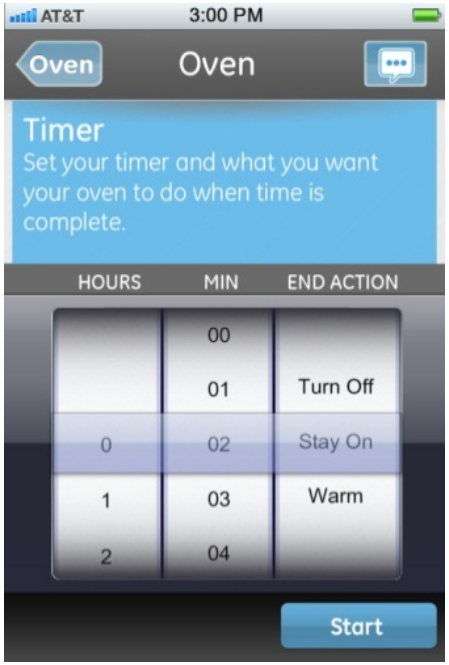
Oven User Interface (iOS)





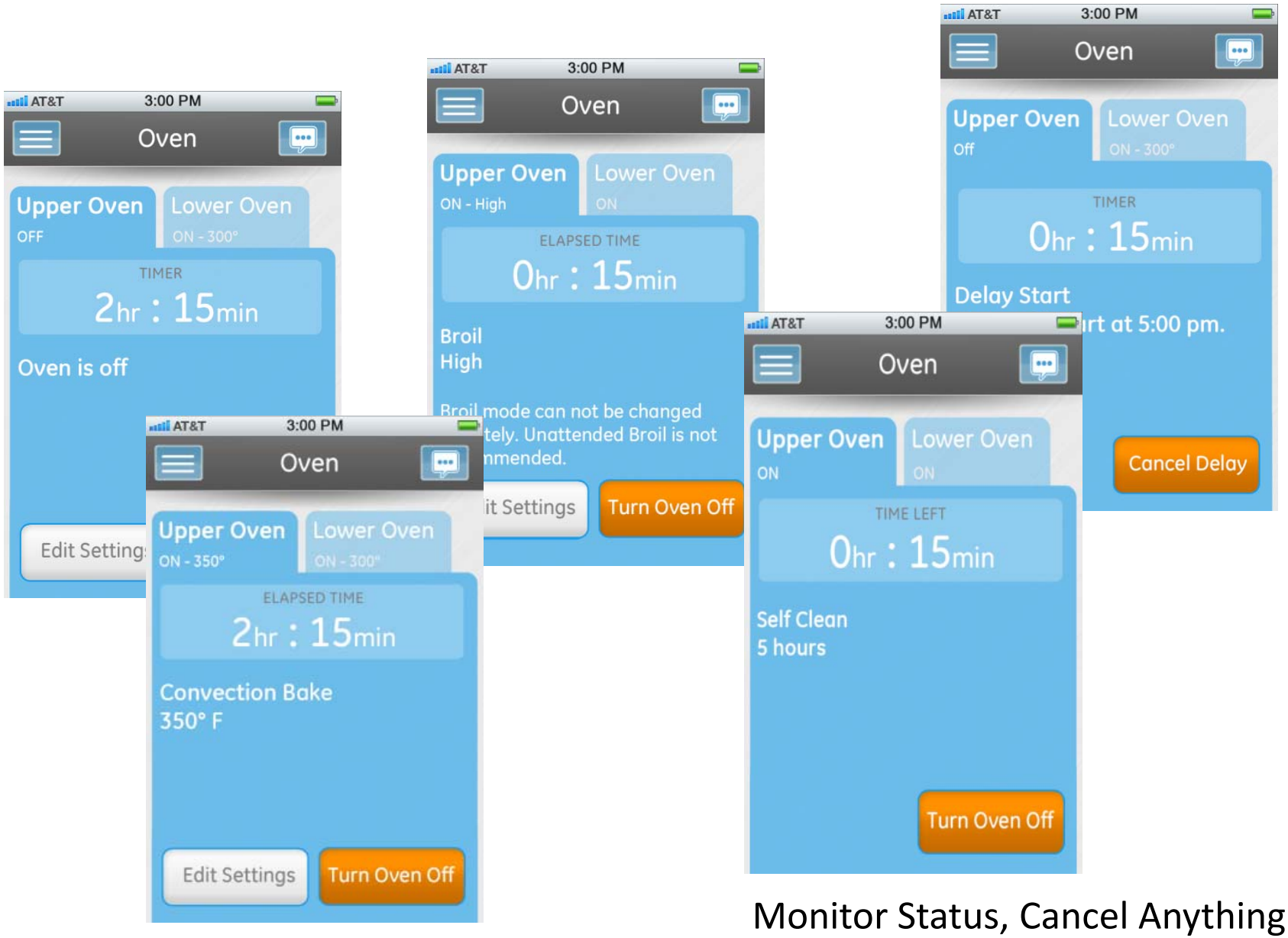
Control





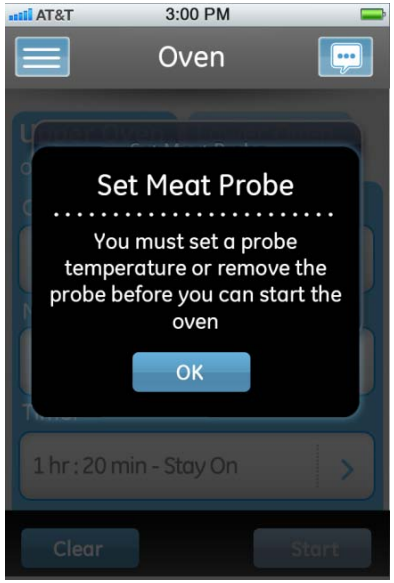
Set Mode, Timers, Meat Probe

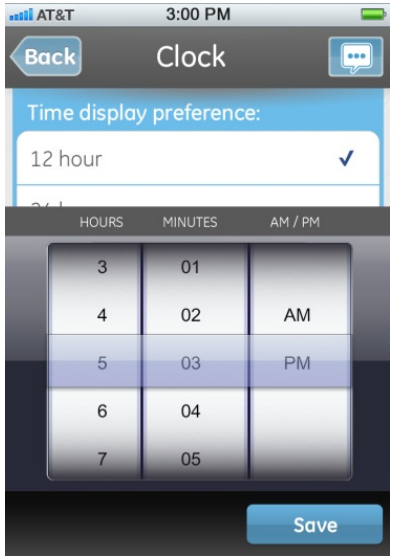
Monitoring

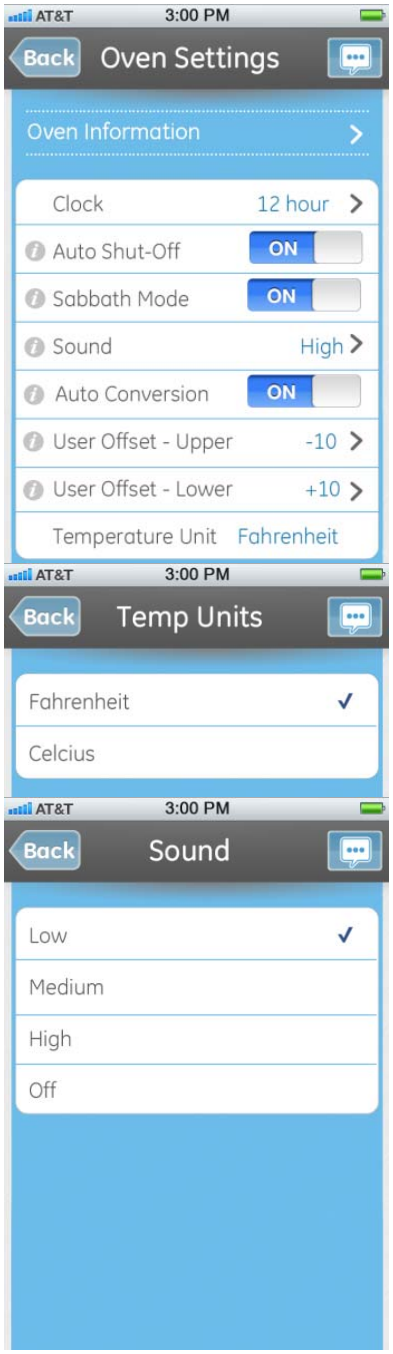


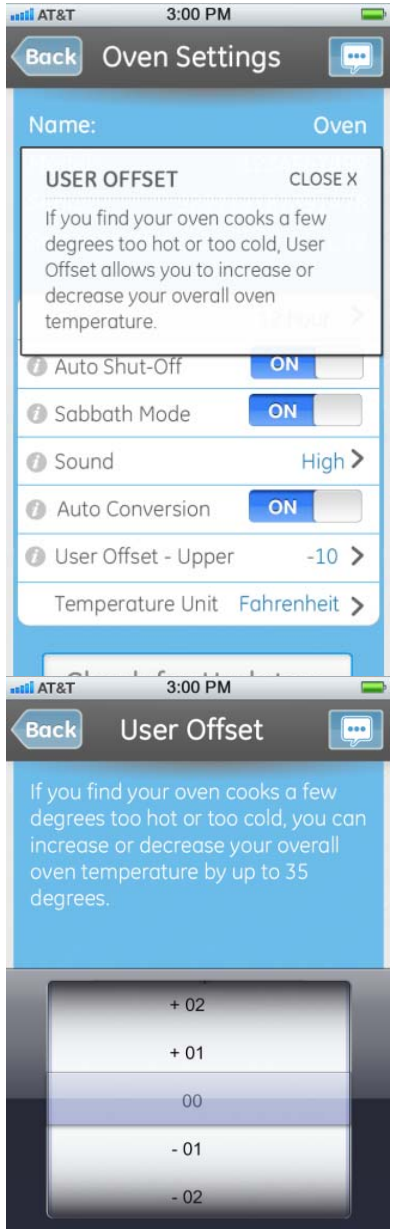
Monitor Status, Cancel Anything

Convenience







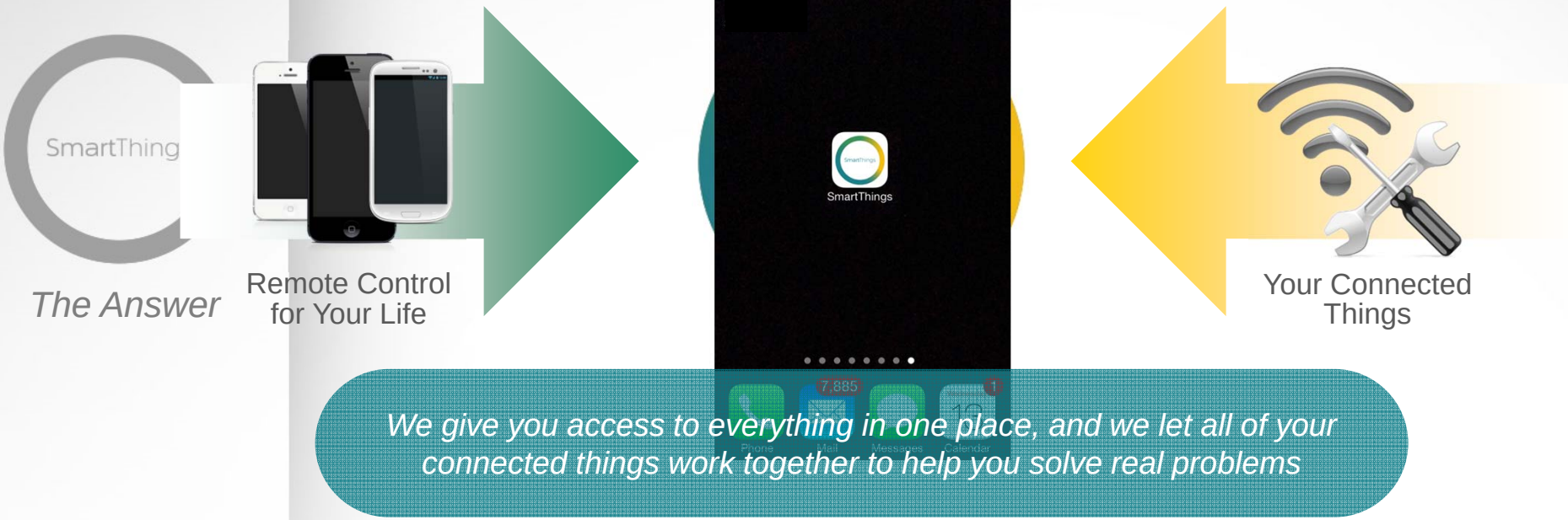


- Educates User About Oven
- Makes Special Features more user-friendly

Make your world smarter.


SmartThing
The Problem
Ubiquitous
Smartphones
AT&T
9:10 AM
84%
hue
ecobee
Pebble
Life360
Dropcam
Fitbit
Withings
Nest
UP
FuelBand
Kēvo
Craftsman
Lockitron
SYLVANIA...
In.Sight
WeMo
Sonos
Harmony
Rain Bird
Thermostat
Explosion of
Connected Devices

SmartThings puts an life-changing Smart Home experience in the palm of every consumer's hand.



We give you access to everything in one place, and we let all of your connected things work together to help you solve real problems

SmartThings

What We Sell

SmartSense **Multi**

SmartSense **Presence**

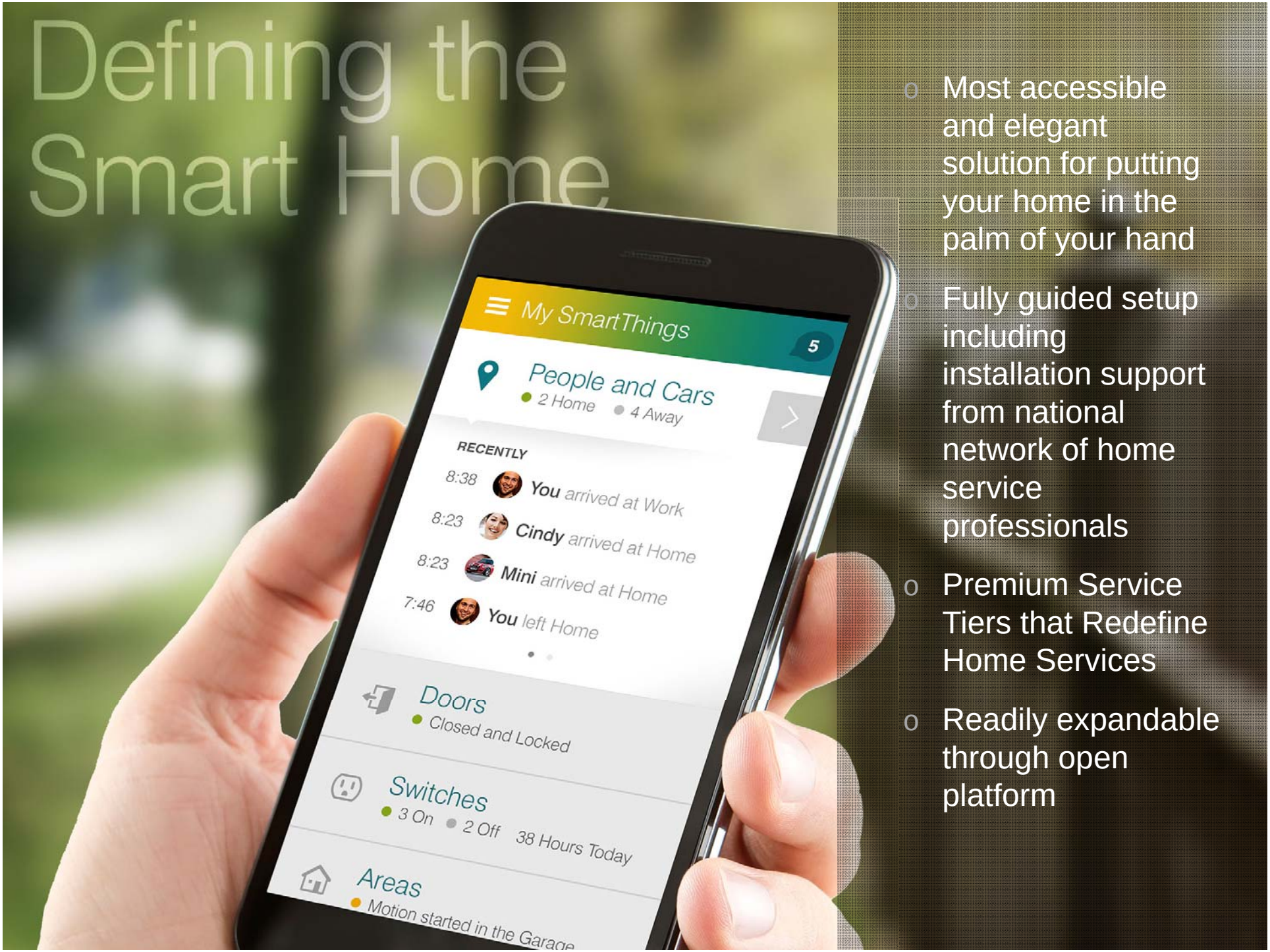
SmartThings **Hub**

SmartSense **Motion**

SmartPower **Outlet**

Including all devices and software needed to deliver an immediate life benefit

Defining the Smart Home



- Most accessible and elegant solution for putting your home in the palm of your hand
- Fully guided setup including installation support from national network of home service professionals
- Premium Service Tiers that Redefine Home Services
- Readily expandable through open platform

The Potential

- The Internet of Things (done correctly) will …
  - Support & Improve Our Freedoms
  - Make us Safer
  - Help Us To Be Healthier
  - Save Time
  - Save Money
  - Reduce Waste
  - Allow for Extreme Personalization
  - Improve Control
  - Give us Greater Choice

Security & Privacy

- As Long As …
  - Our “Things” and Data are Secure
  - We (the consumer) Own Our Things and Therefore the Data that Results from Those Things
  - Sharing of Our Things (and the related data) is Contextual & Explicit
  - It is Highly Reliable & Available
  - It is Open

Make your world smarter.

Panel 1: The Smart Home

- **Michael Beyerle,** GE Appliances
- **Jeff Hagins,** SmartThings
- **Craig Heffner**, Tactical Network Solutions
- **Eric Lightner**, Department of Energy
- **Lee Tien**, Electronic Frontier Foundation

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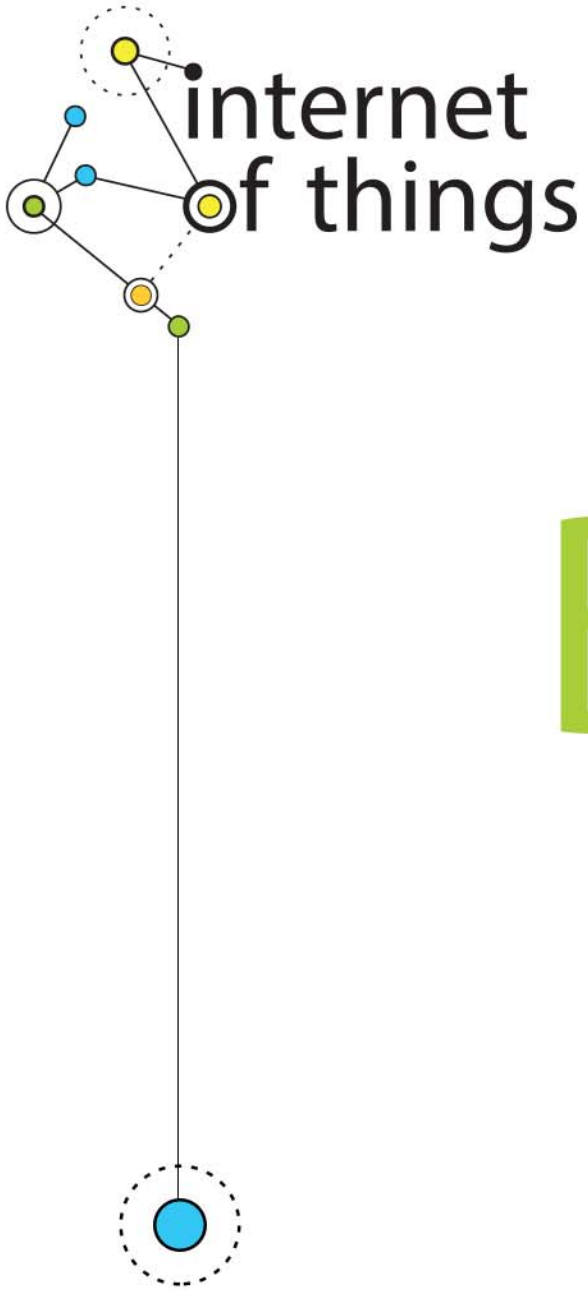
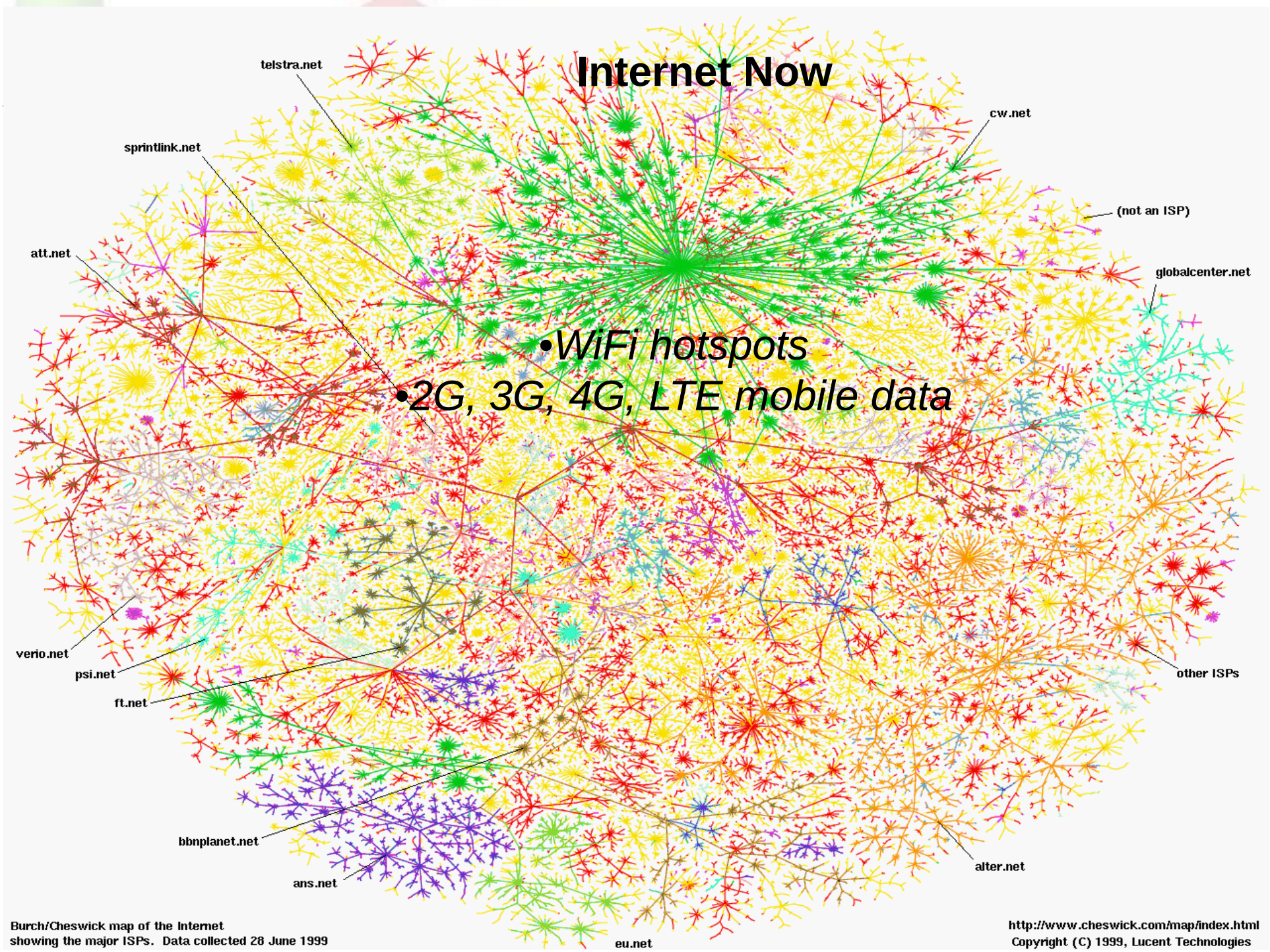


Break

An Internet of Things

Vint Cerf

November 2013


Internet Now
telstra.net
sprintlink.net
cw.net
(not an ISP)
att.net
globalcenter.net
•WiFi hotspots
•2G, 3G, 4G, LTE mobile data
verio.net
psi.net
ft.net
other ISPs
bbnplanet.net
alter.net
ans.net
eu.net
Burch/Cheswick map of the Internet
showing the major ISPs. Data collected 28 June 1999
http://www.cheswick.com/map/index.html
Copyright (C) 1999, Lucent Technologies

Internet - Global Statistics 2013

996.2 Million

(http://ftp.isc.org/www/survey/reports/2013/07/)

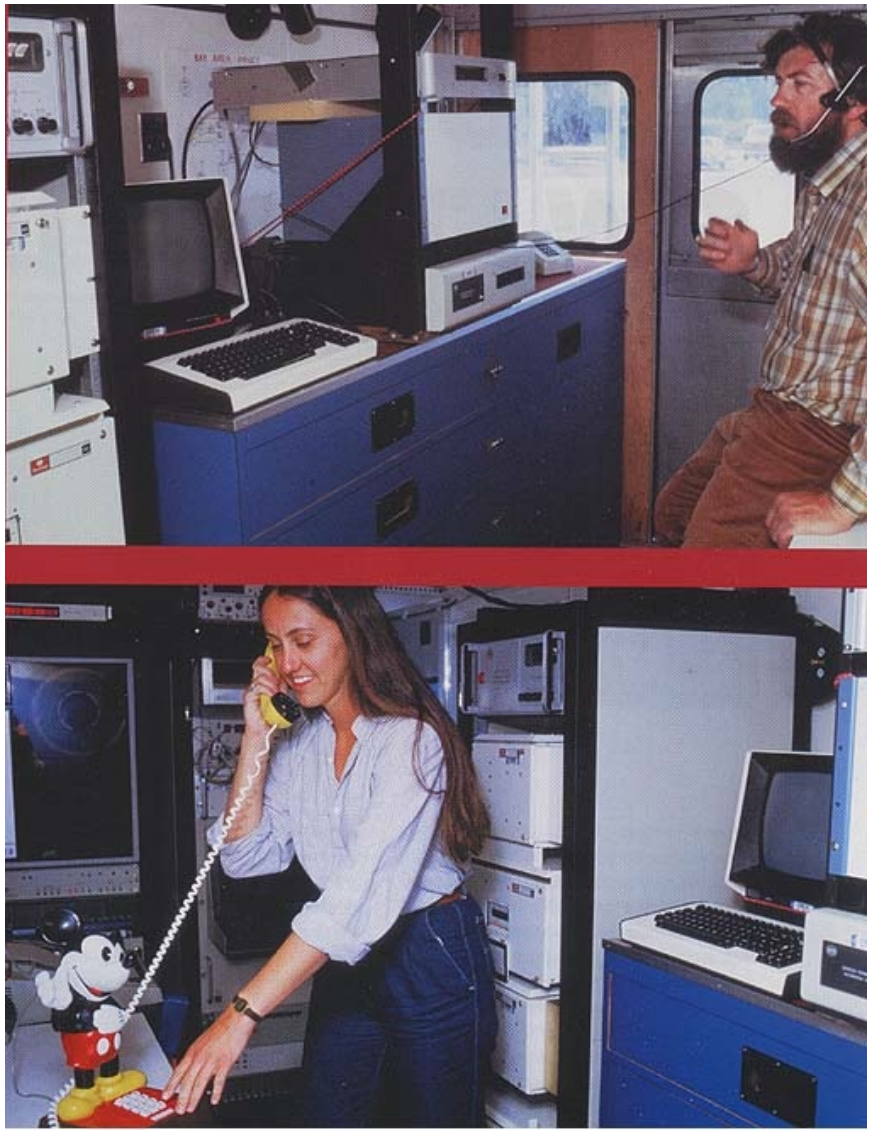
3.0 Billion Users

(InternetWorldStats.com, extrapolation)

(approx. 7 B mobiles and >1.5 Billion PCs)

Packet Radio Van

Inside the PR Van (2)



Increasing numbers of networked appliances

Google

- Consumer goods (televisions, mobile, tablets, picture frames …)
- Sensor systems (security, agriculture, environmental monitoring, HVAC …)
- Personal medical instruments (e.g., insulin pumps, biometric monitoring)
- Fitness (e.g., FitBit, sneakers …)
- Remotely Controlled Devices (e.g., crisis response)
- Wearables (assisting those with disabilities, assisted living)
- Automobiles (think GM OnStar, etc.)

An Internet of Things

Woodhurst sensor net – Home – Arch Rock PhyNet Server

http://woodhurst.webhop.org:8080/mgmt/

Moma GMail logout

ARCH ROCK PhyNet Server

Woodhurst sensor net

2008-09-21 4:16:38 pm EDT

Help on this Page
How to Build this Page

I wish this page would...

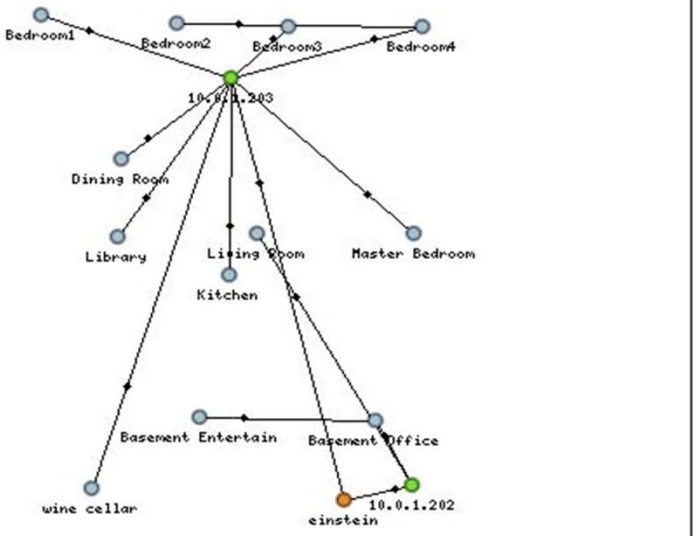
Send Feedback

Home

Server Router Node Missing Router or Node

Deployment started on 2008-07-11 12:35:48 pm EDT, running for 72d 3h 40m 51s.

Deployment Map



Network Devices

15 Devices

- einstein
- 10.0.1.202
  4:15:01 pm
- 10.0.1.203
  4:15:00 pm

1st Floor

- Dining Room
  4:15:05 pm
  71 °F 55.3 % 10 lux 1 lux
- Kitchen
  4:12:03 pm
  72.9 °F 51 % 21 lux 1 lux
- Library
  4:12:35 pm
  73.3 °F 50.1 % 10 lux 0 lux
- Living Room
  4:14:57 pm
  70.4 °F 51.5 % 7 lux 0 lux
- Master Bedroom
  4:15:13 pm
  70.1 °F 56 % 14 lux 2 lux

2nd Floor

- Bedroom1
  4:12:14 pm
  74 °F 48 % 14 lux 1 lux
- Bedroom2
  4:15:10 pm
  74.4 °F 49 % 80 lux 17 lux
- Bedroom3
  4:15:12 pm
  73.5 °F 47.9 % 14 lux 1 lux
- Bedroom4
  4:15:06 pm
  70.7 °F 56.7 % 3 lux 0 lux

Done

Beer Keg Sensor System…

http://www.steadyserv.com/videos/ikeg-solving-the-beer-inventory-challenge

Smart Cities

- Monitoring and reporting of status of city services
  - Traffic flow, power (use, availability, outage), water (use, availability, outage), gas (use, availability, outage), road repairs, public transportation, communication services …
  - Government/citizen communication (licenses, fees, taxes, fines, library services, special needs services, ombudsman functions ...)
- Open access to city information (enables new businesses)
  - Facilitating third party applications, analysis, planning…
  - Scheduling and licensing of events
  - Tourism information (sites, availability, …)
- Smart Grid Program
  - Feedback to users on power usage
  - Demand response capability
  - Extension to other resource utilization (water, gas, …)

Self-Driving Cars!

Google

Global Implications

- Potential for local, regional, national and global optimization of resource management
- Standards enable global business opportunities for products and services (including maintenance and updates)
- Potential health management and wellness improvement through continuous monitoring (note also potential for early epidemic detection)
- Potential educational implications (access to content from any source)
- Potential for new inventions and products for consumers

Challenges and Opportunities Posed by IOT

Google

- Standard interfaces and protocols (IPv6…)
- Configuration of massive numbers of devices
- Dynamic and Self-configuration (moving house/office)
- Strong access control (and authentication)
- Privacy and Safety (access to control and data)
- Instrumentation, feedback
- Dealing with software errors, vulnerabilities, updates
- Potential opportunities for third-party businesses

Lunch

Commissioner Maureen Ohlhausen

Panel 2: Connected Health & Fitness

- **Stan Crosley**, Indiana University
- **Joseph Lorenzo Hall**, Center for Democracy & Technology
- **Anand Iyer**, WellDoc Communications
- **Scott Peppet**, University of Colorado School of Law
- **Jay Radcliffe**, InGuardians

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Jay Radcliffe: Hacking An Insulin Pump

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Anand Iyer
WellDoc Communications

Demonstration of BlueStar™

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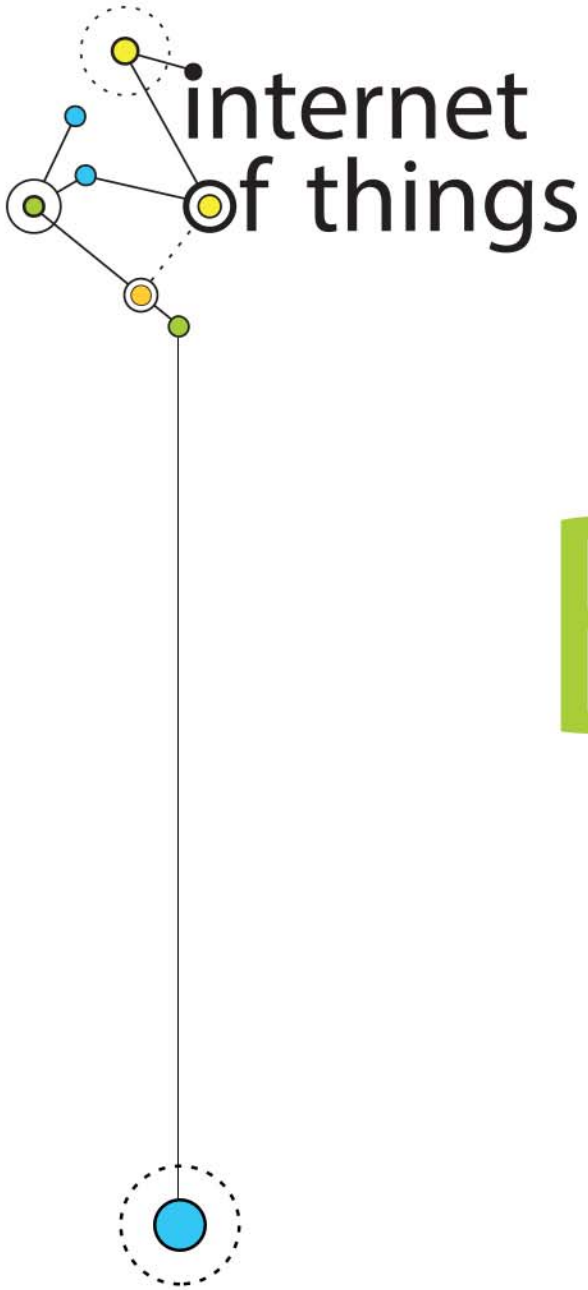

Break

Panel 3: Connected Cars

- **Yoshi Kohno**, University of Washington
- **John Nielsen**, American Automobile Association
- **Wayne Powell**, Toyota Technical Center
- **Christopher Wolf**, Future of Privacy Forum

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Panel 4: Privacy and Security in a Connected World

- **Ryan Calo**, University of Washington Law School
- **Dan Caprio**, McKenna Long & Aldridge LLP
- **Michelle Chibba**, Office of Information & Privacy Commissioner of Ontario
- **Drew Hickerson**, Happtique
- **David Jacobs**, Electronic Privacy Information Center
- **Marc Rodgers**, Lookout Security

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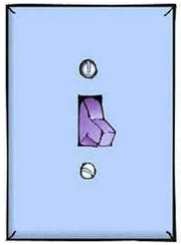
Scenario 1

- Sue wants to design a system that will control the interconnected devices in her home via her smartphone
- She wants her smartphone to be able to:
  - Lock and unlock the front door
  - Turn off her alarm as she approaches
  - Control the lights in her bedroom so they turn on before she wakes up



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Scenario 2

- Jane wants to start training for a marathon and she considers buying a new smart device to help her training. The device can:
  - Connect to her online calendar to schedule times for runs
  - Calibrate optimal training programs and design running courses
  - Offer discounts on medical insurance
  - Post progress on her social networks

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Scenario 3

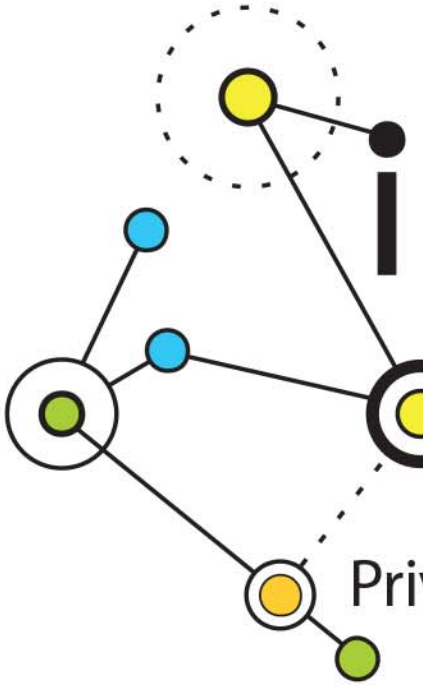
- Sue's system for controlling interconnected devices via the smartphone is extremely successful
- One day Sue gets a call from Tom who runs the home security system that is compatible with Sue's application
- Tom tells Sue that the login credentials for his system were compromised and that criminals have posted live video feeds of some of Sue's customers on the Internet

Scenario 4

- One day Sue is approached by a marketing company that wants to buy data about Sue's customers

Jessica Rich

Director, Bureau of Consumer Protection



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Privacy & Security in a Connected World