Crashing Drones and Hijacked Cameras: CyberPhysical meets CyberTrust

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Microsoft Research

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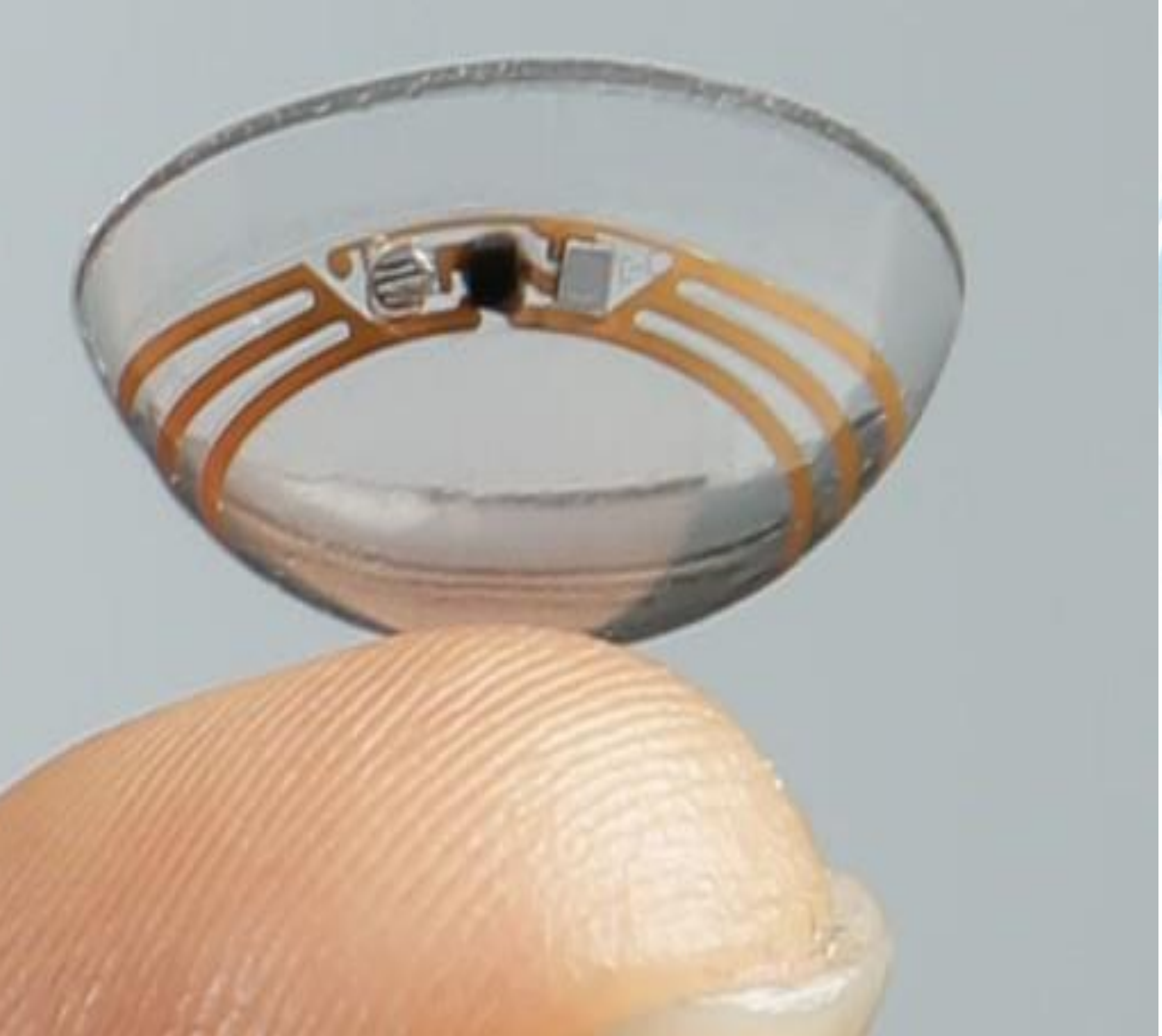
Los Angeles, CA
9 December 2015


nest
IN 25 MIN
72


LIVING ROOM


PHANTOM
PROFESSIONAL



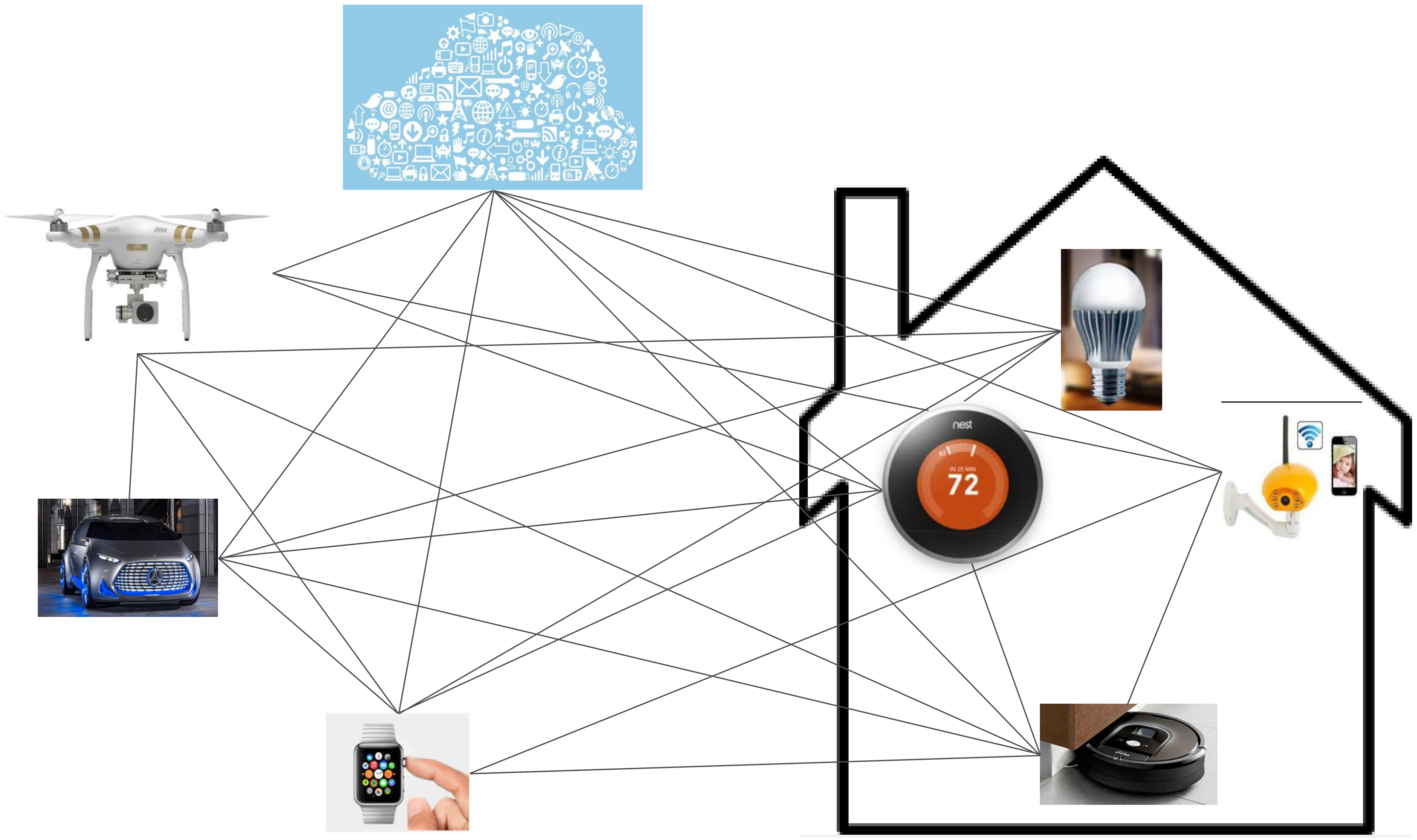






Carnegie Mellon


TEAM GLEASON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72

What is Common?

They have a computational core that interacts with the physical world.

Cyber-physical systems are engineered systems that require tight conjoining of and coordination between the computational (discrete) and the physical (continuous).

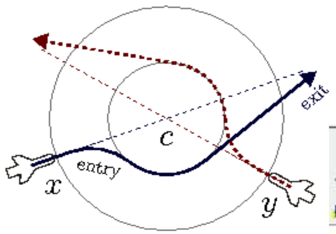
Trends for the future

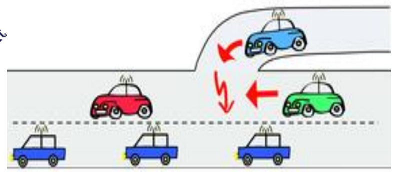
- Cyber-physical systems will be smarter and smarter.
- More and more intelligence will be in software
- More and more connectivity and data flow

What could go wrong?

Trustworthiness in Cyber-Physical Systems

Reliability Challenges





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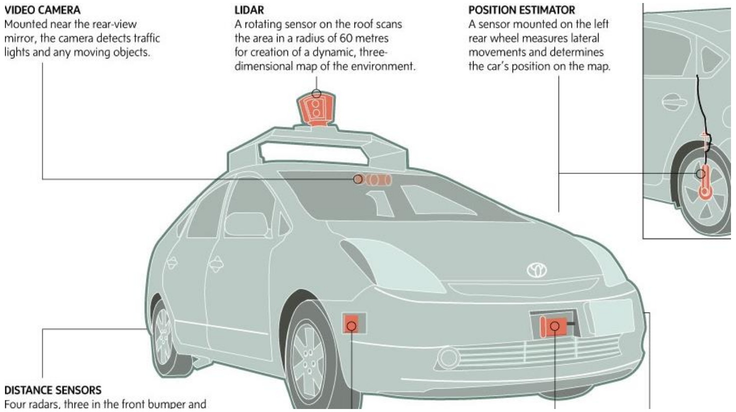


Challenge 1:
Reasoning about Continuous and Discrete

Challenge 2:
Uncertainty in Environment

Challenge 3:
Sensors and Actuators Can Fail

Computable Reals:
A Fundamentally Hard Problem

"A real number is computable if its digit sequence can be produced by some algorithm or Turing machine. The algorithm takes an integer $n \geq 1$ as input and produces the *n*-th digit of the real number's decimal expansion as output. " [Turing 1936]

Fact: While the set of real numbers is uncountable, the set of computable numbers is only countable and thus almost all real numbers are not computable.

Computable Reals:
Verification Challenge

On the one hand:

A real number *a* is said to be **computable** if it can be approximated by some computable function in the following manner: given any integer $n \geq 1$, the function produces an integer *k* such that:

$$\frac{k-1}{n} \leq a \leq \frac{k+1}{n}$$

On the other:

The computable numbers include many of the specific real numbers which appear in practice, including all real algebraic numbers, as well as e, π, and many other transcendental numbers.

Uncertainty at Multiple Levels

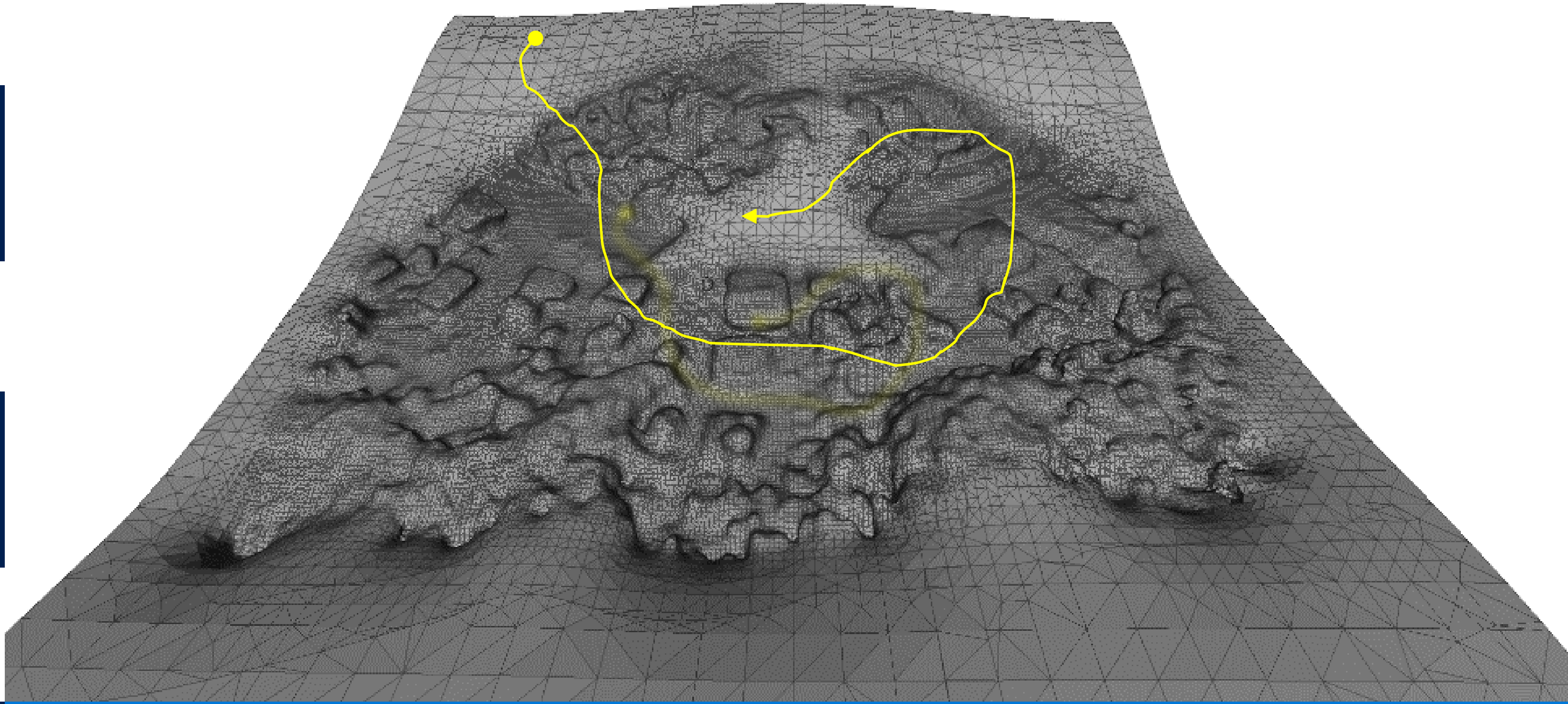
High-level Planning

Correct Control

Robust Sensing

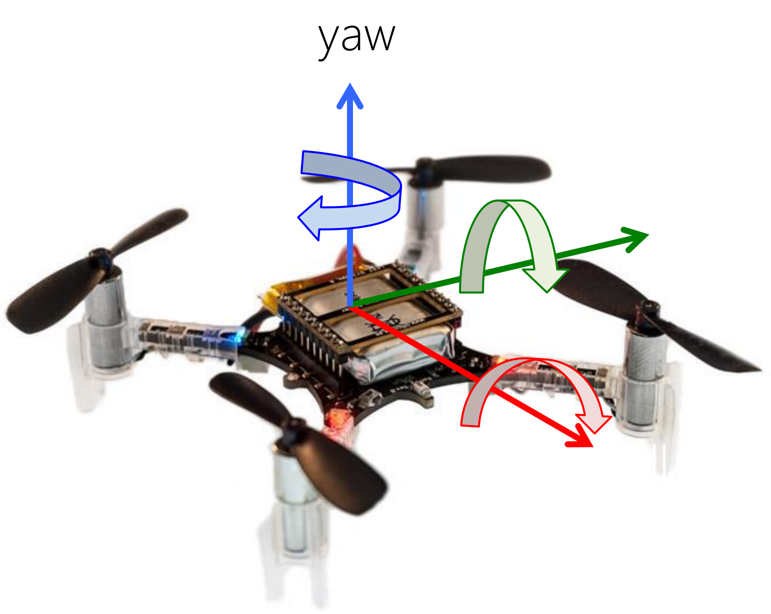
Secure OS

Safe despite limited power, external disturbances,



Sensor noise, and complex missions

System = (State + Control) || Environment



State = $\begin{matrix} [x, y, z, \psi, \phi, \rho \\ \dot{x}, \dot{y}, \dot{z}, \dot{\psi}, \dot{\phi}, \dot{\rho} \\ d_1, d_2, d_3, d_4] \end{matrix}$

(not directly observed)

Control = RPM of the motors

Limited Battery Power: Typically less than 20 minutes

Not enough computational power on board

Not very robust to changes in environment or disturbances e.g., wind, obstacles

Not very robust to changes in system properties, weight, aging of rotors, etc.

Safe Control Under Uncertainty

$$\dot{x}(t) = Ax(t) + Bu(t)$$

Optimal control: minimize cost on deviation from reference + cost on control.

$$\min_{u} \sum_{t=1}^{T} (x_t - \hat{x}_t)^\top Q (x_t - \hat{x}_t) + u_t^\top R u_t$$

Subject to: We are safe!

$$(x_1, u_1, \ldots, x_T, u_T) \models \phi$$

Security Challenges

theguardian

Skateboards, drones and your brain: everything got hacked

At Defcon in Las Vegas, hackers gather to show off the latest vulnerabilities. That's why last weekend was just full of bad news

The Washington Post

Cyber search engine Shodan exposes industrial control systems to new risks

Government and business leaders in the United States and around the world are rushing to build better defenses -- and to prepare for the coming battles in the digital universe. To succeed, they must understand one of the most complex, man-made environments on Earth: cyberspace. (Whitney Shefte, Sohail Al-Jamea and Robert O'Harrow Jr./The Washington Post)

BUSINESS INSIDER

Security will be critical to the success or failure of Internet of Things

fedscoop

FBI warns of Internet of Things risks

What could go wrong? The bureau's Internet Crime Complaint Center lays out a laundry list of horrors.

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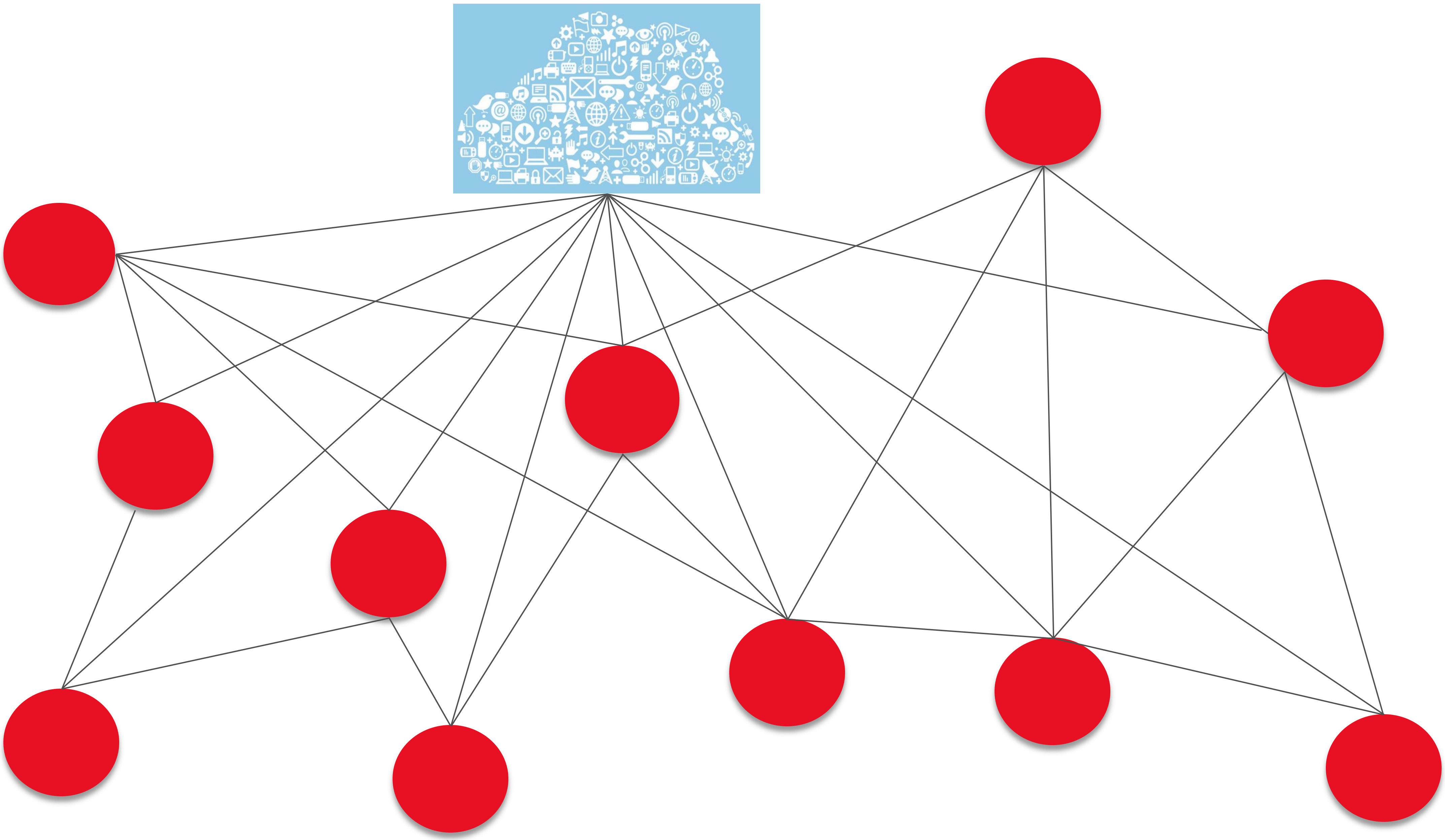
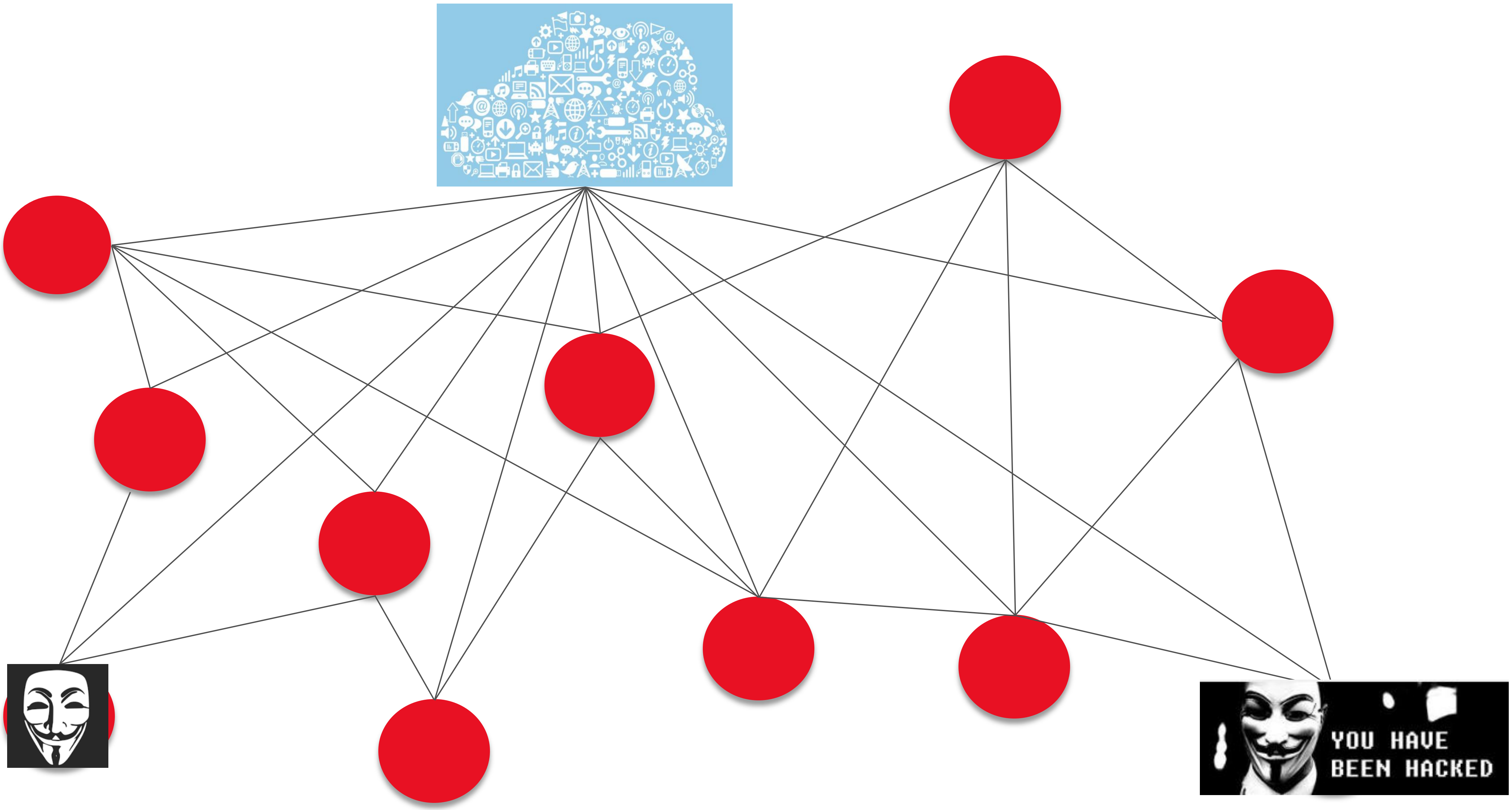



YOU HAVE
BEEN HACKED

Secure System

- Secure configuration
- Security protocols and encryption
- Secure storage
- Secure boot
- Device identity in hardware

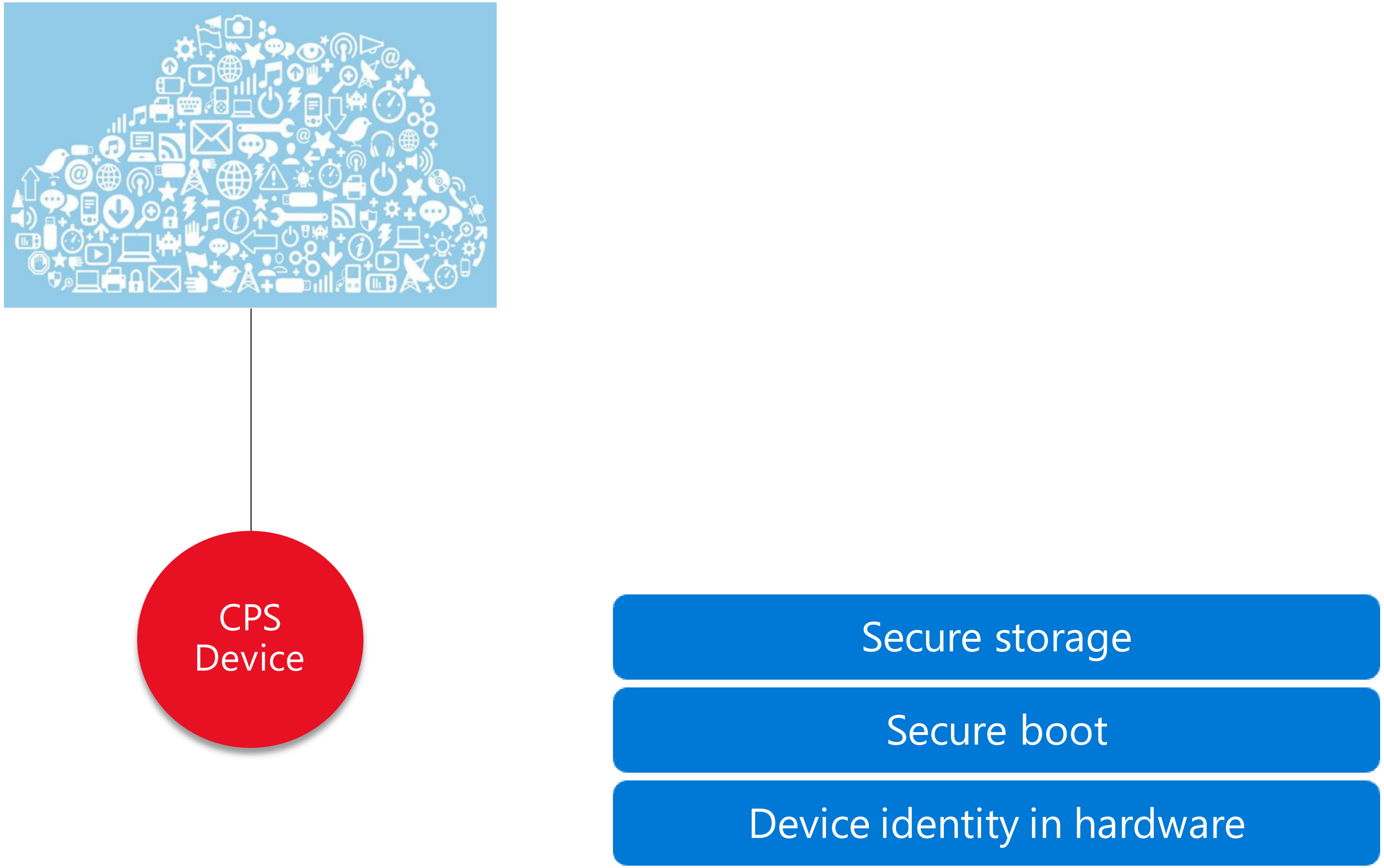
CPS
Device

Device identity in hardware

CPS Device

Secure boot

Device identity in hardware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Security protocols and encryption

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CPS Device

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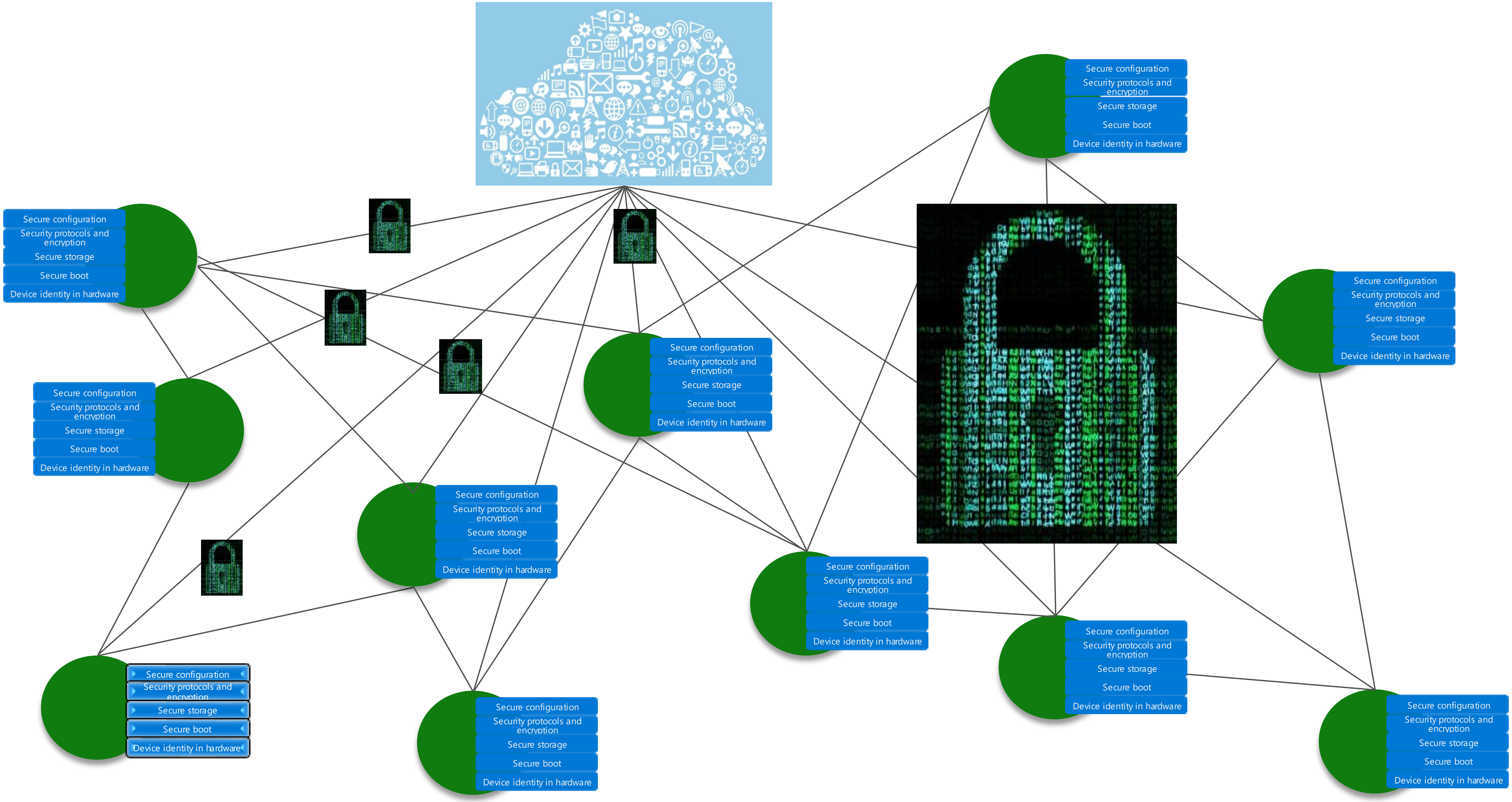
CPS Device

Built for low power and limited computing resources

- Secure configuration
- Security protocols and encryption
- Secure storage
- Secure boot
- Device identity in hardware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Privacy Challenges

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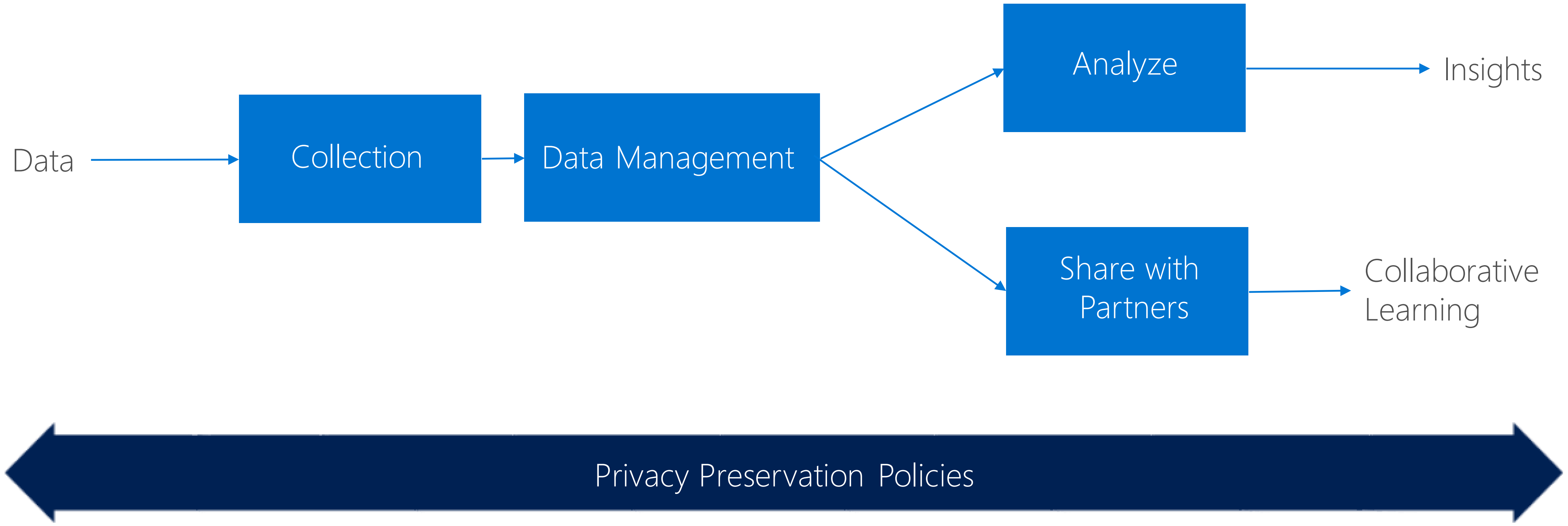
Privacy is about...

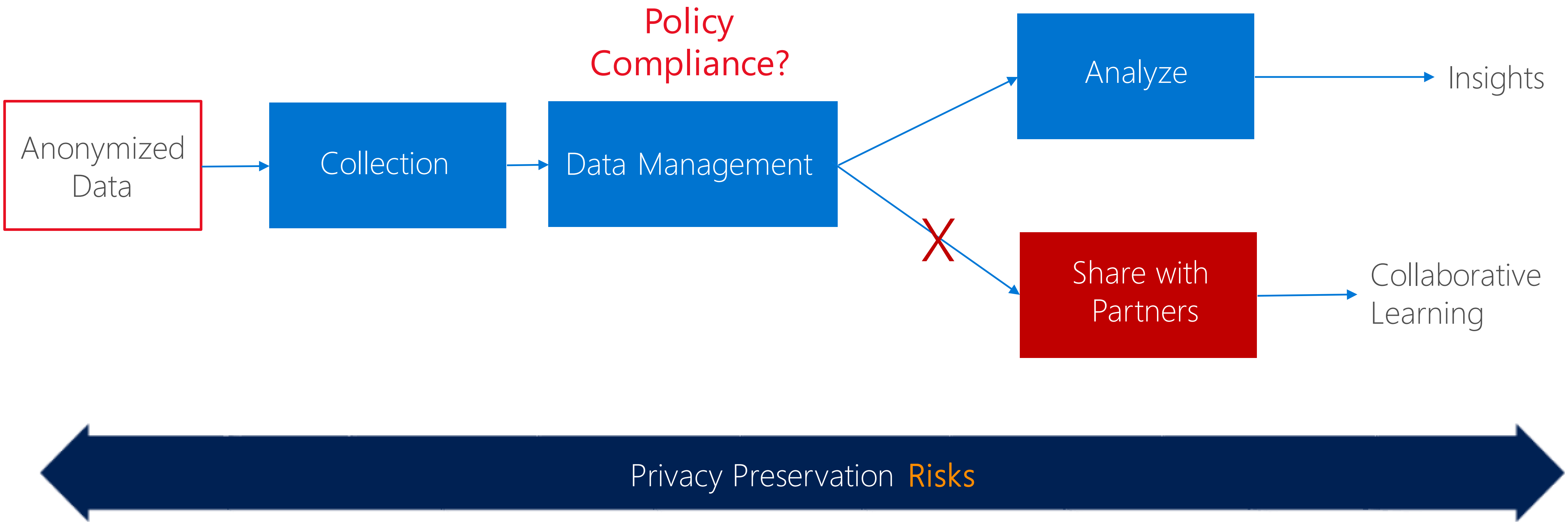
social norms, context, ethical values, company policies, legal rules, individual preferences

... the appropriate collection and processing of information about a data subject by a data holder and the flow of information between data holders.

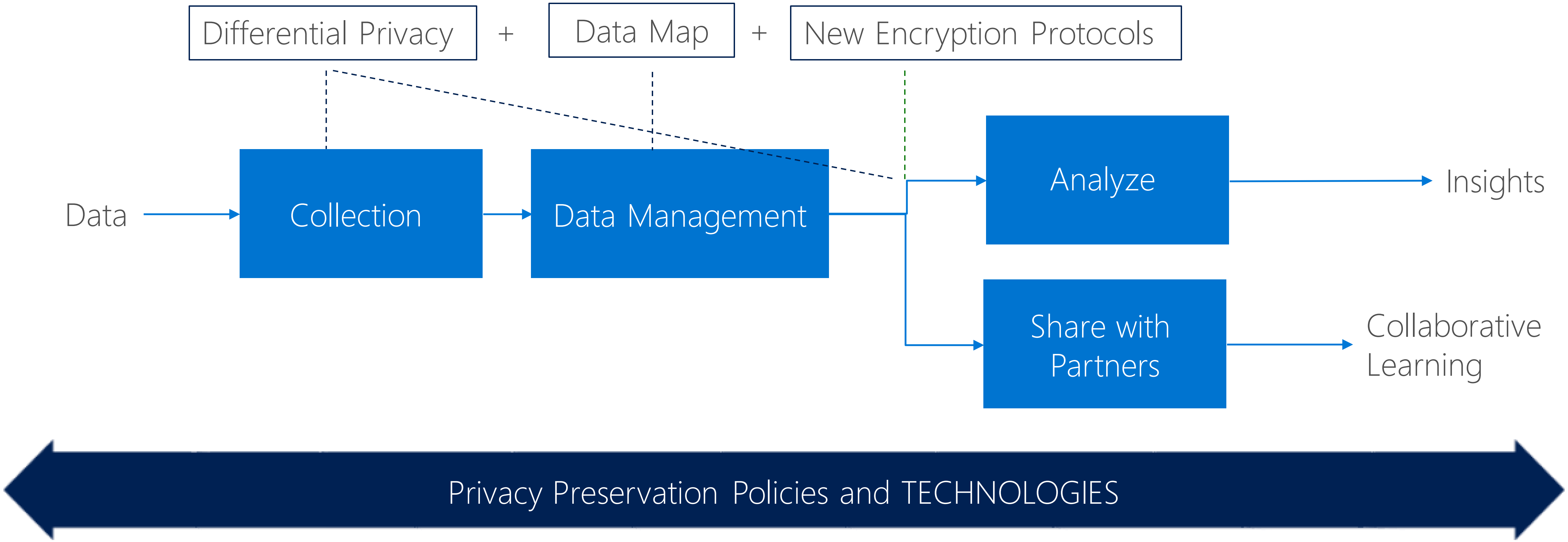
Data Lifecycle



Data Lifecycle



Data Lifecycle and Privacy Preservation



Anonymization is Insufficient

- "Anonymized" data combined across data sources can identify individuals
  - Netflix users have been re-identified based on 'anonymous' viewing habits
  - Mass. Governor Weld (and many others) were re-identifiable based on 'anonymous' medical records
  - Credit Card metadata and aggregate cell phone data have fallen to re-identification attacks.

- The President's Council of Advisors on Science and Technology 2014 Big Data report

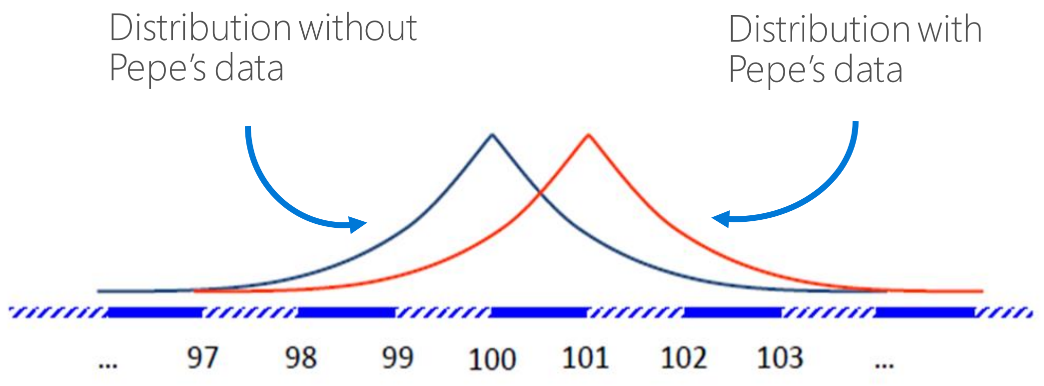
"**Anonymization** is increasingly by the very techniques that are being developed for many legitimate applications of big data. In general **easily defeated**, **as the size and diversity of available data grows**, the likelihood of being able to re-identify individuals (that is, re-associate their records with their names) grows substantially. While anonymization may remain somewhat useful as an added safeguard in some situations, approaches that deem it, by itself, a sufficient safeguard need updating".

What Differential Privacy Is

- Technique that enables learning about populations or population segments, while preserving the privacy of individuals

- With DP the same query outputs will be observed with essentially the same probabilities, even if an individual record is added or deleted from the database

- Privacy is achieved by adding noise *either* to data prior to collection or to the results of queries against pristine databases



The Privacy Compliance Challenge

Legal Team
Crafts Policy

Meetings

Privacy Champion
Interprets Policy

Meetings

Developer
Writes Code

Meetings

Audit Team
Verifies Compliance

English Privacy Policy

Specification

Scale

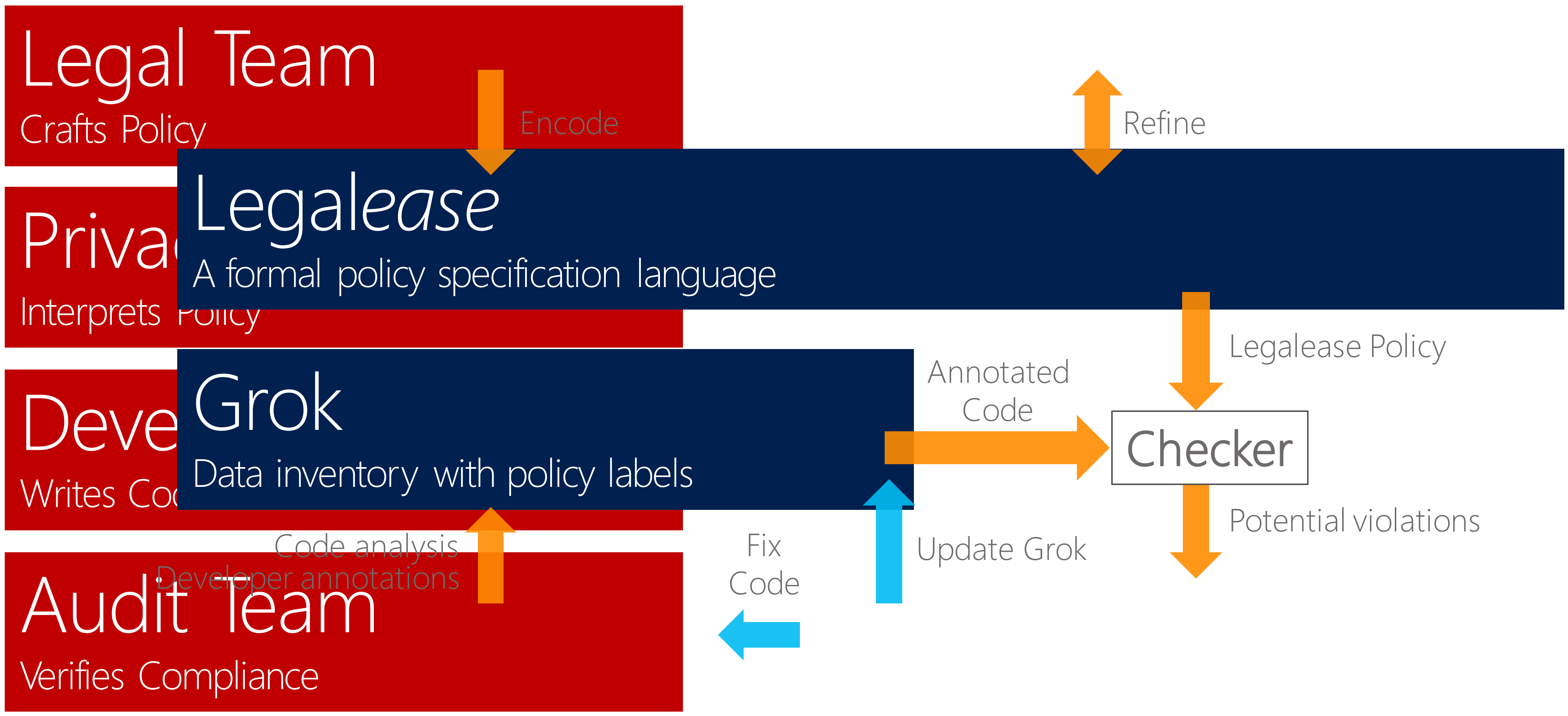
Compliance?

Millions of Lines of Code

Verification

Data Collection And Management

A Streamlined Audit Workflow



Designed for Expressibility
(Bing, October 2013)

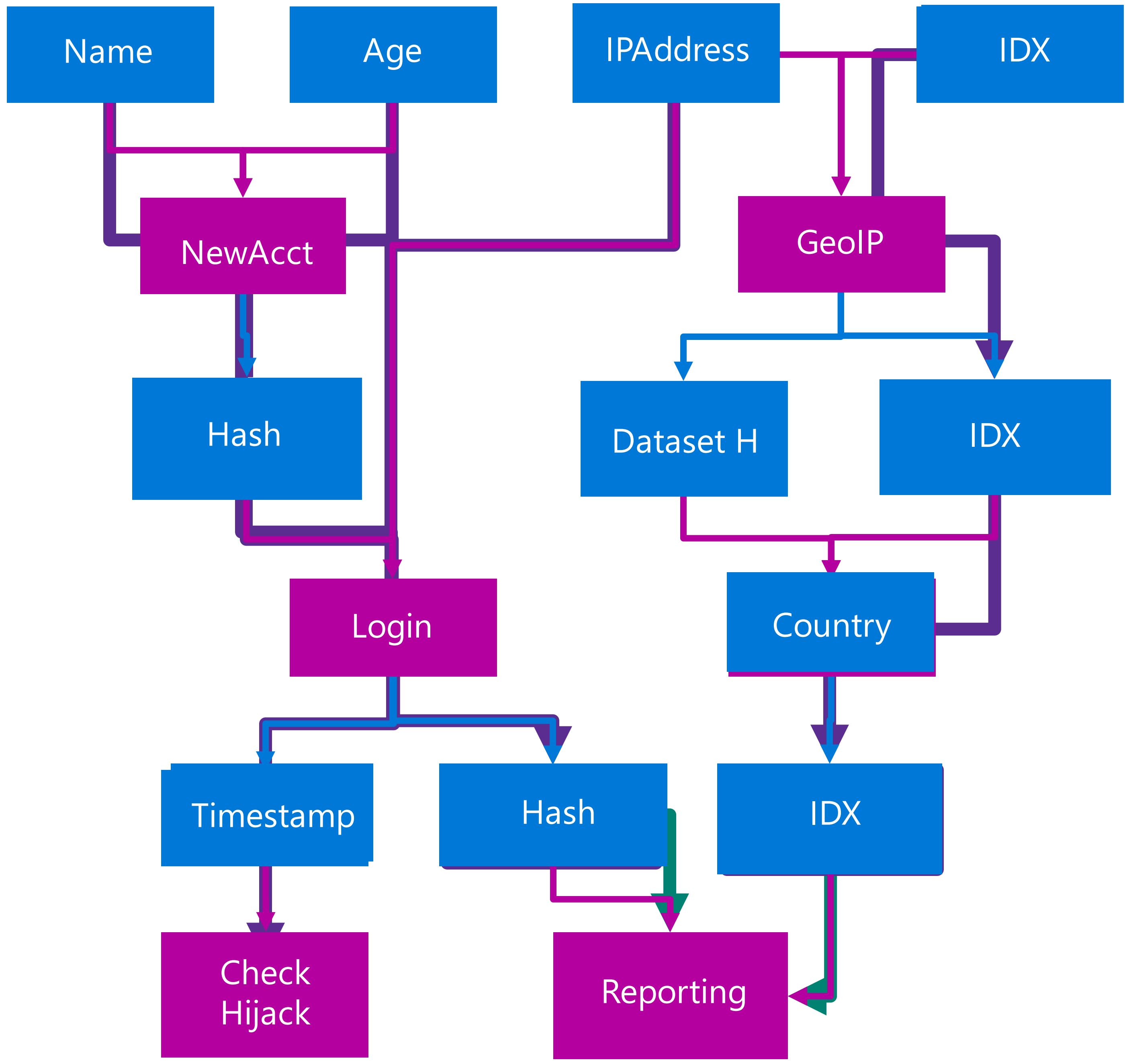
ALLOW	
EXCEPT	
DENY *DataType* IPaddress:Expired	◁ “we remove the entirety of the IP address after 6 months”
DENY *DataType* UniqueIdentifier:Expired	◁ “[we remove] cookies and other cross session identifiers, after 18 months”
DENY *DataType* SearchQuery, PII *InStore* Store DENY *DataType* UniqueIdentifier, PII *InStore* Store	◁ “We store search terms (and the cookie IDs associated with search terms) separately from any account information that directly identifies the user, such as name, e-mail address, or phone numbers.”
DENY *DataType* BBEPData *UseForPurpose* Advertising	◁ “we do not use any of the information collected through the Bing Bar Experience Improvement Program to identify, contact or target advertising to you”
DENY *DataType* BBEPData, PII *InStore* Store	◁ “we take steps to store [information collected through the Bing Bar Experience Improvement Program] separately from any account information we may have that directly identifies you, such as name, e-mail address, or phone numbers”
DENY *DataType* BBEPData:Expired	◁ “we delete the information collected through the Bing Bar Experience Program at eighteen months.”
DENY *DataType* UserProfile, PII *InStore* Store	◁ “we store page views, clicks and search terms used for ad targeting separately from contact information you may have provided or other data that directly identifies you (such as your name, e-mail address, etc.).”
DENY *DataType* PII *UseForPurpose* Advertising DENY *DataType* PII *InStore* AdStore	◁ “our advertising systems do not contain or use any information that can personally and directly identify you (such as your name, email address and phone number).”
DENY *DataType* SearchQuery *UseForPurpose* Sharing EXCEPT ALLOW *DataType* SearchQuery:Scrubbed	◁ “Before we [share some search query data], we remove all unique identifiers such as IP addresses and cookie IDs from the data.”

Grok

Data Inventory

Annotate code + data with policy data types

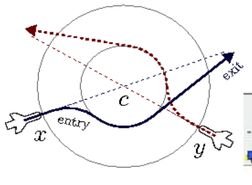
Source labels propagated via data flow graph



D. E. Denning. "A lattice model of secure information flow"

How can we build cyber-physical systems that people can bet their lives on?

Reliability



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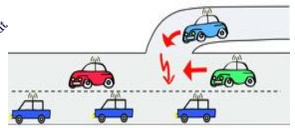
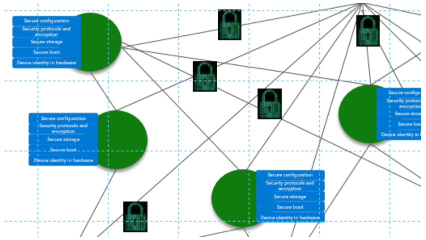


Security



Privacy

Thank you!

Microsoft