Cybersecurity and Privacy Challenges in the Internet of Things (IoT)

Bogota, Colombia
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University of Maryland University College (UMUC)
# Internet of Things (IoT)

Cybersecurity and Privacy

<table>
<thead>
<tr>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the IoT?</td>
</tr>
<tr>
<td>Where is it?</td>
</tr>
<tr>
<td>Cybersecurity Concerns in the IoT</td>
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<tr>
<td>Privacy Concerns in the IoT</td>
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<tr>
<td>Legal and Other Concerns</td>
</tr>
<tr>
<td>Challenges and The Future</td>
</tr>
</tbody>
</table>
Many meanings, A Buzz Word to Commerce... etc.

“The Internet of Things (IoT) is the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment.” – Gartner Research

“The Internet of Things (“IoT”) refers to the ability of everyday objects to connect to the Internet and to send and receive data.” – US Federal Trade Commission

“The internet of things (IoT) is the internetworking of physical devices, vehicles, buildings and other items—embedded with electronics, software, sensors, actuators, and network connectivity that enable these objects to collect and exchange data.” – Wikipedia
Different Meanings

Word Associations Reflect the Many Facets of IoT

- Connected (53%)
- Intelligent System (40%)
- Smart (40%)
- Futuristic (29%)
- Data Streams (36%)
- Machine-to-Machine (27%)
- Solution Looking for a Problem (25%)
- Security Disaster Waiting to Happen (19%)
- Nothing New – Extension of Internet (16%)

Source: CompTIA’s Internet of Things Insights and Opportunities study
IoT Devices (Things)

Source: http://www.prweb.com/
Where are these Things?
When was the IoT Born?

<table>
<thead>
<tr>
<th>Year</th>
<th>World Population</th>
<th>Connected Devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>6.3 Billion</td>
<td>500 Million</td>
</tr>
<tr>
<td>2010</td>
<td>6.8 Billion</td>
<td>12.5 Billion</td>
</tr>
<tr>
<td>2015</td>
<td>7.2 Billion</td>
<td>25 Billion</td>
</tr>
<tr>
<td>2020</td>
<td>7.6 Billion</td>
<td>50 Billion</td>
</tr>
</tbody>
</table>

Source: Cisco IBSG, April 2011
Projected Growth of IoT

- **Past and current projections for 2020**
  - Ericsson
  - Cisco
  - IHS Markit
  - Gartner
  - International Data Corp.

- **Current estimates for 2016**

*Ericsson projections are for 2021.*
## Internet Users

<table>
<thead>
<tr>
<th>Year</th>
<th>Internet Users**</th>
<th>Penetration (% of Pop)</th>
<th>World Population</th>
<th>Non-Users (Internetless)</th>
<th>1Y User Change</th>
<th>1Y User Change</th>
<th>World Pop. Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016*</td>
<td><strong>3,424,971,237</strong></td>
<td>46.1 %</td>
<td>7,432,663,275</td>
<td>4,007,692,038</td>
<td>7.5 %</td>
<td>238,975,082</td>
<td>1.13 %</td>
</tr>
<tr>
<td>2015*</td>
<td><strong>3,185,996,155</strong></td>
<td>43.4 %</td>
<td>7,349,472,099</td>
<td>4,163,475,944</td>
<td>7.8 %</td>
<td>229,610,586</td>
<td>1.15 %</td>
</tr>
<tr>
<td>2014</td>
<td><strong>2,956,385,569</strong></td>
<td>40.7 %</td>
<td>7,265,785,946</td>
<td>4,309,400,377</td>
<td>8.4 %</td>
<td>227,957,462</td>
<td>1.17 %</td>
</tr>
<tr>
<td>2013</td>
<td><strong>2,728,428,107</strong></td>
<td>38 %</td>
<td>7,181,715,139</td>
<td>4,453,287,032</td>
<td>9.4 %</td>
<td>233,691,859</td>
<td>1.19 %</td>
</tr>
<tr>
<td>2012</td>
<td><strong>2,494,736,248</strong></td>
<td>35.1 %</td>
<td>7,097,500,453</td>
<td>4,602,764,205</td>
<td>11.8 %</td>
<td>262,778,889</td>
<td>1.2 %</td>
</tr>
<tr>
<td>2011</td>
<td><strong>2,231,957,359</strong></td>
<td>31.8 %</td>
<td>7,013,427,052</td>
<td>4,781,463,693</td>
<td>10.3 %</td>
<td>208,754,385</td>
<td>1.21 %</td>
</tr>
<tr>
<td>2010</td>
<td><strong>2,023,202,974</strong></td>
<td>29.2 %</td>
<td>6,929,725,043</td>
<td>4,906,522,069</td>
<td>14.5 %</td>
<td>256,799,160</td>
<td>1.22 %</td>
</tr>
<tr>
<td>2009</td>
<td><strong>1,766,403,814</strong></td>
<td>25.8 %</td>
<td>6,846,479,521</td>
<td>5,080,075,707</td>
<td>12.1 %</td>
<td>191,336,294</td>
<td>1.22 %</td>
</tr>
<tr>
<td>2008</td>
<td><strong>1,575,067,520</strong></td>
<td>23.3 %</td>
<td>6,753,732,879</td>
<td>5,188,665,359</td>
<td>14.7 %</td>
<td>201,840,532</td>
<td>1.23 %</td>
</tr>
<tr>
<td>2007</td>
<td><strong>1,373,226,988</strong></td>
<td>20.6 %</td>
<td>6,681,607,320</td>
<td>5,308,380,332</td>
<td>18.1 %</td>
<td>210,310,170</td>
<td>1.23 %</td>
</tr>
<tr>
<td>2006</td>
<td><strong>1,162,916,818</strong></td>
<td>17.6 %</td>
<td>6,600,220,247</td>
<td>5,437,303,429</td>
<td>12.9 %</td>
<td>132,815,529</td>
<td>1.24 %</td>
</tr>
<tr>
<td>2005</td>
<td><strong>1,030,101,289</strong></td>
<td>15.8 %</td>
<td>6,519,635,850</td>
<td>5,489,534,561</td>
<td>12.8 %</td>
<td>116,773,518</td>
<td>1.24 %</td>
</tr>
<tr>
<td>2004</td>
<td><strong>913,327,771</strong></td>
<td>14.2 %</td>
<td>6,439,842,408</td>
<td>5,526,514,637</td>
<td>16.9 %</td>
<td>131,891,788</td>
<td>1.24 %</td>
</tr>
<tr>
<td>2003</td>
<td><strong>781,435,983</strong></td>
<td>12.3 %</td>
<td>6,360,764,684</td>
<td>5,579,328,701</td>
<td>17.5 %</td>
<td>116,370,969</td>
<td>1.25 %</td>
</tr>
<tr>
<td>2002</td>
<td><strong>665,065,014</strong></td>
<td>10.6 %</td>
<td>6,282,301,757</td>
<td>5,617,236,753</td>
<td>32.4 %</td>
<td>162,772,769</td>
<td>1.26 %</td>
</tr>
<tr>
<td>2001</td>
<td><strong>502,292,245</strong></td>
<td>8.1 %</td>
<td>6,204,310,739</td>
<td>5,702,018,494</td>
<td>21.1 %</td>
<td>87,497,288</td>
<td>1.27 %</td>
</tr>
<tr>
<td>2000</td>
<td><strong>414,794,957</strong></td>
<td>6.8 %</td>
<td>6,126,622,121</td>
<td>5,711,827,164</td>
<td>47.3 %</td>
<td>133,257,305</td>
<td>1.28 %</td>
</tr>
</tbody>
</table>

http://www.internetlivestats
Future Value and Growth

$14.4 trillion^2 —
Est. value of the global Internet of Things market by 2022

$3.7 trillion
from improved customer experience

$3.0 trillion
from reduced time to market

$2.7 trillion
in supply chain and logistics

$2.5 trillion
in reduced costs

$2.5 trillion
in increased employee productivity

IoT by the numbers

IoT network connections — 2014 vs. 2015 % growth

<table>
<thead>
<tr>
<th>Industry</th>
<th>2014</th>
<th>2015</th>
<th>Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthcare/Pharma</td>
<td>26%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home monitoring</td>
<td></td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>Energy/Utilities</td>
<td></td>
<td>58%</td>
<td></td>
</tr>
<tr>
<td>Smart cities</td>
<td></td>
<td>43%</td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td></td>
<td>33%</td>
<td></td>
</tr>
<tr>
<td>Transportation/Distribution</td>
<td></td>
<td>49%</td>
<td></td>
</tr>
</tbody>
</table>

Source: Verizon data


Who’s investing in IoT

### The Most Active IoT Investors

**VCs Ranked by Unique IoT Investments, 2010 - 2015 YTD (11/24/15)**

<table>
<thead>
<tr>
<th>Investor</th>
<th>Rank</th>
<th>Companies</th>
</tr>
</thead>
</table>
Can I see the IoT?

Search Engines for the IoT

Shodan is the world's first search engine for Internet-connected devices.

Censys is a search engine that allows computer scientists to ask questions about the devices and networks that compose the Internet. Driven by Internet-wide scanning, Censys lets researchers find specific hosts and create aggregate reports on how devices, websites, and certificates are configured and deployed.
Current Uses
The Connected Home

Devices inside and outside of the home talk to users, each other and the grid to optimize energy use and comfort.

Solar Tracking. Homeowners can monitor the energy production of their solar PV arrays and compare output to consumption.

Peace of Mind. A smoke and carbon monoxide detector not only sounds an alarm, but will send a text or email alert if something’s amiss.

Illuminating Technology. Lighting controls sense when the room is occupied; lights also automatically adjust to available daylight, saving energy.

Programmed Security. Homeowners provide unique access codes for different people, set to work on specific days/times.

Smart Appliances. The washer and dryer delay the start of loads until after periods of peak energy demand.

Climate Control. A smart thermostat detects occupancy and adjusts the temperature accordingly.

Managed EV Charging. A connected electric vehicle charger suspends charging when electricity demand on the grid is high.

Wise Watering. The Wi-Fi-connected irrigation system adjusts the watering schedule based on season and soil moisture, but can be controlled via smartphone or tablet when needed.
Hook connects home appliances and lighting to the Internet using inexpensive outlet adapters and bulb sockets.
Connected Cars
Smart Facilities/Cities
What’s Driving the IoT?

- Low cost of connectivity (The internet)
- Low cost of electronic components (sensors, microcontrollers, storage, etc)
- Cloud and Mobile Computing
- Wide range of communication channels
- Increase in computing speed
- Easy to use (consumers)
- More Revenues

IoT is now growing faster than smartphones
U.S. mobile carriers added more cars than phones to their networks in the second quarter
## Cybersecurity and Privacy Concerns

<table>
<thead>
<tr>
<th>What concerns people about a world of connected devices</th>
<th>Objects that consumers would be most concerned about being connected to the Internet</th>
</tr>
</thead>
<tbody>
<tr>
<td>- 62% -- Privacy</td>
<td>- 30% -- Home security</td>
</tr>
<tr>
<td>- 54% -- Security</td>
<td>- 12% -- Car</td>
</tr>
<tr>
<td>- 27% -- Physical safety</td>
<td>- 10% -- TV</td>
</tr>
<tr>
<td>- 24% -- Unable to repair</td>
<td>- 6% -- Iron</td>
</tr>
<tr>
<td>- 21% -- Machines taking over the earth</td>
<td>- 6% -- Heating system,</td>
</tr>
<tr>
<td>- 17% -- Not knowing how to use them</td>
<td>- 6% -- Smoke detector</td>
</tr>
<tr>
<td>- 11% -- No tangible benefits</td>
<td>- 5% -- Oven</td>
</tr>
<tr>
<td></td>
<td>- 5% -- Lighting</td>
</tr>
</tbody>
</table>

Cybersecurity Concerns

- Vector for penetration into the network by facilitating attacks on other systems (Spam, DDoS)
- Not ONE define “standard” for processing or communication
- Patching and vulnerabilities devices – Many failing points (sensors, microcontrollers, actuators, cloud, mobile apps, communication)
- Weak login credentials (username, password)
- Poor configuration of the device
- Life Cycle of Things must be addressed
- IoT Devices (sensors and consumer items) are deployed at a massive scale compare to other internet connected devices
- Upgrades may be difficult (car recalls because of bad sensors on board)
- Many identical devices, same vulnerability
## OWASP Internet of Things (IoT) Project
### Top 10 Risks (Devices)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Insecure Web Interface</td>
</tr>
<tr>
<td>2</td>
<td>Insufficient Authentication/Authorization</td>
</tr>
<tr>
<td>3</td>
<td>Insecure Network Services</td>
</tr>
<tr>
<td>4</td>
<td>Lack of Transport Encryption/Integrity Verification</td>
</tr>
<tr>
<td>5</td>
<td>Privacy Concerns</td>
</tr>
<tr>
<td>6</td>
<td>Insecure Cloud Interface</td>
</tr>
<tr>
<td>7</td>
<td>Insecure Mobile Interface</td>
</tr>
<tr>
<td>8</td>
<td>Insufficient Security Configurability</td>
</tr>
<tr>
<td>9</td>
<td>Insecure Software/Firmware</td>
</tr>
<tr>
<td>10</td>
<td>Poor Physical Security</td>
</tr>
</tbody>
</table>

Privacy Concerns

- Open Collection (data, metadata) from the manufacturer or third party
- Worry about anything with a Microphone or Camera
- Surveillance/tracking concerns (private companies and government)
- Where is the privacy policy notice?

When Alexa is listening, what do you tell houseguests?

In offices of the future, sensors may track your every move – even in the bathroom

Objects will soon be able to ‘talk’ to each other, locate staff and monitor workplace temperature, but what will this mean for privacy?

Sex toys and the Internet of Things collide—what could go wrong?

Lawsuit: Mobile app siphons data on vibrator intensity settings, other usage stats.

Samsung's voice-recording smart TVs breach privacy law, campaigners claim
Legal and other Concerns

* Law does not catch up with technology
* Need to provide more information to consumers
* Data Geolocation (jurisdiction)
* Law enforcement use of IoT data (backdoors?)
* Legal Liability (will insurance company pay for hacking of IoT)
* May create safety risks (cars, nuclear plants)
* Increase dependency on IoT devices (make things easy)
* They are being used in Legal Actions (divorces, claims, etc)
Mary Barra, Chairman & CEO, GM at Billington CyberSecurity Summit 7-22-16

“The auto industry have the opportunity to control the risks before a major incident, they are starting to work on it.”
DRAFT NISTIR 8114

Report on Lightweight Cryptography

Kerry A. McKay
Larry Bassham
Meltem Sonmez Turan
Nicky Mouha

NIST Special Publication 800-183

Networks of ‘Things’

Jeffrey Voas

The Future
The Future... Super Smart IoT
Specially for Consumers

Nest Gives Its Security Cameras Brains Using Google's Computer Vision Software
## Handbook: Internet of Things Alliances and Consortia

### Technology Architecture Focused

- **Link / Comms**
  - IEEE
  - ZigBee Alliance
  - Wi-Fi Alliance
  - Bluetooth Special Interest Group
  - LoRa Alliance
  - WEIGHTLESS

- **Core / Session / Transport / Messaging / Semantic**
  - IETF
  - ISO
  - IEC
  - ISA
  - OGC
  - W3C

- **Multi-layer**
  - OASIS
  - UPnP
  - OMA
  - HyperCat

### Vertical Focused

#### Connected Body
- Healthcare
  - HealthKit
  - HGI
  - Wave Alliance

#### Connected Home
- Home Automation
  - HomeKit
  - eHome Alliance

#### Connected City / Buildings
- Smart Cities
  - ONIV
  - GENIVI

#### Transportation
- Intelligent Transportation
  - Open Automotive Alliance
  - Modbus

#### Industrial IoT
- Industrial IoT
  - Industrial Internet Consortium

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This is not 1976!
IoT by all and for all!
The Future Internet of Everything (IoE)

Source: Cisco
With a right implementation, IoT will improve the quality of our lives in many sectors of our society, but in order to do exactly that we cannot repeat the same mistakes of the past.

We must build cybersecurity and privacy by default on all IoT devices (things).

Implement policies, guides, procedures BEFORE we rush to a massive deployment.
Thank you!

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