The RFID Story

Sanjay Sarma

Dean of Digital Learning, Professor of Mechanical Engineering

Computer Science and Artificial Intelligence Laboratory (CSAIL)
Massachusetts Institute of Technology

CLASSIFYING SENSORS

By what you measure (measurand):

- Acoustic signal strength, or chemical concentration, or optical signal, or magnetic strength

By how you measure directly:

- Mechanical displacement or voltage or chemical reaction

By transduction for indirect measurement:

- Thermoeletric or photoelectric or photoelastic

By higher level function:

- Sensing ID or human gesture or explosive material

SENSOR MODALITIES

Static time-series: temperature, say

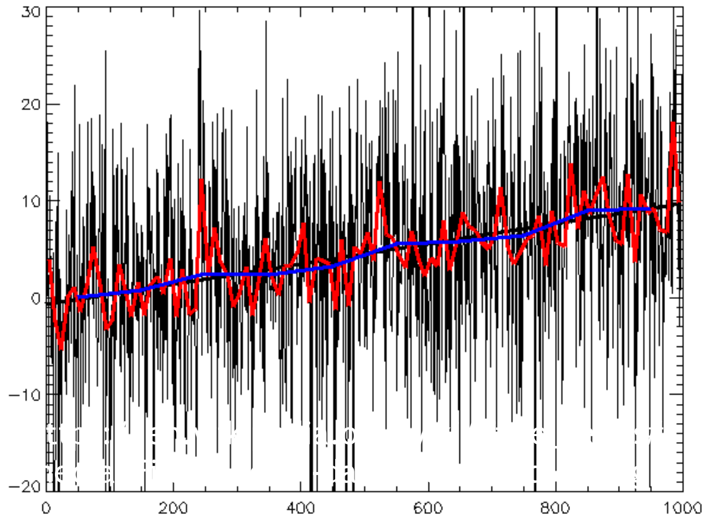
2D arrays: Imaging in EO or IR, say

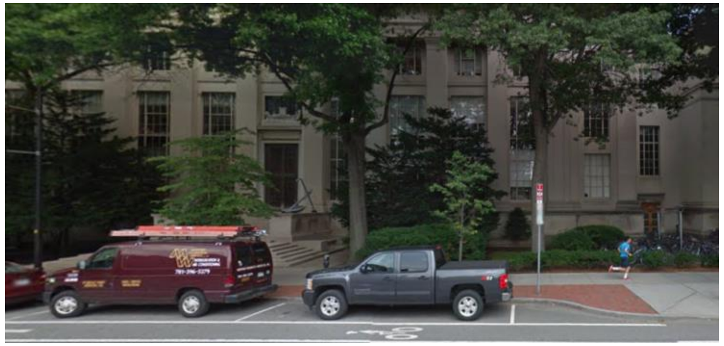
3D sensing: Kinect, or radar

Mobile sensors: Your phone

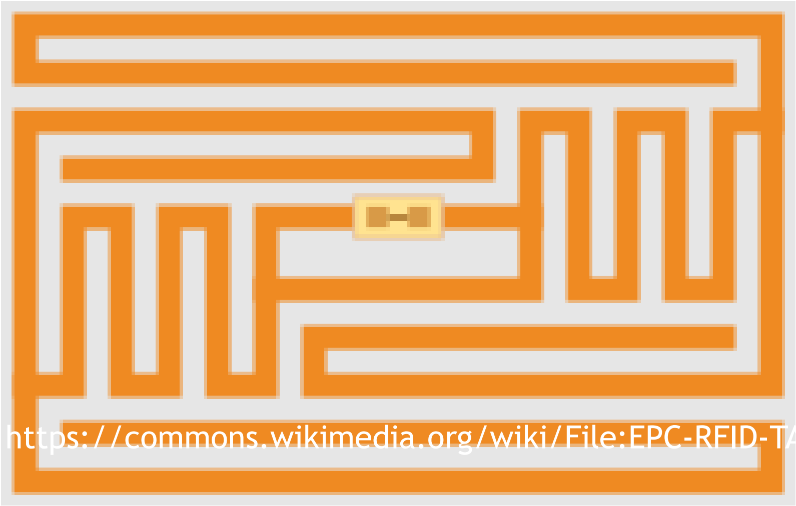
Scanning sensors: Google Street View

Fiducial sensing: Homing beacons, say





THE RFID Story



A RF-based sensing of fiducial ID RFID tags, with static or mobile application, usually a time-series Of a membership set.

TIMELINE

1948: Backscatter

Stockman, H. "Communication by Means of Reflected Power", Proceedings of the IRE, pp1196-1204, October 1948.

1974: Automotive license plates

Sterzer, F., "An electronic license plate for motor vehicles", RCA Review, 1974, 35, (2) pp 167-175

1998: DISC, Auto-ID Center founded at MIT (Sarma, Brock, Ashton)

2001: First standards presented

2002: Gillette orders 500,000,000 tags from Alien

2003: Wal-Mart, DoD Mandates

EPCglobal launched, Center retired

2004: More mandates

2005: First bulk tagging

Emergence of Gen 2

2010: Wal-Mart tag all men's innerwear, socks, all stores

2013: 4.1 billion EPC tags

THE HYPOTHESIS

Place unique number on tag

- Electronic Product Code, EPC
- Low-cost protocol

01. 203D2A. 916E8B. 8719BAE03C

Header 8 bits

Serial Number 40 bits

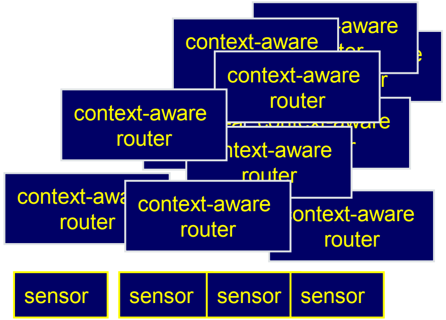
Product 24 bits

Manufacturer 24 bits

Develop manufacturing technology for small chips and tags

Move data on the network

- Network service for resolving EPC
- Network architecture for gathering and routing data



MARKET GROWTH

4-5 billion Gen 2 RFID tags in 2014

Growth expected:

- Healthcare expected ~$5B by 2022 (Grand View Research)
- Total market expected ~$15B by 2022

My prediction:

- 30% will be tags, commoditized
- 30% will be readers
- Rest will be software, services and solutions

RFID APPLICATIONS

Retail:

Store front (items)

Backroom

Supply chain

Supply Chain

Pallets

Cases

Containers

Cages and totes

Medical:

- Staff
- Patients
- Equipment
- Pharma

Transportation:

- Baggage handling
- Vehicle/tolls

Other:

- Agriculture
- Livestock
- Construction
- Passports
- Posts
- Archiving
- Books
- Tickets
- …

CROSSING THE CHASM

RFID did not take off until several things happened:

- Identification of the ideal market: apparel
- 2008 crash helped because inventory became readioactive


Welcome, Guest | Sign In | Register

RIS RETAIL INFO SYSTEMS NEWS

CONTACT US SUBSCRIBE

HEADLINES BLOG RESEARCH REPORTS EVENTS

Add To Favorite Email | Print | Text Size + –

Macy's Expands RFID Adoption to 850 Stores

— September 29, 2011

Macy's announced its Macy's and Bloomingdale's stores are adopting radio frequency identification (RFID) technology on an accelerated timeline to more precisely manage item-level merchandise inventories. By the third quarter of 2012, the company expects to begin using RFID in all of its 850 Macy's and Bloomingdale's stores nationwide to count items regularly stocked and automatically resupplied as they are sold to customers, representing about 30% of the company's sales. Macy's has been testing RFID technology for nearly two years in selected stores and distribution centers.

"To Macy's and Bloomingdale's, RFID is a tool to better serve customers and drive sales by ensuring we have the right product in the right place at the right time for our in-store and omni-channel shoppers," says Tom Cole, chief administrative officer of Macy's. "RFID will allow us to more frequently count item-level inventory with precision so our inventory is readily accessible to our customers. This is technology that has proven effective in our testing, and we believe now is the right time to roll out RFID aggressively."

With RFID, Macy's and Bloomingdale's store associates can count inventory significantly faster. This will enable multiple counts throughout the year compared with the … ng has shown t… r better. Frequer… ght range of sizes, c…

The initial … technology will … -intensive replenishment categories such as men's furnishings, intimate apparel, men's slacks, denim and women's shoes in each store nationwide. Macy's and Bloomingdale's private brands are included in the initiative.

For related content: **The Magic is Back in RFID**

Bloomingdale's Uses RFID to Increase Inventory Accuracy to 96%

http://risnews.edgl.com/retail-news/Macy-s-Expands-RFID-Adoption-to-850-Stores75872

https://en.wikipedia.org/wiki/File:Chossing-the-chasm-cover.jpg

STANDARDS

Before the Auto-ID center, RFID was a mess of standards.

Working with over 100 companies, we defined a new class of standards under the EPC banner.

2001: The Class 0 and Class 1 standards

2004: The EPC Gen 2 UHF standard 2004

Later became an ISO standard: 18000-6c

EPCglobal (disclosure, I was chair of the board) also release standards for readers and for data sharing

Published June 1, 2003. Early Release July, 2003

AUTO-ID CENTER

TECHNICAL REPORT

On the Future of RFID Tags and Protocols

Sanjay Sarma, Daniel W. Engels

AUTO-ID CENTER MASSACHUSETTS INSTITUTE OF TECHNOLOGY, 400 TECHNOLOGY SQ, BUILDING NE46, 6TH FLOOR, CAMBRIDGE, MA 02139-4307, USA

ABSTRACT

We present a roadmap for the future of RFID protocols. We cover two dimensions: added functionality and new versions. We show that functionality can be added to RFID tags without compromising modularity. We also show that new versions of tags can evolve and co-exist with older versions without interference. A software defined radio reader can make the investments of end-users future-proof and insulate end-users from the gradual evolution of technology. This will enable the Auto-ID community to keeps its system and standards abreast of the state-of-the-art.

SOME PUBLICATIONS

Engels, Daniel W., and Sanjay E. Sarma. "**The reader collision problem.**" In *Systems, Man and Cybernetics, 2002 IEEE International Conference on*, vol. 3, pp. 6-pp. IEEE, 2002.

Waldrop, James, Daniel W. Engels, and Sanjay E. Sarma. "**Colorwave: A MAC for RFID reader networks.**" In *Wireless Communications and Networking, 2003. WCNC 2003. 2003 IEEE*, vol. 3, pp. 1701-1704. IEEE, 2003.

Chawathe, Sudarshan S., Venkat Krishnamurthy, Sridhar Ramachandran, and Sanjay Sarma. "**Managing RFID data**." In *Proceedings of the Thirtieth international conference on Very large data bases-Volume 30*, pp. 1189-1195. VLDB Endowment, 2004.

Weis, Stephen A., Sanjay E. Sarma, Ronald L. Rivest, and Daniel W. Engels. "**Security and privacy aspects of low-cost radio frequency identification systems**." In *Security in pervasive computing*, pp. 201-212. Springer Berlin Heidelberg, 2004.

Floerkemeier, Christian, and Sanjay Sarma. "**RFIDSim—a physical and logical layer simulation engine for passive RFID**." *Automation Science and Engineering, IEEE Transactions on* 6, no. 1 (2009): 33-43.

THANK YOU!

Sanjay Sarma

Dean of Digital Learning, Professor of Mechanical Engineering

Computer Science and Artificial Intelligence Laboratory (CSAIL)
Massachusetts Institute of Technology

MODULE | Architectures

PROFESSIONAL EDUCATION

CSAIL
MIT COMPUTER SCIENCE AND ARTIFICIAL INTELLIGENCE LABORATORY

Importance of Architectures

Sanjay Sarma

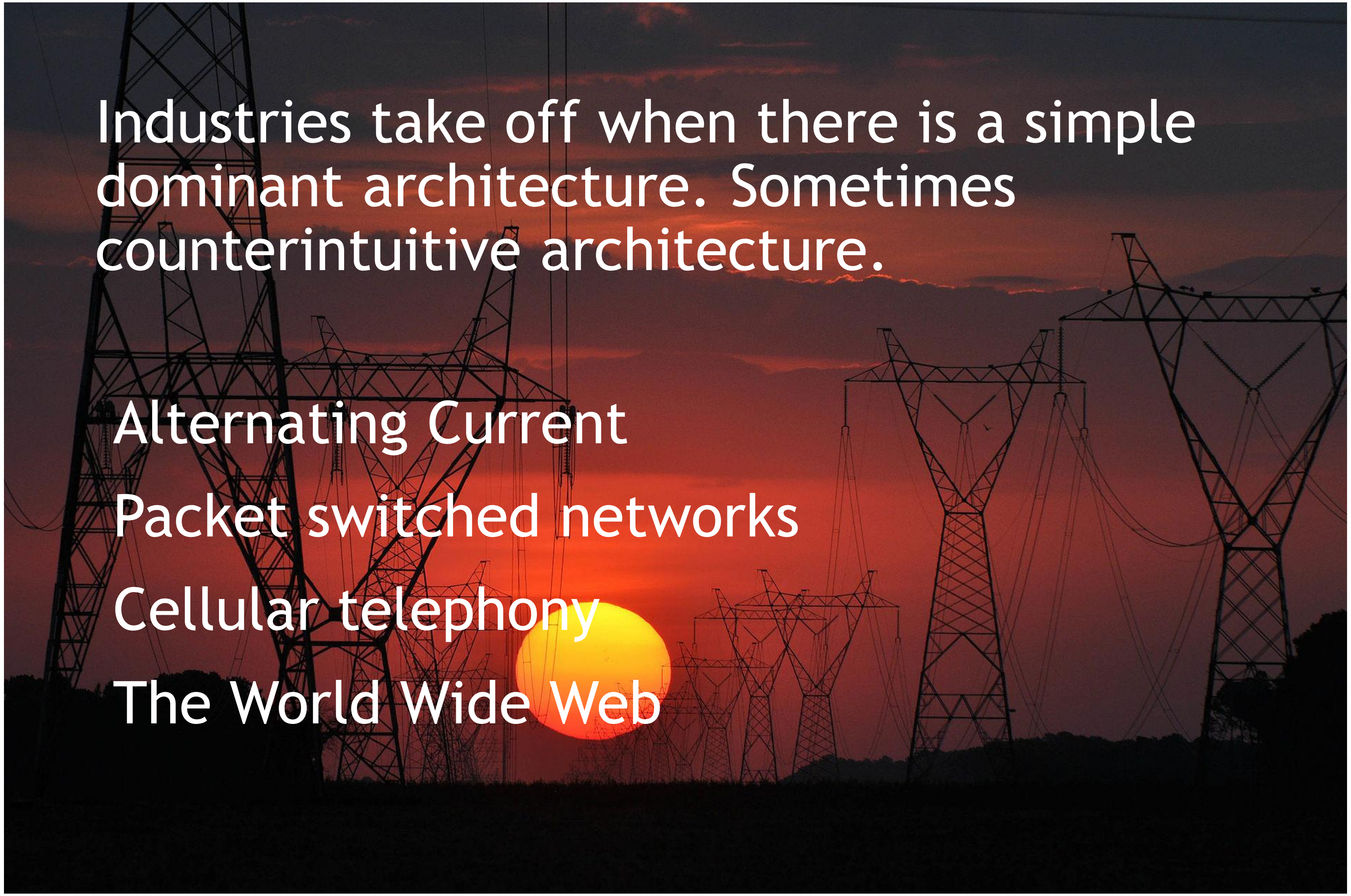
Dean of Digital Learning, Professor of Mechanical Engineering

Computer Science and Artificial Intelligence Laboratory (CSAIL)
Massachusetts Institute of Technology

PROFESSIONAL EDUCATION

CSAIL

MIT COMPUTER SCIENCE AND ARTIFICIAL INTELLIGENCE LABORATORY



"Evoluir para conectar" by Heris Luiz Cordeiro Rocha - Own work. Licensed under CC BY-SA 3.0 via Wikimedia Commons - https://commons.wikimedia.org/wiki/File:Evoluir_para_conectar.jpg#/media/File:Evoluir_para_conectar.jpg

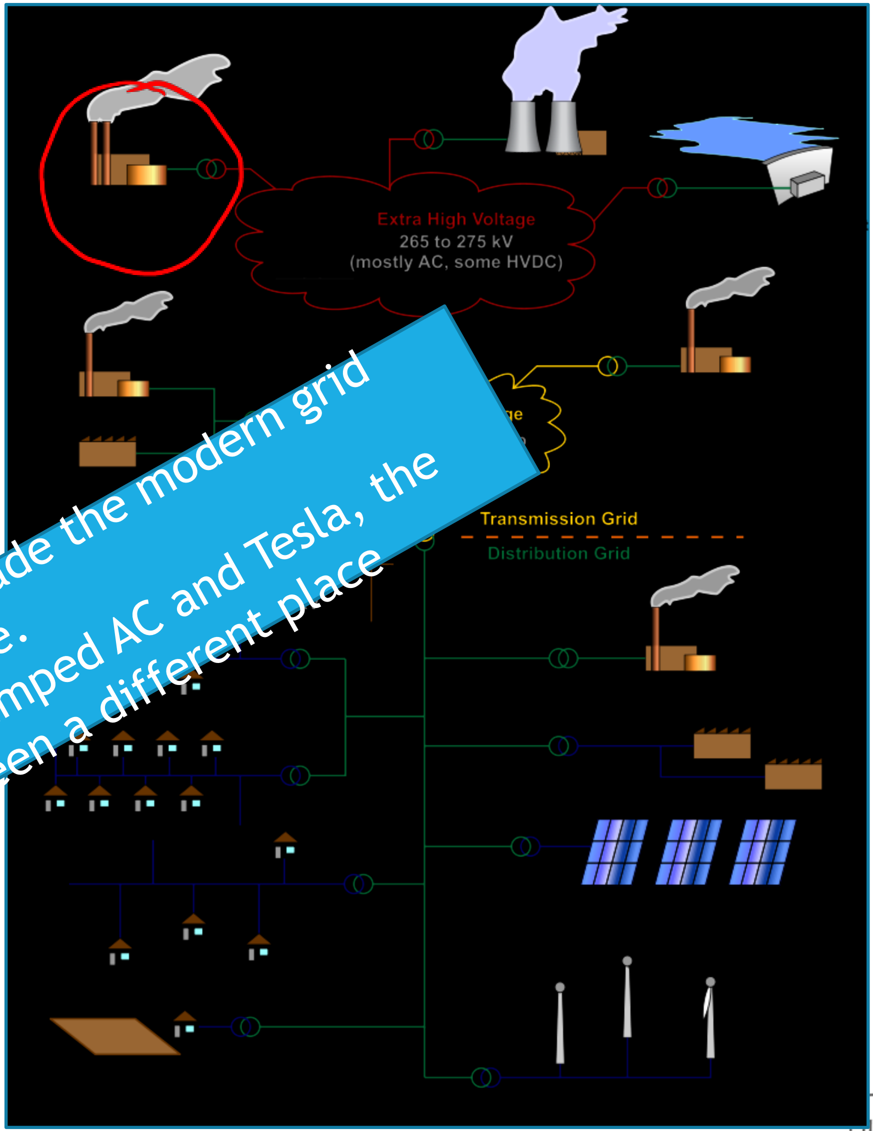
CONSIDER POWER GRIDS

AC was not intuitive but:

- It enables step-up and and step-down transformation
- So long-distance transmission
- And rotati ery

The choice of AC over DC made the modern grid possible.

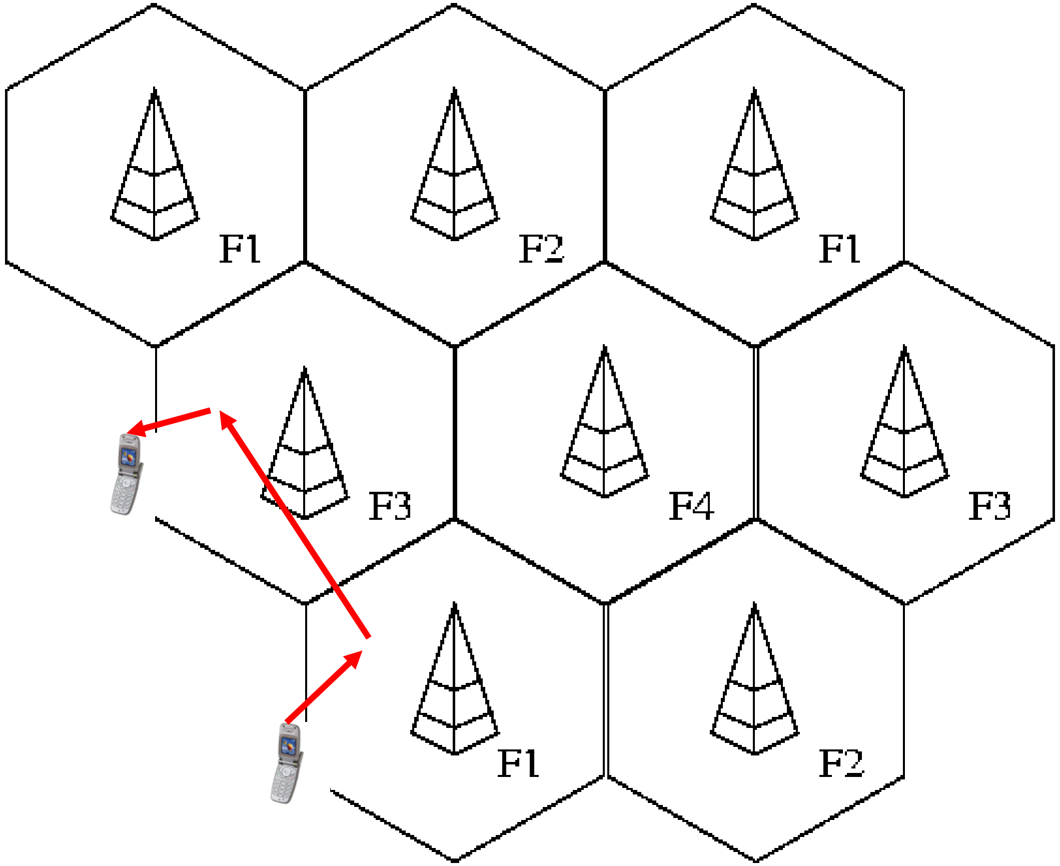
IF DC, and Edison, had trumped AC and Tesla, the world would have been a different place



"Electricity Grid Schematic English" by MBizon - Own work Originally derived from de:Datei:Stromversorgung.png. Licensed under CC BY 3.0 via Commons - https://commons.wikimedia.org/wiki/File:Electricity_Grid_Schematic_English.svg#/media/File:Electricity_Grid_Schematic_English.svg

CELLULAR TELEPHONY

https://commons.wikimedia.org/wiki/File:Wikipedia_images_011.jpg



https://commons.wikimedia.org/wiki/File%3AFrequency_reuse.png

GOOD ARCHITECTURES

Offer a simple design metaphor

Standardized interfaces for reuse and reconfiguration

A level of abstraction and modularity

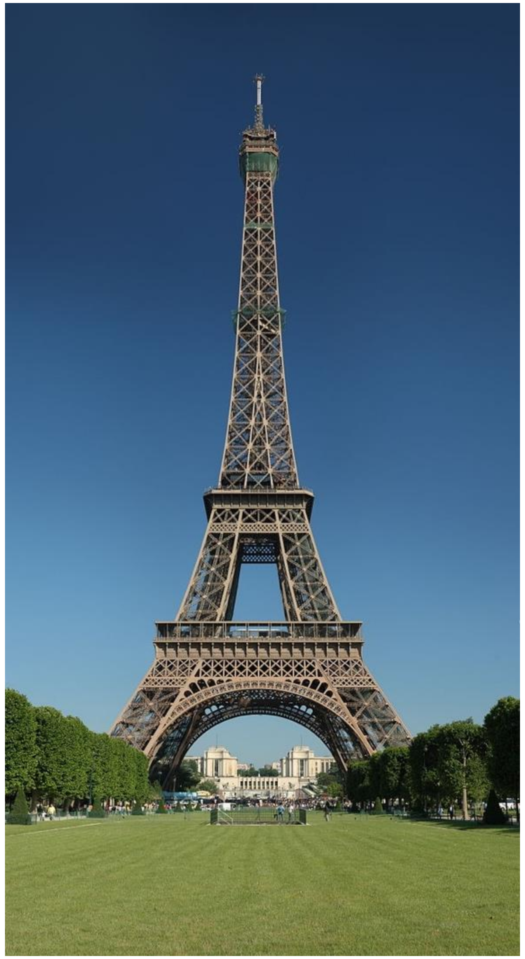
Prevent cascading failure

Enable repair and maintenance

Are often hourglass

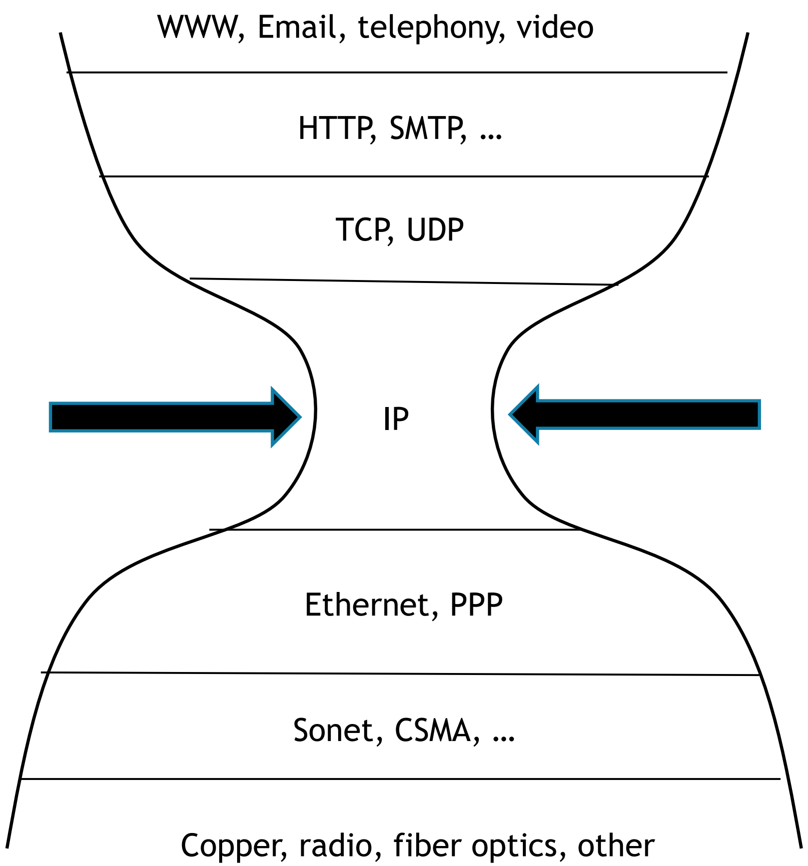
Simpler to secure

Good architectures are often counterintuitive

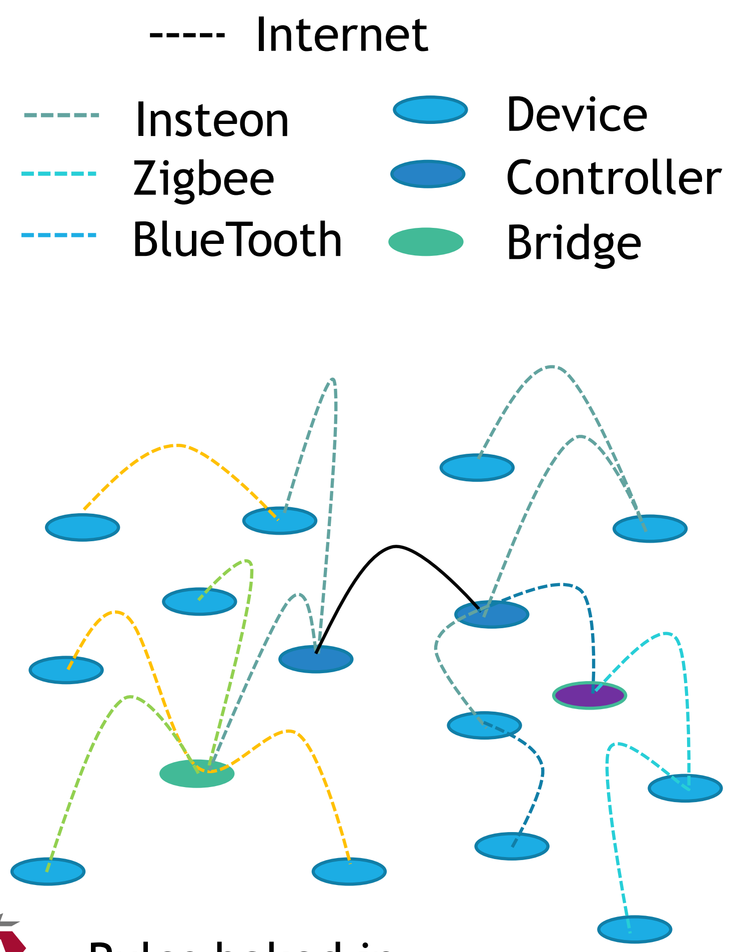


By Benh LIEU SONG (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons

HOURGLASS ARCHITECTURE
HOW THE INTERNET WAS TAMED



COBWEB OF THINGS



Rules baked in

Implemented in layers

Several protocols

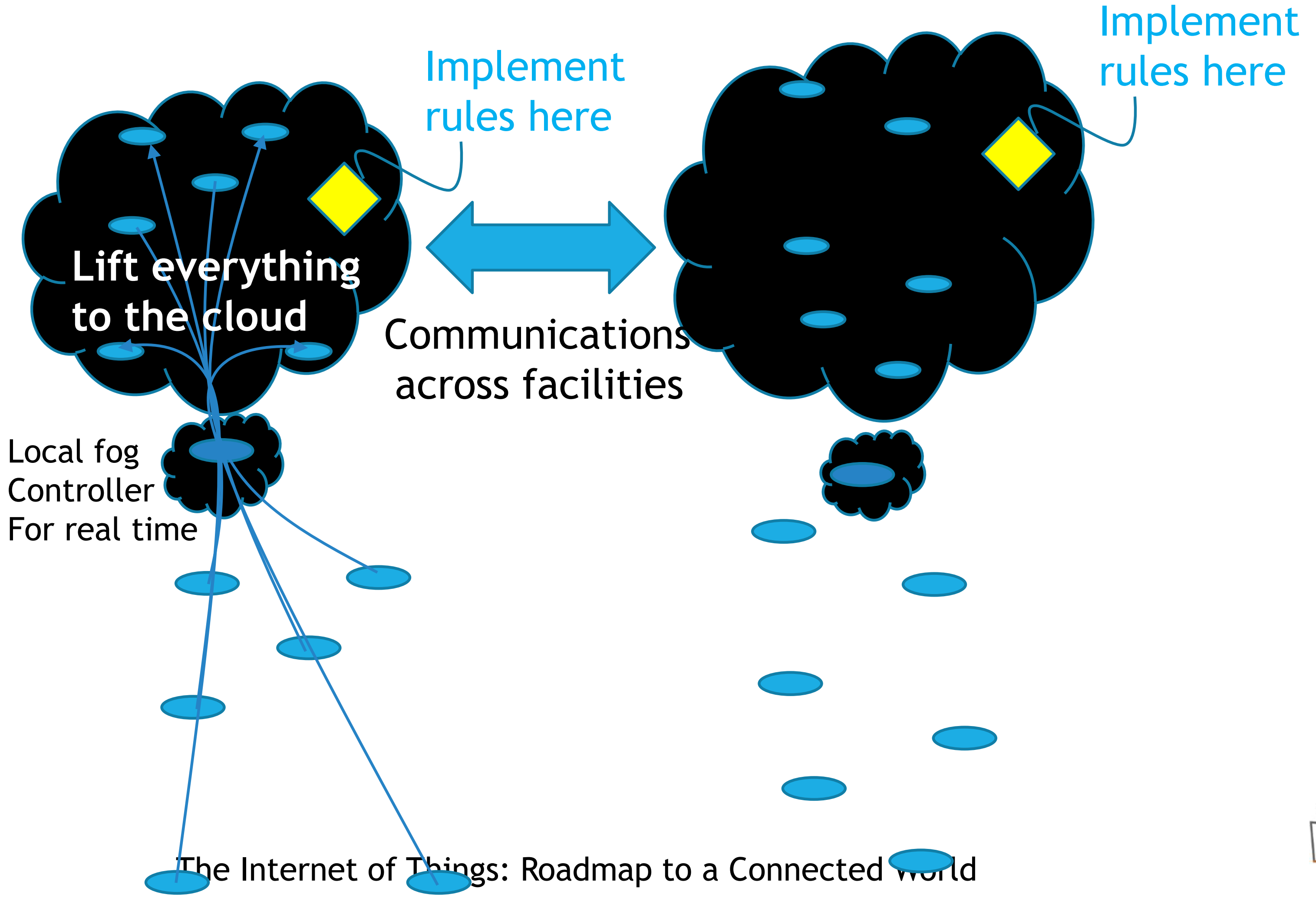
Different bridges, controllers patching system

Security?

Maintainability?

Rules baked in instead of changeable

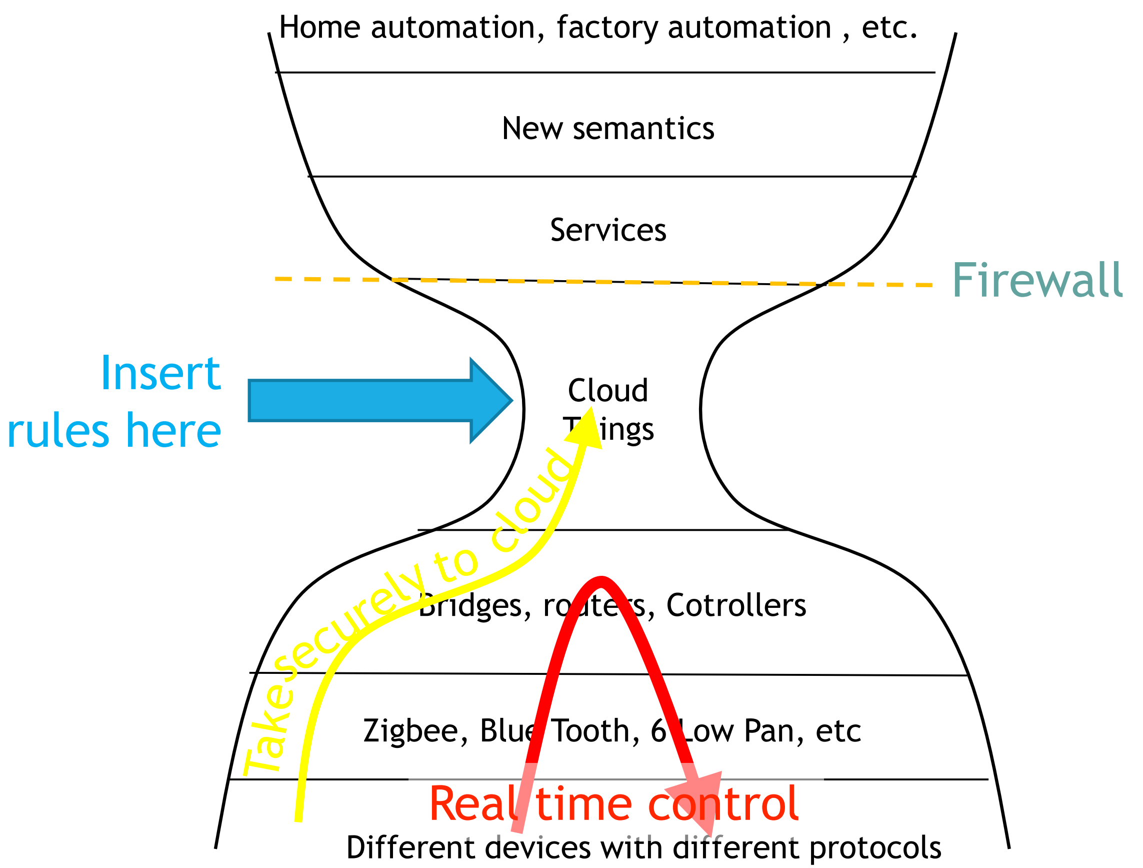
CLOUDY WITH A CHANCE FOR THINGS



MIT PROFESSIONAL EDUCATION

CSAIL
MIT COMPUTER SCIENCE AND ARTIFICIAL INTELLIGENCE LABORATORY

CLOUD THINGS



CONCLUSION: ARCHITECTURES

If we plan to connect $50 billion things to the Internet

We better be very organized

The anthropomorphic framework is a good organizational principle
(sort of like object-oriented programming)

Otherwise we will spend much time undoing what we have done, and suffering security breaches

THANK YOU!

Sanjay Sarma

Dean of Digital Learning, Professor of Mechanical Engineering

Computer Science and Artificial Intelligence Laboratory (CSAIL)
Massachusetts Institute of Technology

Examples of my work

Sanjay Sarma

Dean of Digital Learning, Professor of Mechanical Engineering

Computer Science and Artificial Intelligence Laboratory (CSAIL)
Massachusetts Institute of Technology

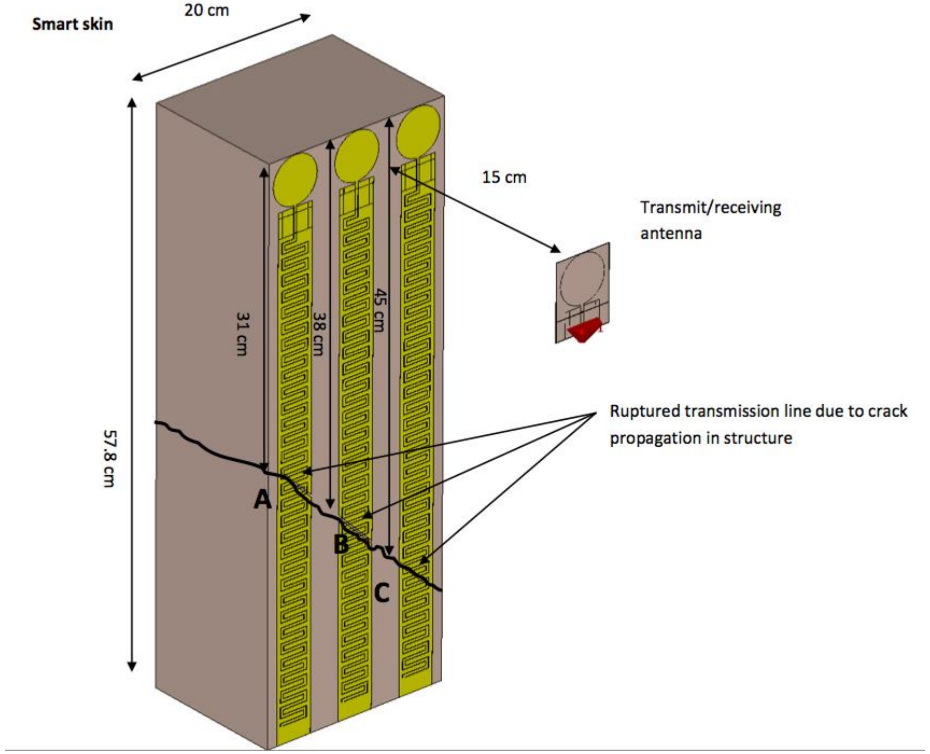
RFID

Without realizing it, RFID complied with many design principles:

1. We used the cloud (put data on the Internet)
2. We used an hourglass architecture
   - Perhaps too hourglass
   - Reader standard, event standard, EPCIS
3. We standardized all the interfaces
   - Gen 2, EPC, etc.
4. But: We were not very good at creating a good design metaphor

SENSORS

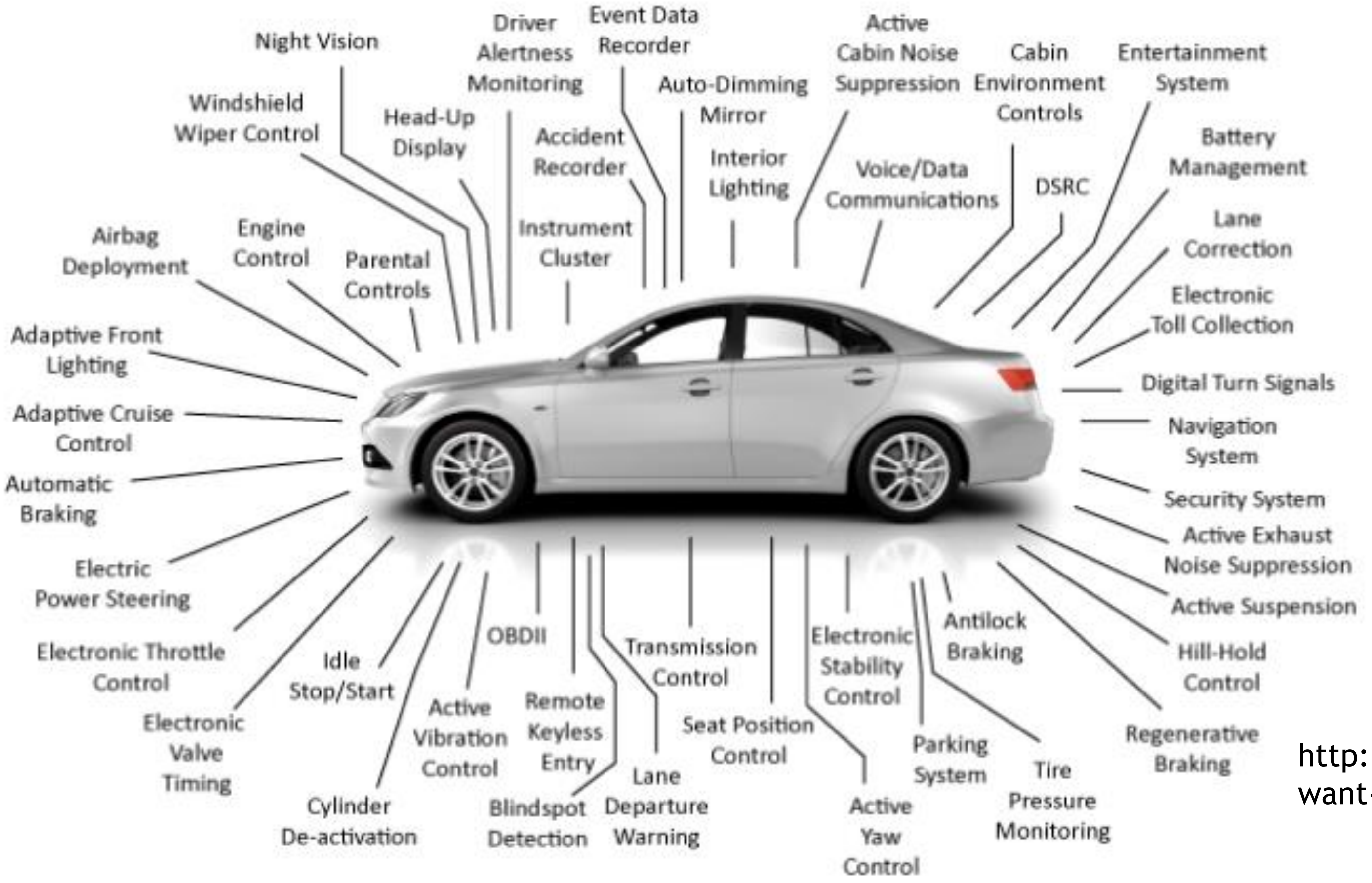
Structural crack detection



Soil Moisture Sensing

Infrared scanning

Case Study: Connected Car

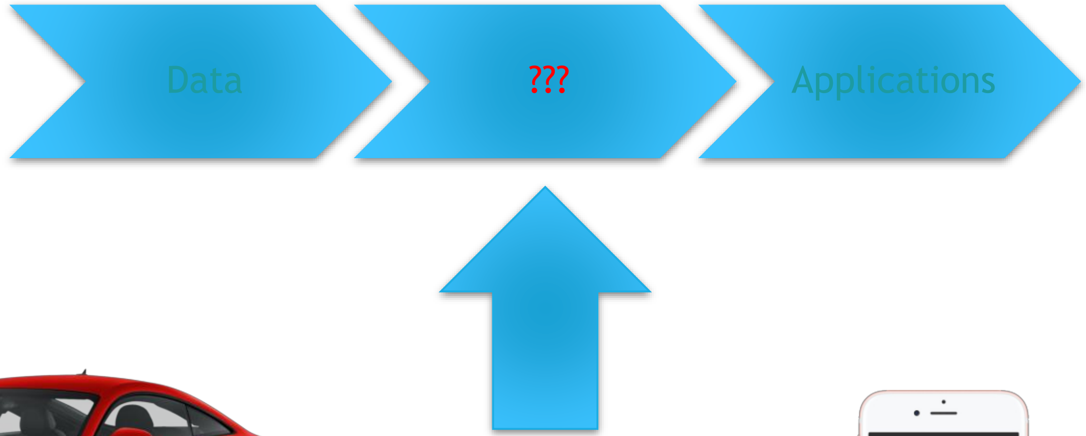


http://qz.com/327326/advertisers-want-to-get-in-your-car/

These are the sensors in a car: they are all ripe for IoT

PROBLEM: GETTING DATA OUT OF VEHICLES IS DIFFICULT

OEMS PROTECT AND SILO INFORMATION, MAKING IT NEAR IMPOSSIBLE TO ACCESS.

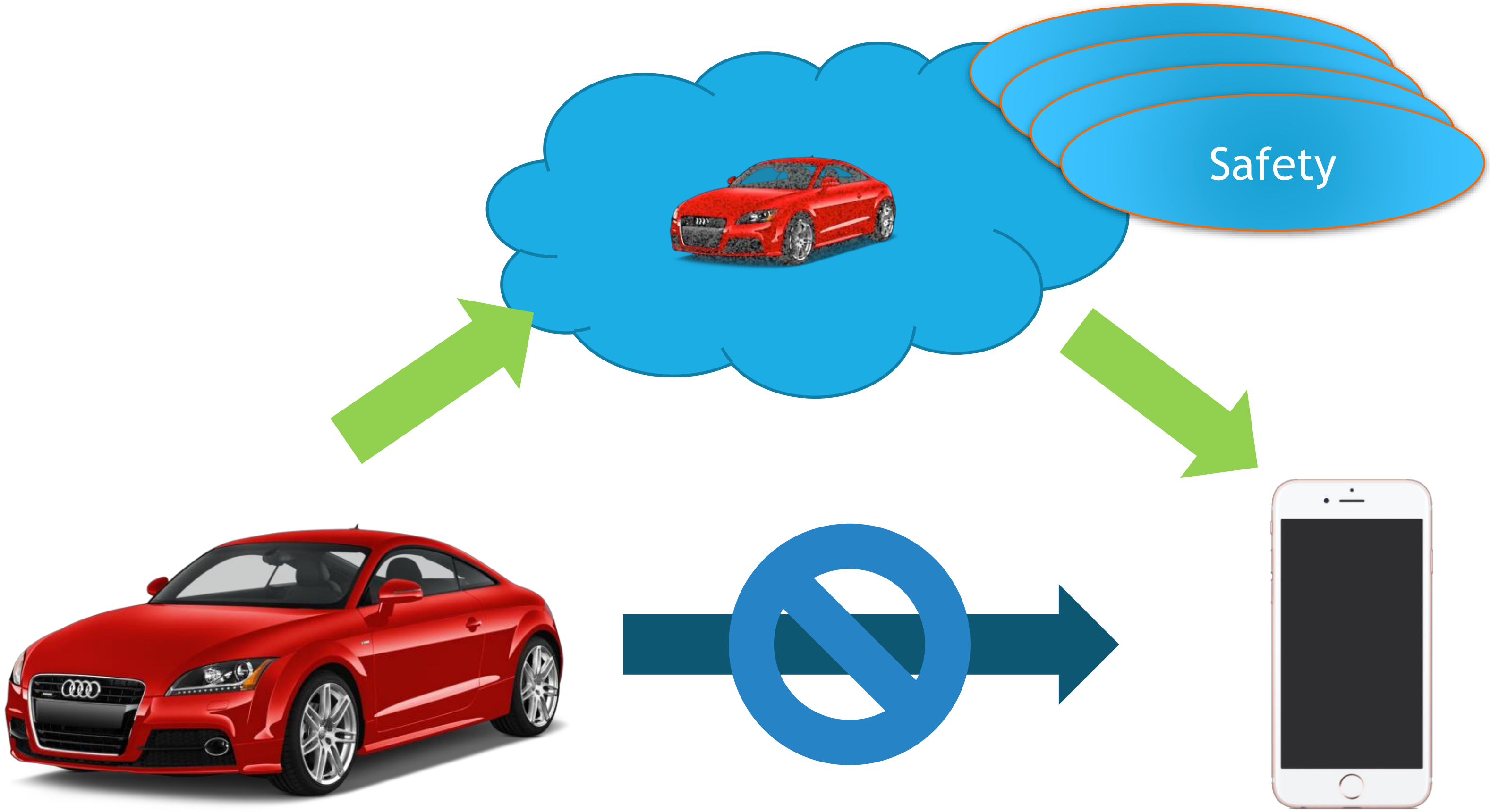


Opportunity

https://scratch.mit.edu/projects/64609742/

https://commons.wikimedia.org/wiki/File:IPhone_6S_Rose_Gold.png

CLOUDCAR STRUCTURE



https://scratch.mit.edu/projects/64609742/

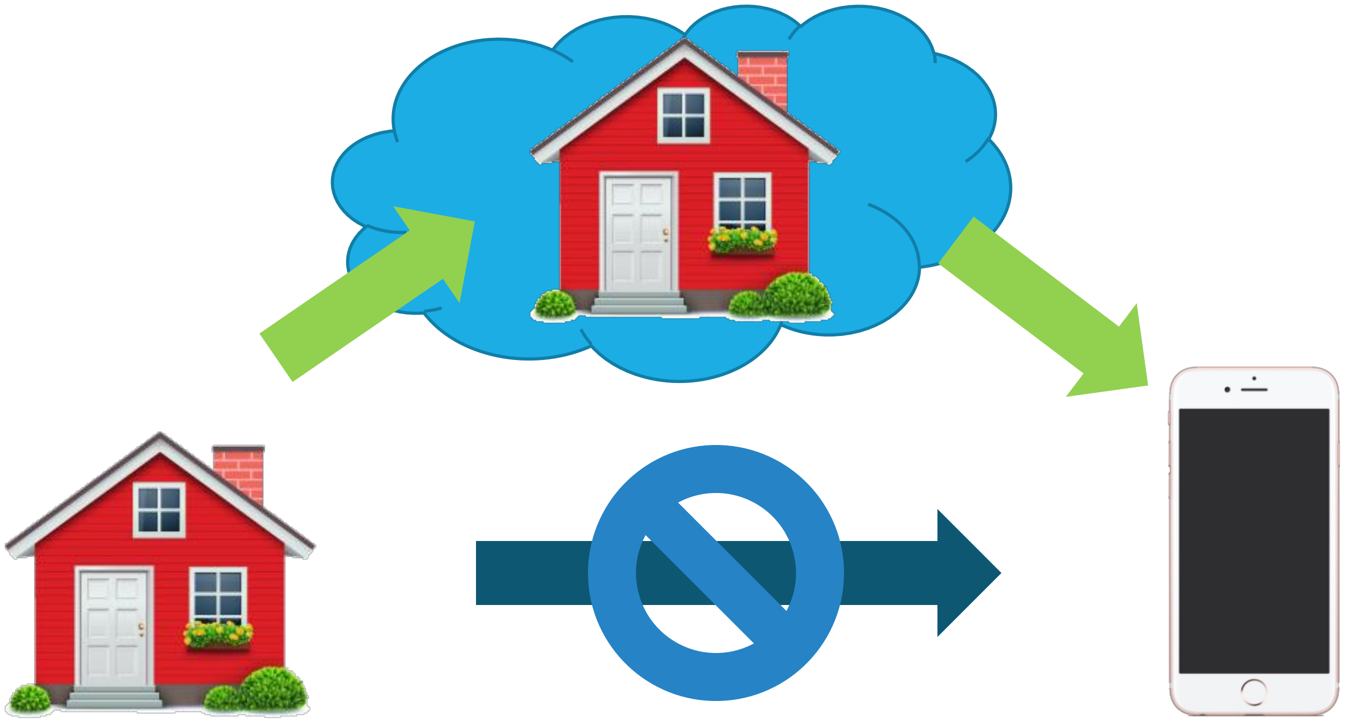
commons.wikimedia.org/wiki/File:IPhone_6S_Rose_Gold.png

CloudCar is Machine-Cloud-Machine (MCM) not M2M

Web Apps on the cloud

A few surmountable disadvantages (e.g. real-time, etc.)

CLOUDHOME STRUCTURE



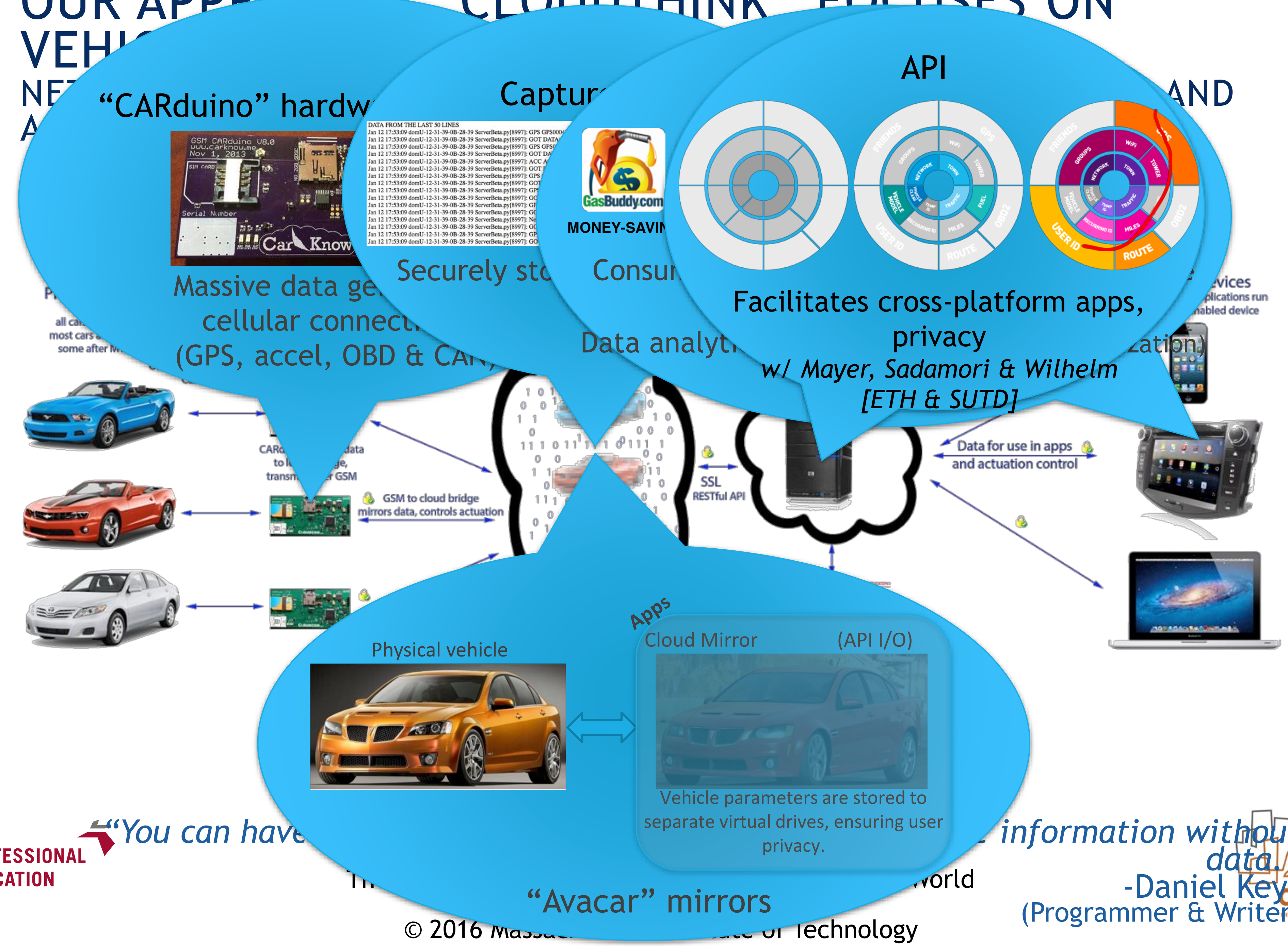
https://commons.wikimedia.org/wiki/File:IPhone_6S_Rose_Gold.png

CloudHome is also MCM

My CloudCar will drive into my CloudHome

My CloudPerson will go from my CloudCar to my CloudHome

OUR APPROACH "CLOUDTHINK" FOCUSES ON VEHI… NE… AND A…



"You can have … information without data."

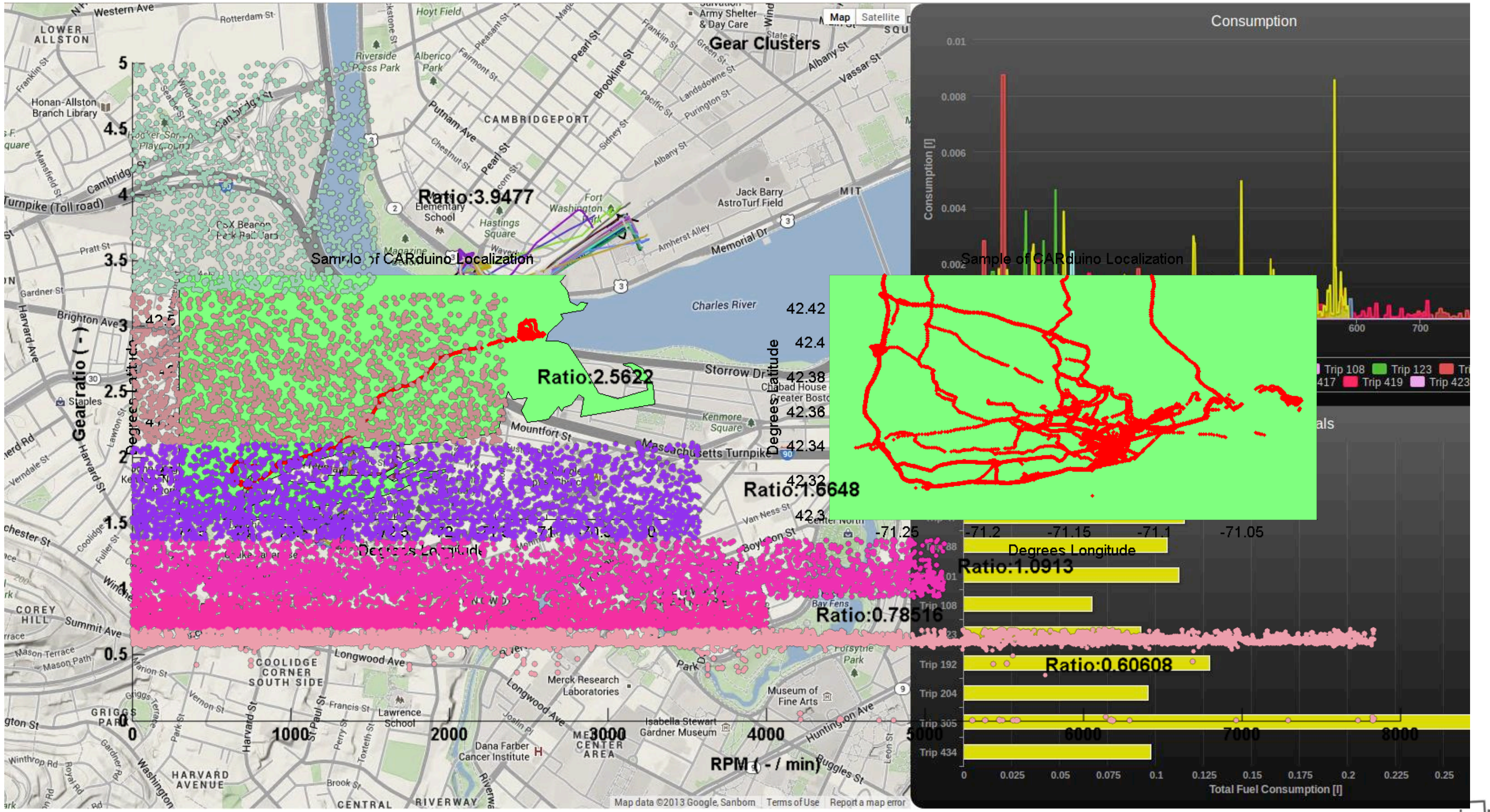
-Daniel Keys (Programmer & Writer)

MIT PROFESSIONAL EDUCATION

CSAIL COMPUTER SCIENCE AND ARTIFICIAL INTELLIGENCE LABORATORY

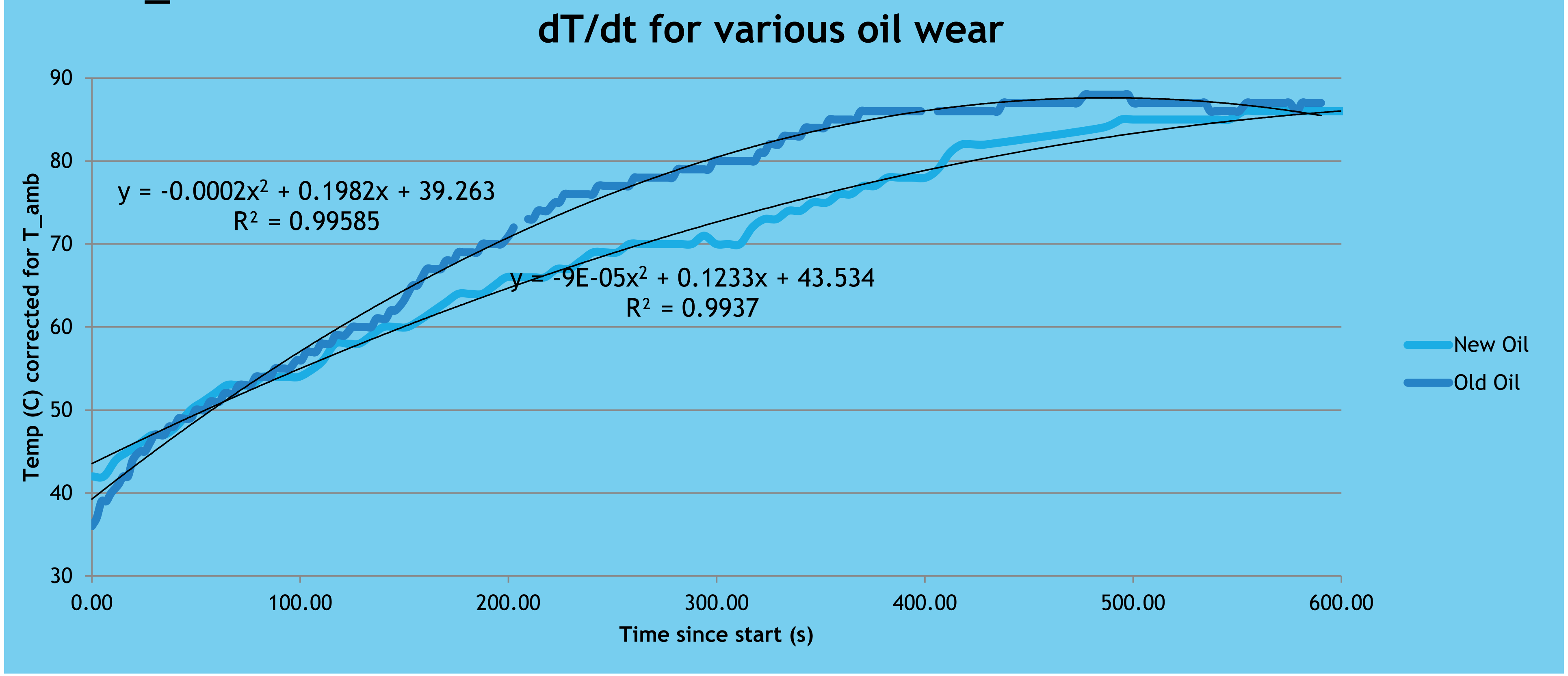
Th… World

RICHER VEHICLE DATA HAS INTERESTING APPLICATIONS



SOME RELATIONSHIPS MAY BE NON-OBVIOUS

- Example using real data: oil life surrogate metric, dT/dt
- Nonlinearity appears to increase as oil ages for similar T_ambient



SOME REFERENCES

Sarma, Sanjay, David L. Brock, and Kevin Ashton. "**The networked physical world.**" *Auto-ID Center White Paper MIT-AUTOID-WH-001* (2000).

Guinard, Dominique, Christian Floerkemeier, and Sanjay Sarma. "**Cloud computing, REST and mashups to simplify RFID application development and deployment.**" In *Proceedings of the Second International Workshop on Web of Things*, p. 9. ACM, 2011.

Engels, Daniel W., Joseph Foley, James Waldrop, Sanjay E. Sarma, and David Brock. "**The networked physical world: an automated identification architecture.**" In *Internet Applications, 2001. WIAPP 2001. Proceedings. The Second IEEE Workshop on*, pp. 76-77. IEEE, 2001.

Floerkemeier, Christian, Elgar Fleisch Friedemann Mattern, Sanjay E. Sarma, eds. *The Internet of Things: First International Conference, IOT 2008, Zurich, Switzerland, March 26-28, 2008, Proceedings*. Vol. 4952. Springer, 2008.

THAT SHOULD GET US GOING

I will be back later to summarize

THANK YOU!

Sanjay Sarma

Dean of Digital Learning, Professor of Mechanical Engineering

Computer Science and Artificial Intelligence Laboratory (CSAIL)
Massachusetts Institute of Technology