IoT

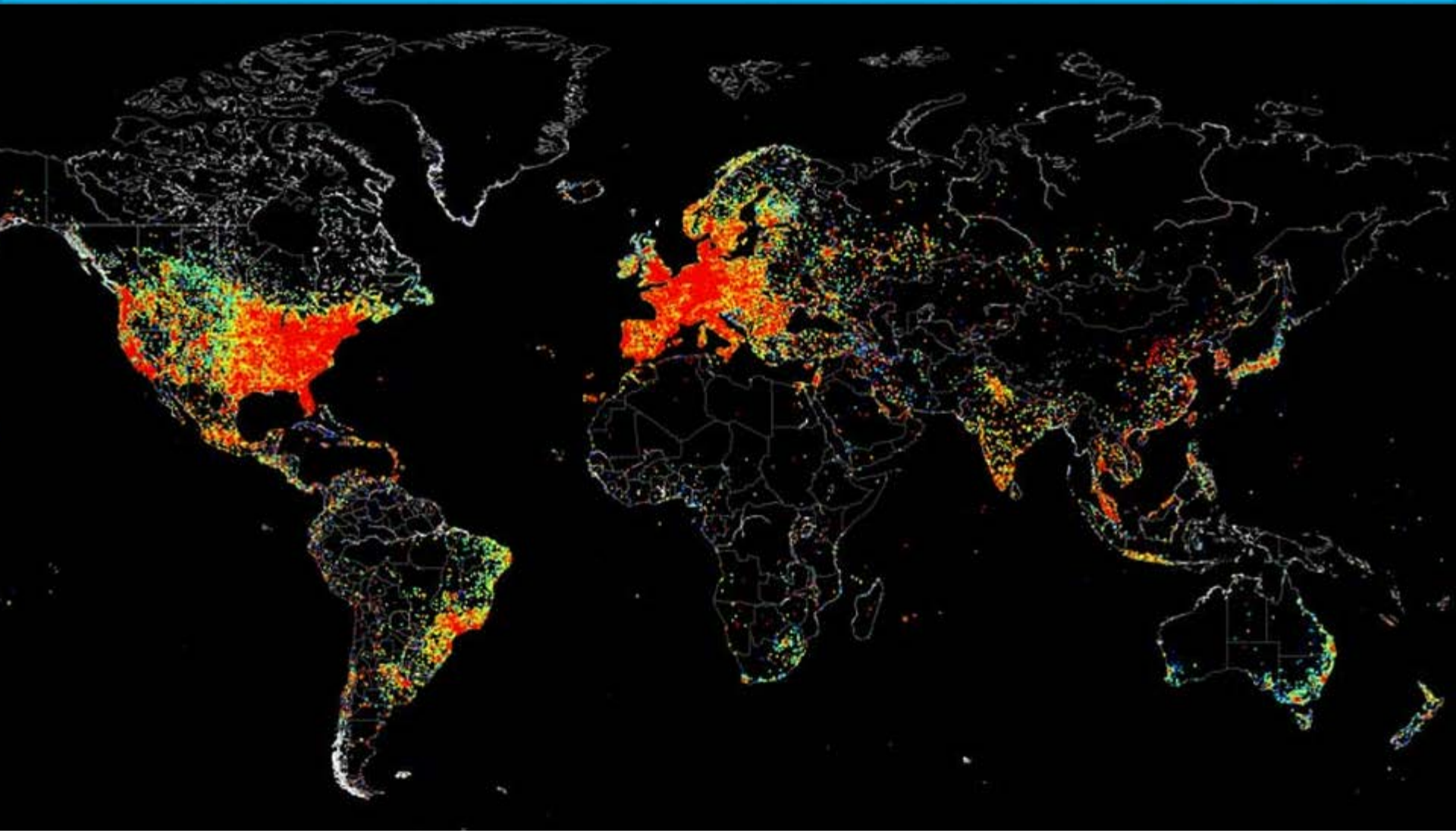
Internet of Things

The Networked Physical World

Dr Shoumen Datta

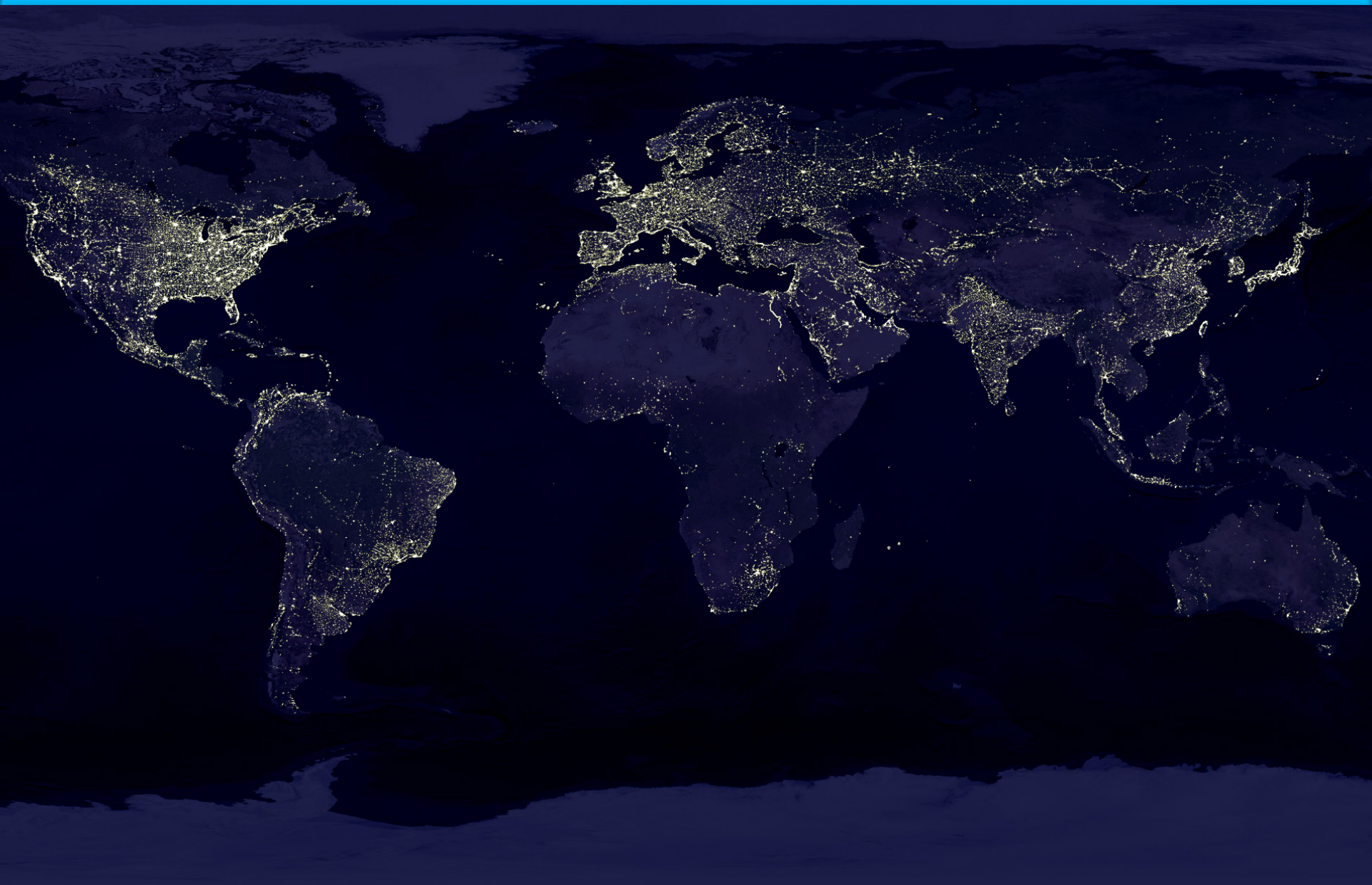
Dr Shoumen Datta <shoumen@mit.edu>

THE NETWORKED PHYSICAL WORLD

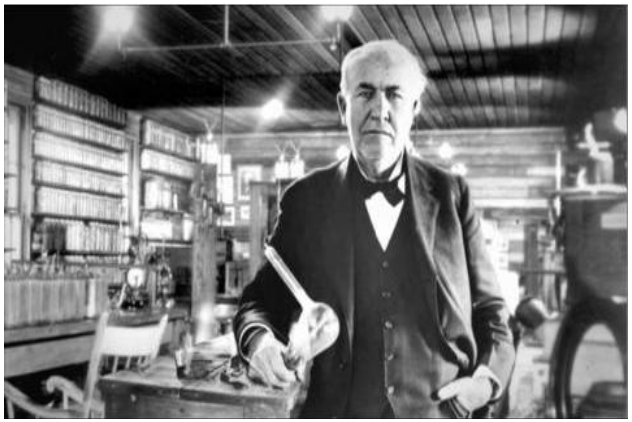


Map of every device connected to the internet on the evening of 2 August 2014 (Shodan). John Matherly pinged all IP addresses of devices online on 2 August (11pm UK). It took about 5 hours. Map represents all the devices (red = many) that pinged back in 12 hours using matplotlib.

IoT development proportional to infrastructure & dependent on energy resources?



The Economic Impact of the Internet of Things – Energy Under The Curve

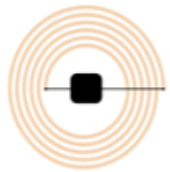


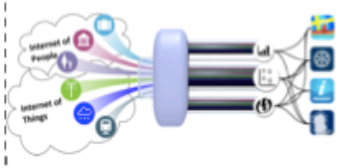
The concept of energy under the curve is directly analogous to an economy's money supply at a given time. Both the energy and the money supply are known amounts. The money is going to be spent by someone (device is going to output its energy). The key is for the money to be spent where it has the most benefit (the light bulb must produce visible light).

In engineering parlance, there is a phrase called 'energy under the curve.' This refers to the total energy output of a device—light bulb, acoustic transducer —as measured on a graph across a range of frequencies. While every effort is made to maximize the amount of energy output from that device, in the end it's still a finite amount. The key to best performance is getting the device to deliver energy that is ***usable***. A light bulb may produce x lumens of energy, but it won't do much good if its output is predominately at ultraviolet frequencies that are invisible to the human eye. An acoustic transducer (speaker) can be modified to produce more or less energy at different frequencies, but the total acoustic energy produced by that specific speaker is finite. The engineers can move the energy output from one frequency region to another, but the 'total energy under the curve' remains the same. The key to a speaker's useful performance, of course, is for it to produce its energy at frequencies that are audible and useful to humans, not bats.

www.americanthinker.com/2004/09/the_light_bulb_economy.html

A Short History of the Development of the Internet of Things starts with the re-invention of RFID





1994~1999

RFID based solutions

early 2000

WSAN oriented, Distributed WSANs, Communication technologies, Smart meter …

mid 2000

Smart Devices/ Web-enabled Apps/Services, initial products, vertical applications, concepts and demos, …

~2010

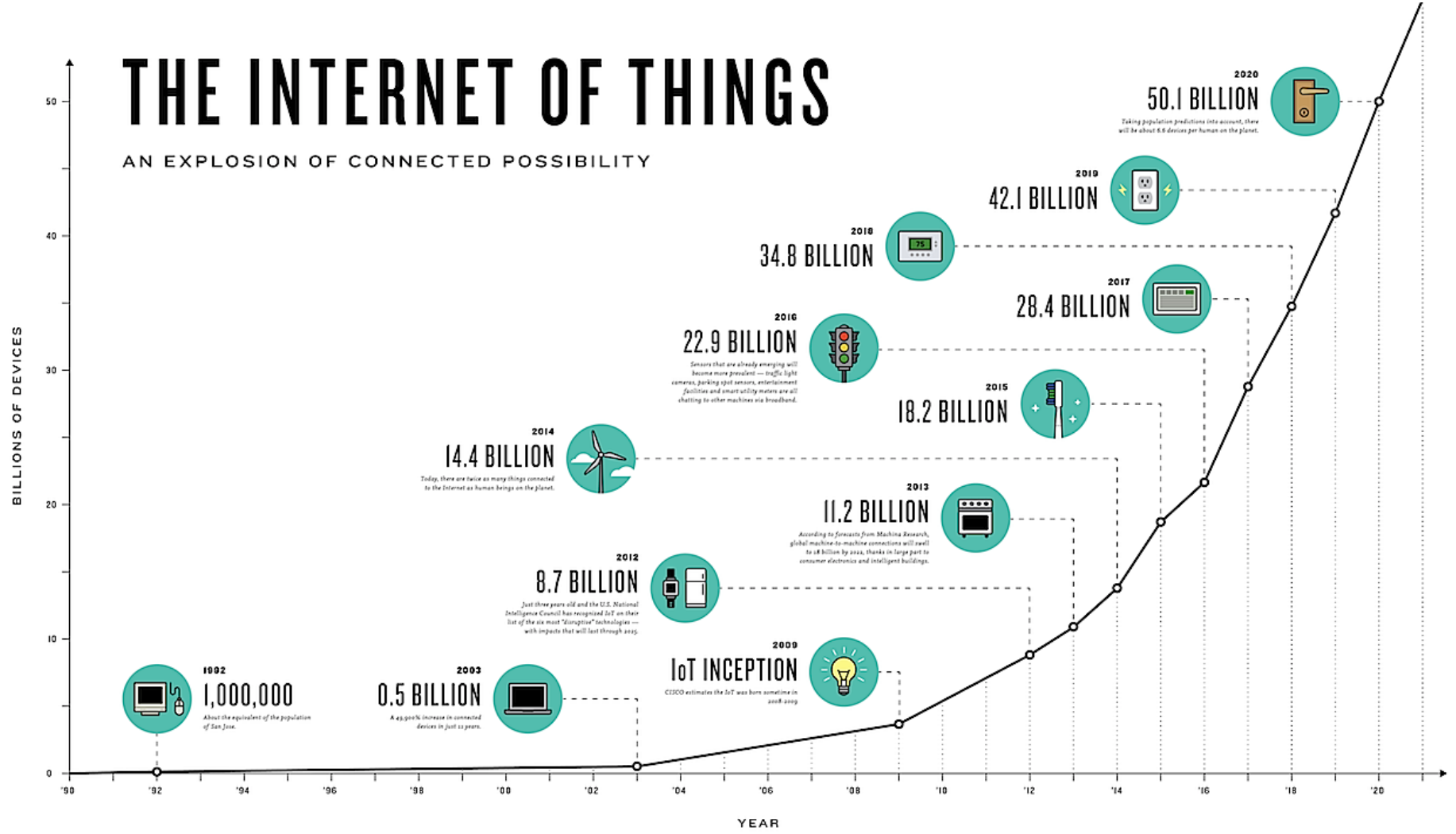
Physical-Cyber-Social Systems, Linked-data, semantics, More products and services (e.g. Smart Buildings), more heterogeneity, control and monitoring applications, …

~2020

Cloud platforms, Big (IoT) Data analytics, Mature IoT applications with actionable information, Multimodal fusion and intelligent data processing, Enhanced cellular/ wireless com. for IoT, Operational use-cases and commercial services/ applications, more Standards…

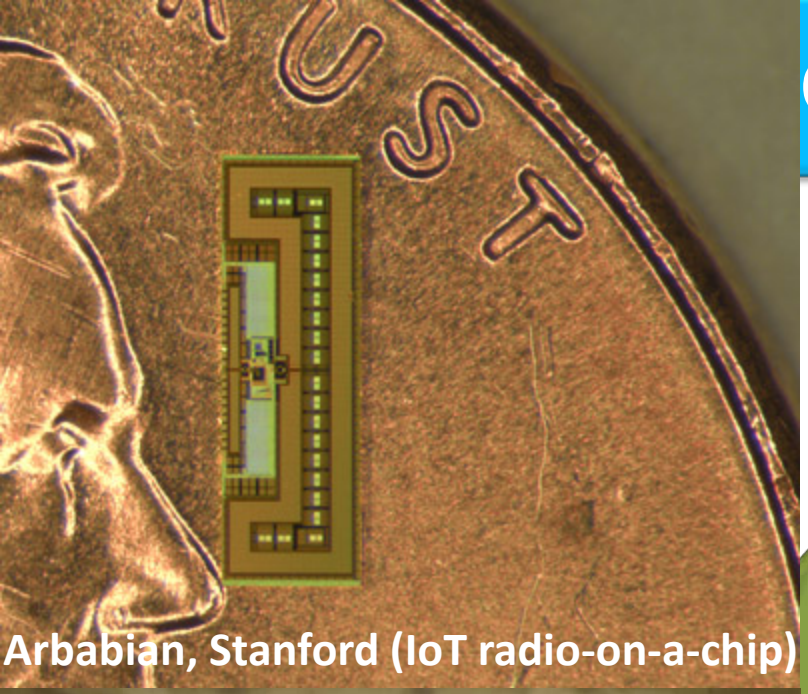
http://iot.ieee.org/images/files/newsletter/201409-barnaghi-figure1.png

THE NETWORKED PHYSICAL WORLD

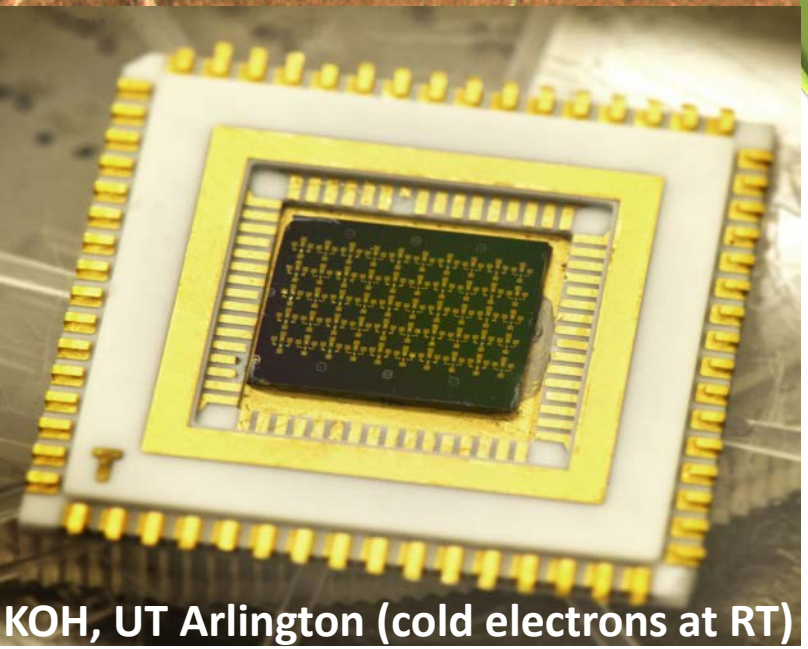


ECONOMIC GROWTH ENGINES

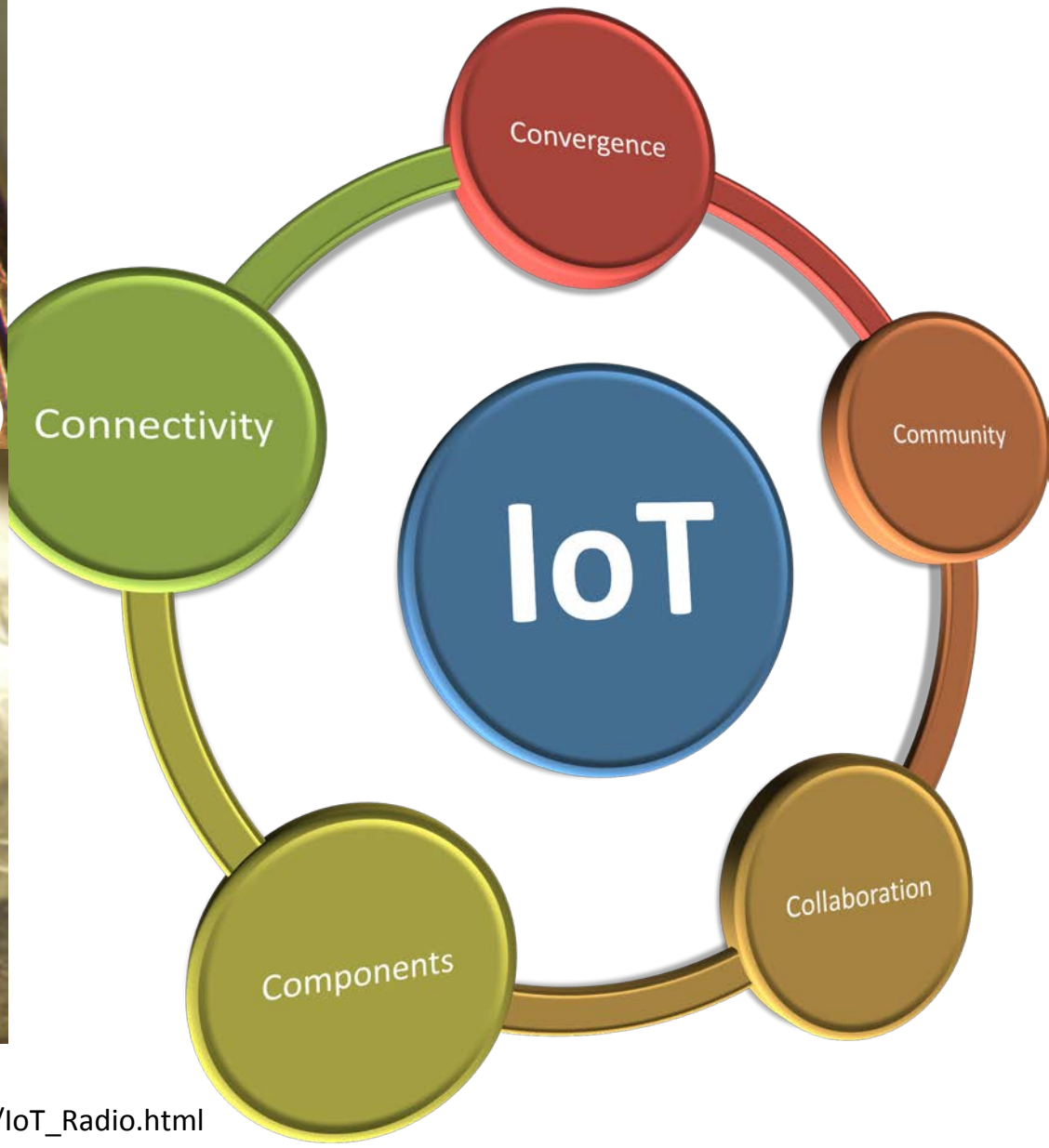
COMBINE THE TWO 2 CONNECT



Arbabian, Stanford (IoT radio-on-a-chip)



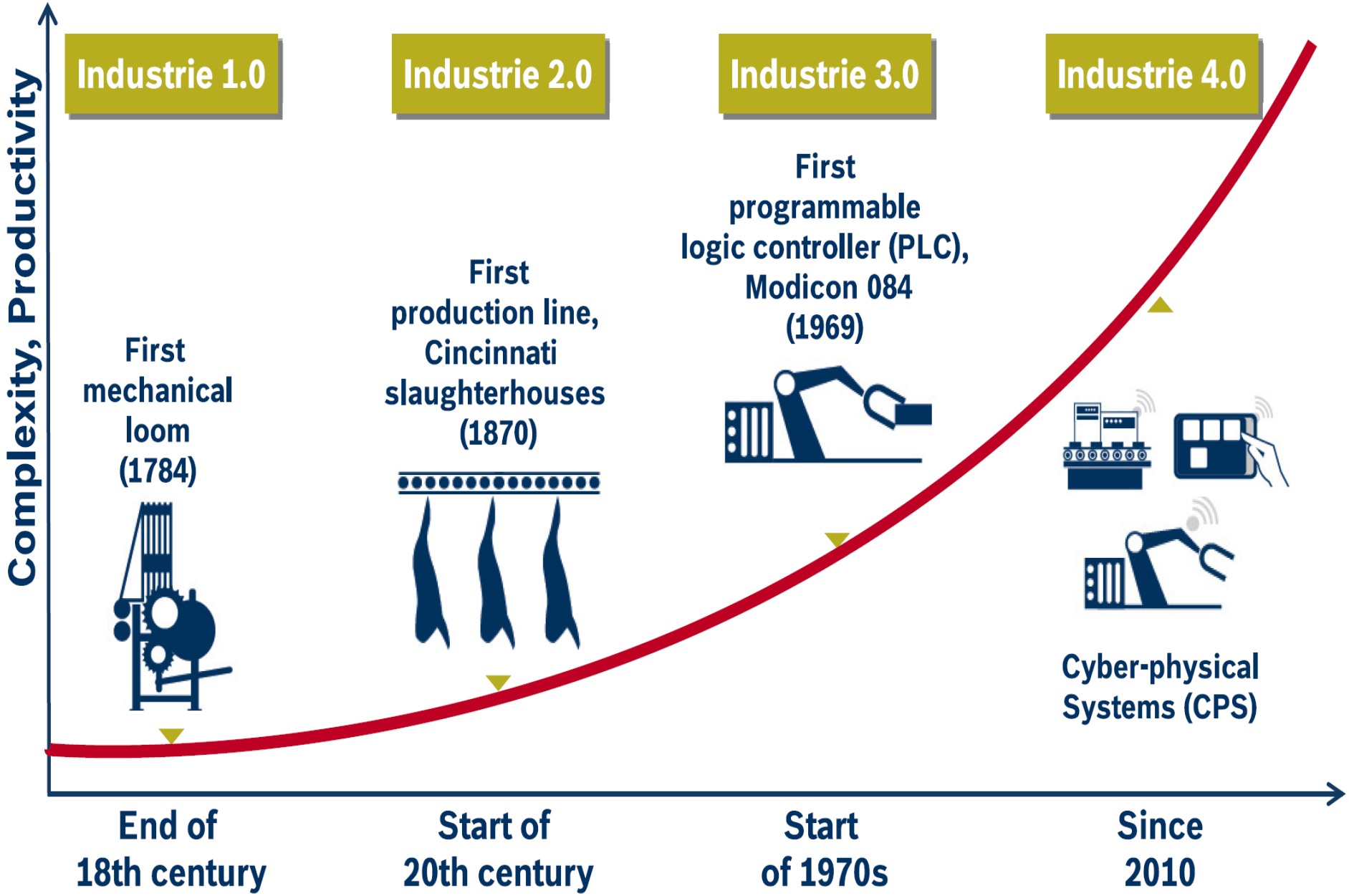
KOH, UT Arlington (cold electrons at RT)



KOH●DOI: 10.1038/ncomms5745

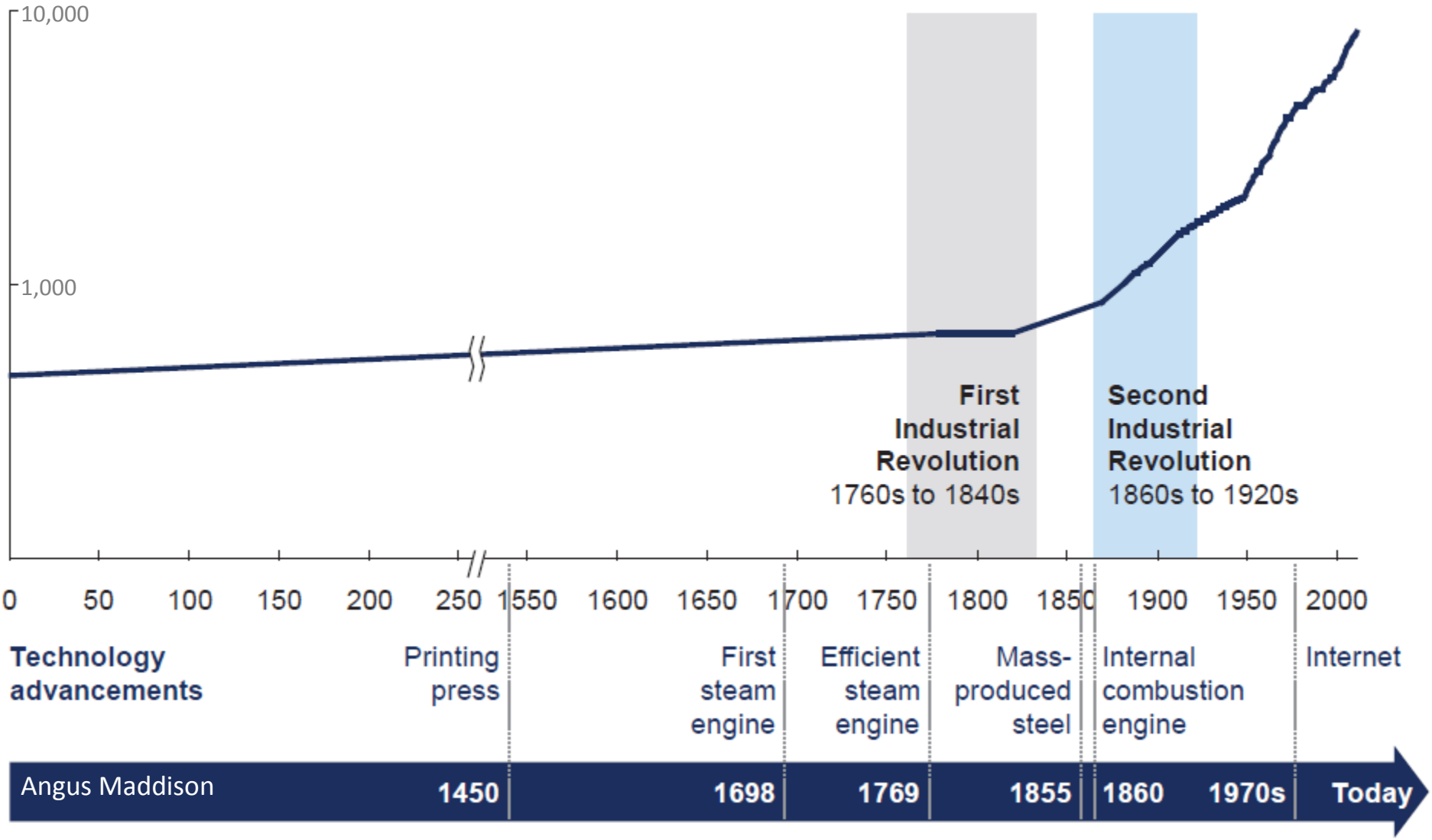
ARBABIAN●http://web.stanford.edu/~arbabian/Home/IoT_Radio.html

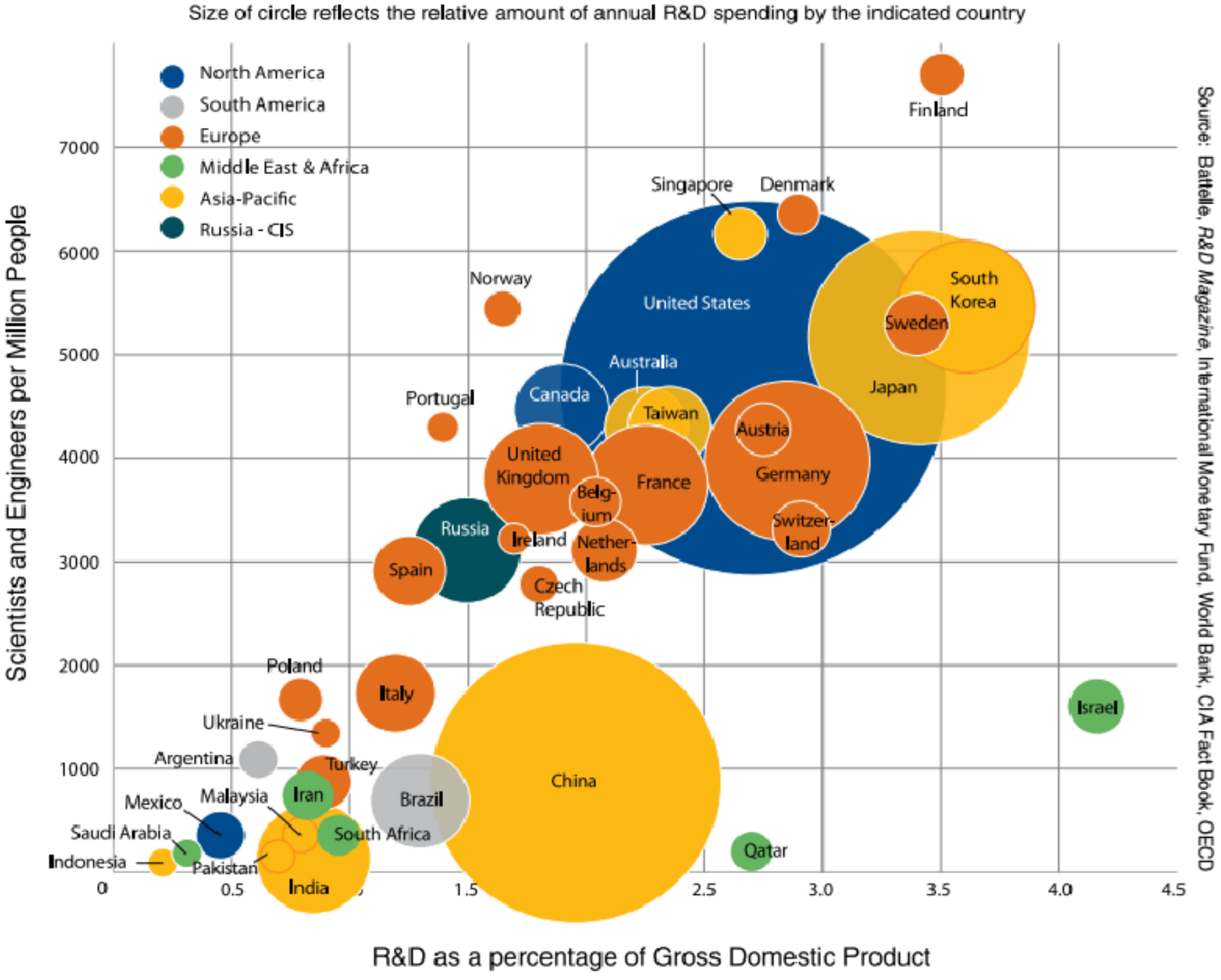
THEN PREPARE FOR THE NEXT REVOLUTION



Context of Economic Growth

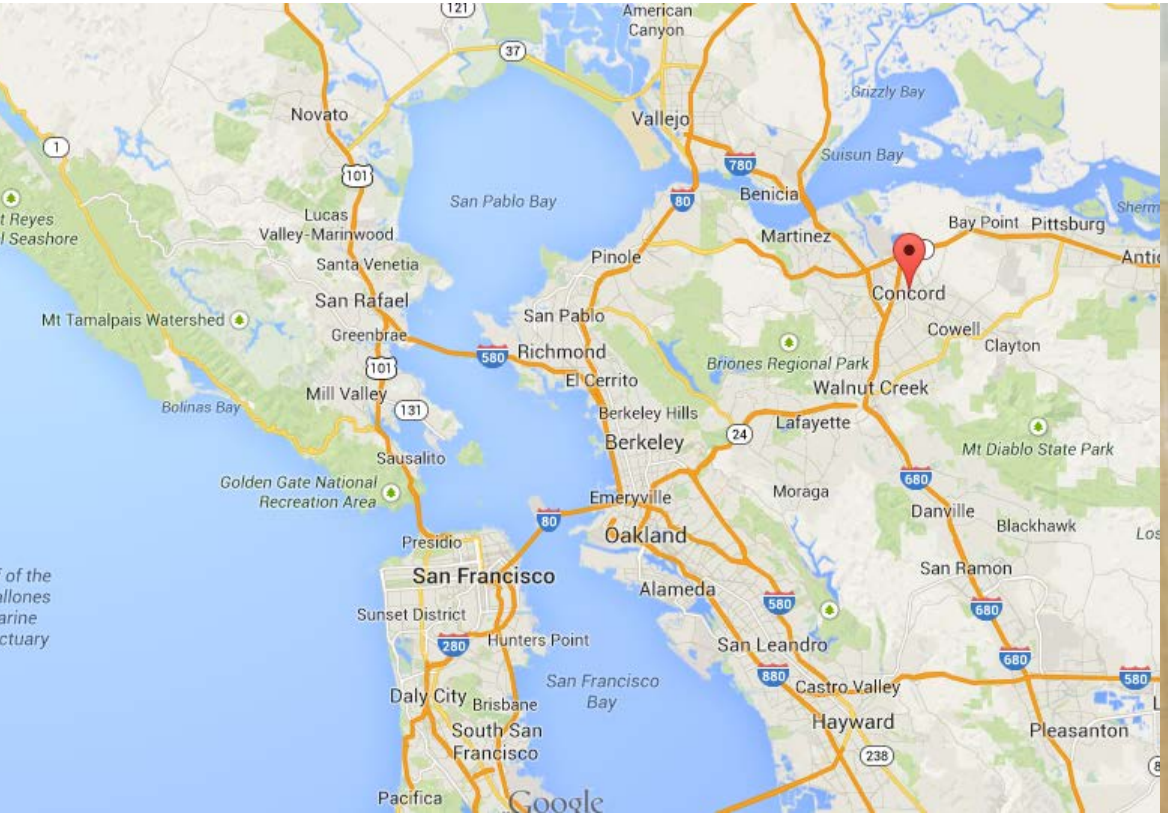
Industrial Growth over 2000 years: measured as global GDP per capita (in US$)




Size of circle reflects the relative amount of annual R&D spending by the indicated country
North America
South America
Europe
Middle East & Africa
Asia-Pacific
Russia - CIS
Scientists and Engineers per Million People
R&D as a percentage of Gross Domestic Product
Source: Battelle, R&D Magazine, International Monetary Fund, World Bank, CIA Fact Book, OECD
Finland
Singapore
Denmark
Norway
United States
South Korea
Sweden
Australia
Japan
Portugal
Canada
Taiwan
Austria
United Kingdom
France
Germany
Belg-ium
Russia
Switzer-land
Ireland
Nether-lands
Spain
Czech Republic
Poland
Italy
Israel
Ukraine
Argentina
Turkey
China
Iran
Brazil
Mexico
Malaysia
South Africa
Saudi Arabia
Qatar
Indonesia
Pakistan
India
0
0.5
1.5
2.5
3.0
3.5
4.0
4.5
1000
2000
3000
4000
5000
6000
7000

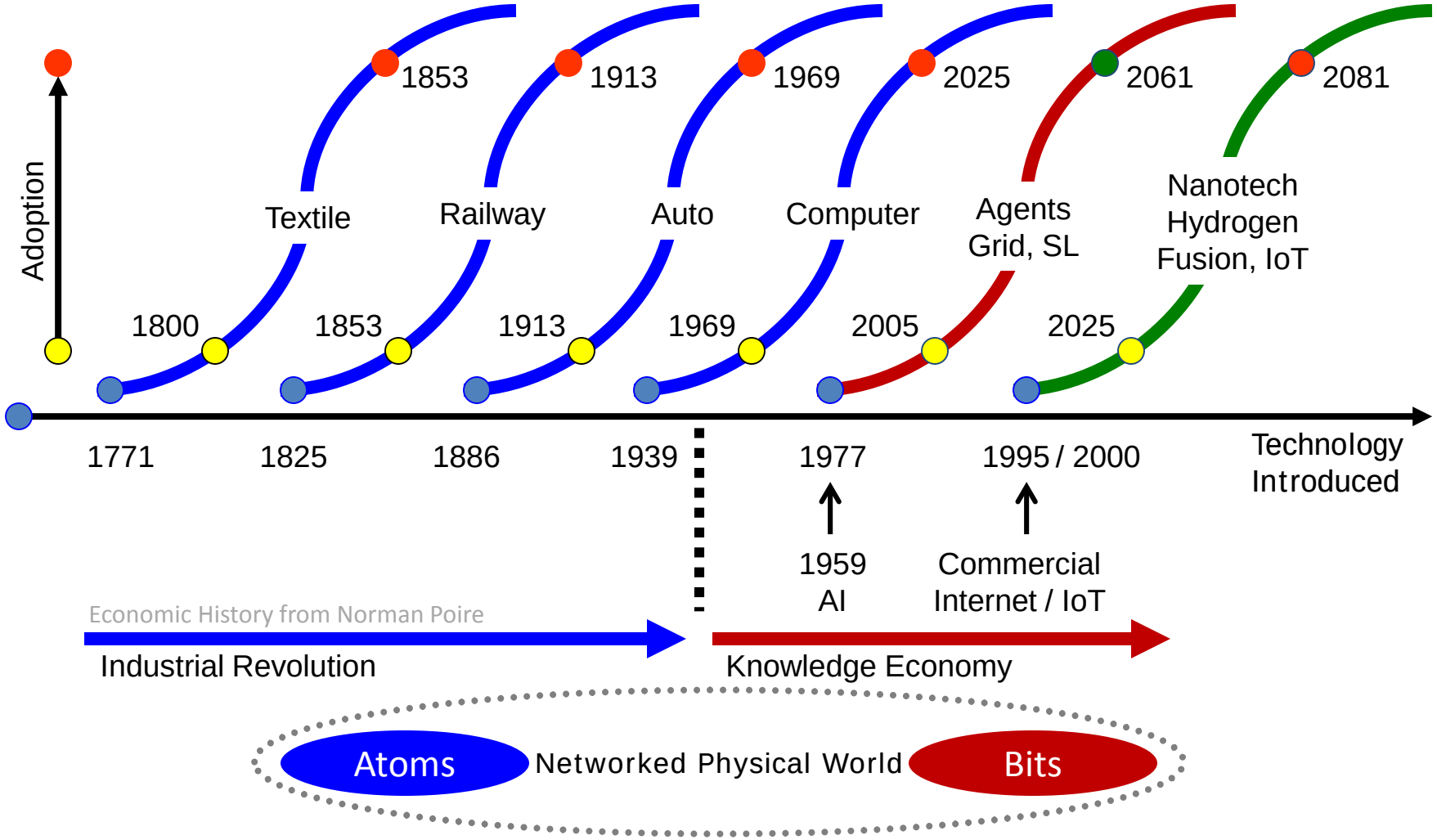
The origins of connectivity

A milestone - Diffusion of the Internet - NetDay 1996



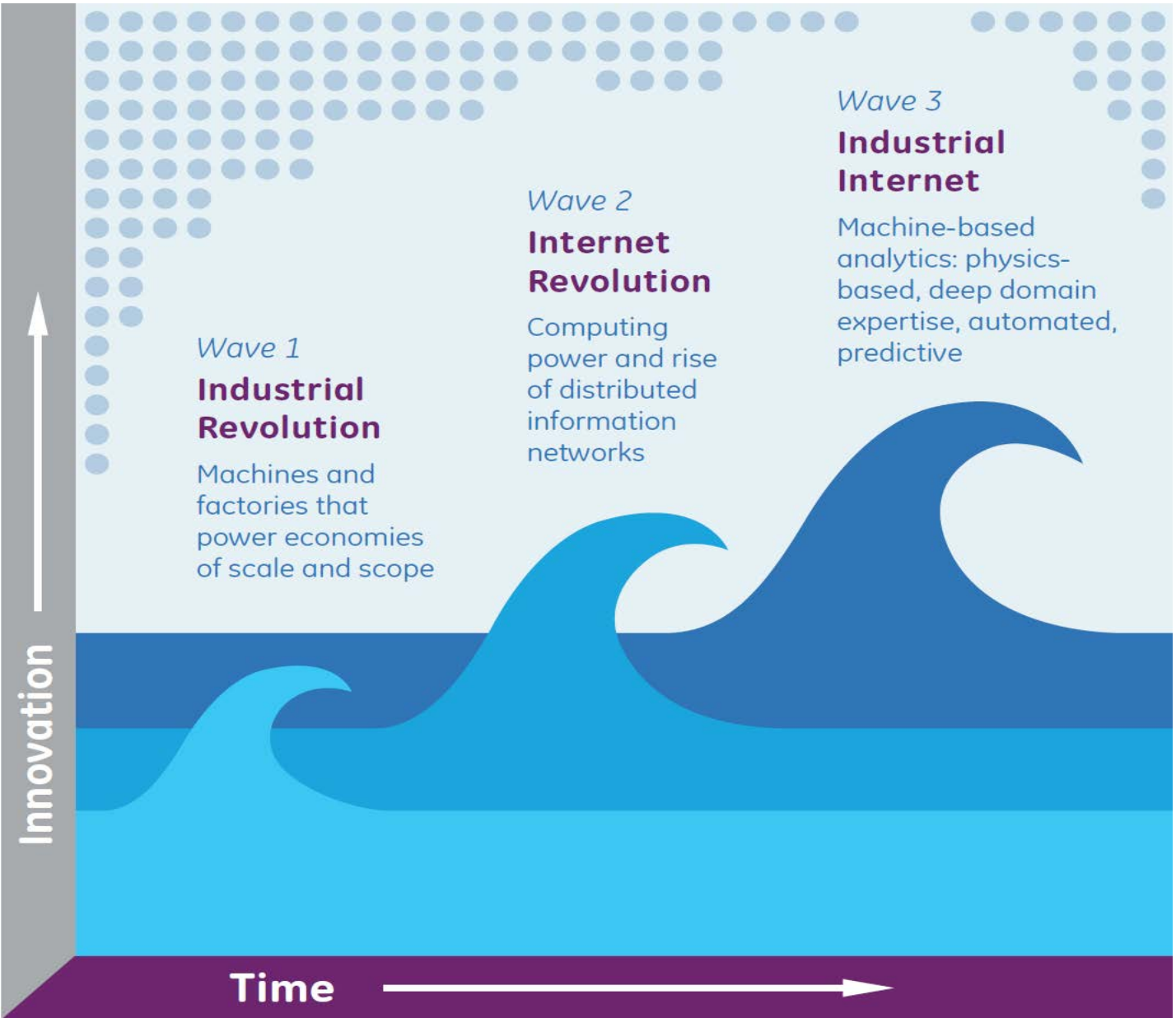
President Bill Clinton installing computer cables with Vice President Al Gore on NetDay at Ygnacio Valley High School (Concord, CA - Mar 9, 1996)

Conceptual advances adds to the *Wealth of Nations* for about 100 years



It takes ~30 years for ideas to gain traction before exponential growth. 1995 is the year of birth for the commercial internet. The exponential (economic) impact from IoT may be unleashed around ~2025.

IoT Sum of Parts – Combination of the Industrial Revolution with the Evolution of the Internet



IoT … the beginning

At the beginning - How did the IoT concept / industrial internet start ?

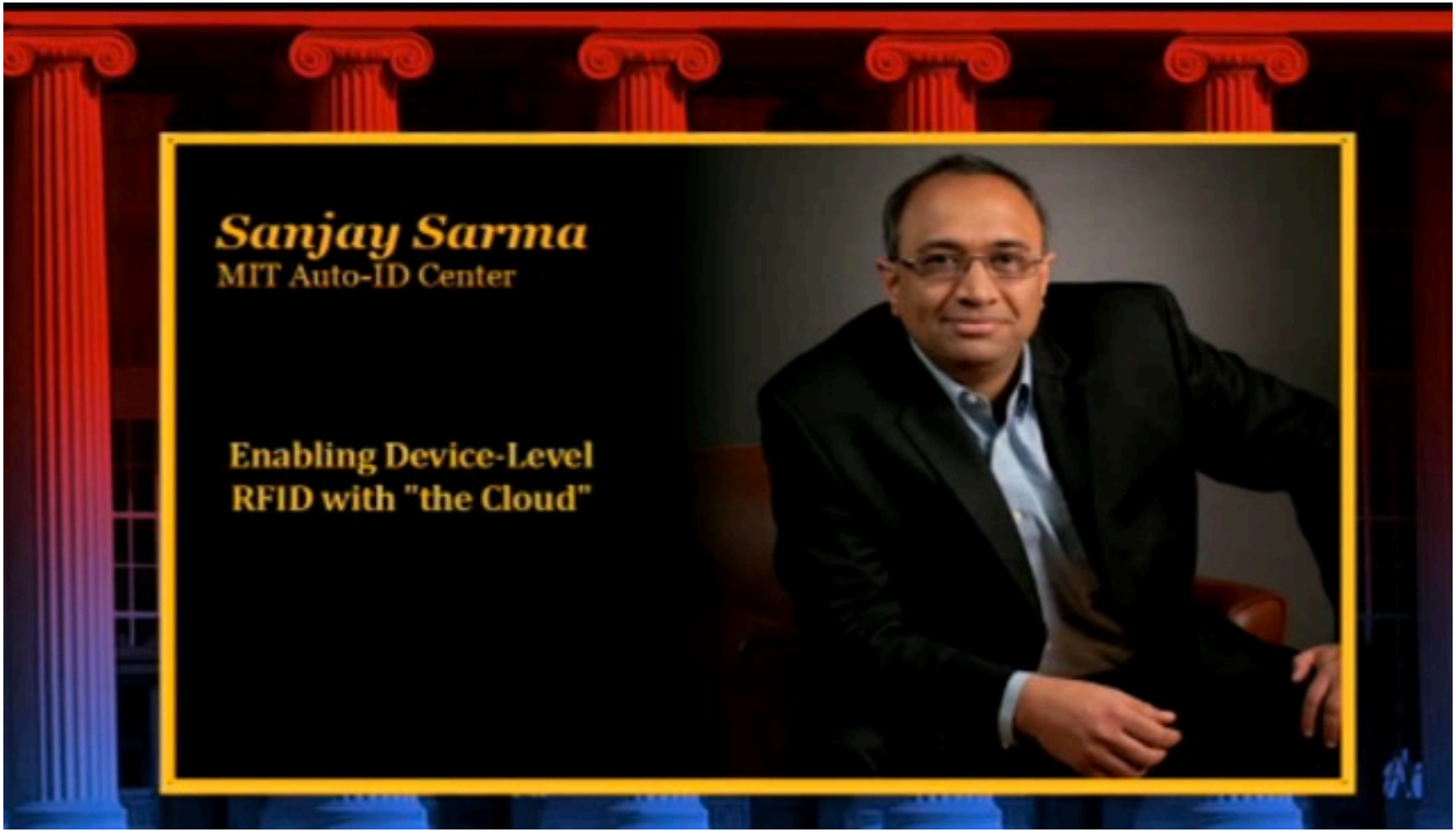
The grand vision of the Industrial Internet may have started circa 1988 with the work of Mark Weiser of Xerox Palo Alto Research Center (XPARC) who predicted that computers may *"weave themselves into the fabric of everyday life"* and influence the future of business as well as lifestyle technologies, in his 1991 article in the *Scientific American*. The release of the commercial internet in 1995 paved the way for the Industrial Internet of the future. In 1998, Sanjay Sarma (MIT) extended the idea of using RFID tags on objects for track and trace purposes. To make it feasible for businesses to use RFID tags in the management of their supply chains, the price of the RFID tag had to be reduced, significantly. Sarma suggested RFID tags contain only a reference number (electronic product code) rather than any actual data about the object. It was against the conventional wisdom. At the time, RFID tags were used and designed to contain data about the object or product. By eliminating need for data storage on the tag, the cost of the RFID tags were reduced. Sarma designed the EPC to act as an unique URL to access the object data stored on the Internet. In 1999, Sarma along with colleagues David Brock and Sunny Siu co-founded the Auto ID Center to transform this vision made possible by the "emerging" medium and the platform of the internet. The internet was still in its infancy and immature to act as a catalyst to augment business processes and industrial productivity. Sarma, Brock and Siu were later joined by Kevin Ashton who was loaned to the Auto ID Center at MIT from Proctor & Gamble. Auto ID Center at MIT developed the EPC and other technical concepts and standards prevalent today in the global RFID industry. Sarma, Brock and Ashton coined the term Internet of Things which envisioned objects /things connected to object-specific data on the internet which could be accessed using the unique EPC on the tag attached to the object. IoT is a vision, not a technology. In 2000, a paper by Sarma *et al* gave birth to that IoT concept. Please download (MIT-AUTOID-WH-001) *THE NETWORKED PHYSICAL WORLD* from this link http://tinyurl.com/Industrial-Internet (this folder contains many papers). Professor Sarma talked about the IoT at the MIT Sloan Symposium. It is on YouTube http://tinyurl.com/MIT-IoT-1998

I was a part of the Auto ID initiative since 2001 as a member of the Technology Board at Auto ID Center.

The industrial internet started with the birth of Internet of Things

IoT thinkers and influencers

IoT concepts, suggestions and applications were influenced by



IoT … impressions

amsix
amsterdam internet exchange

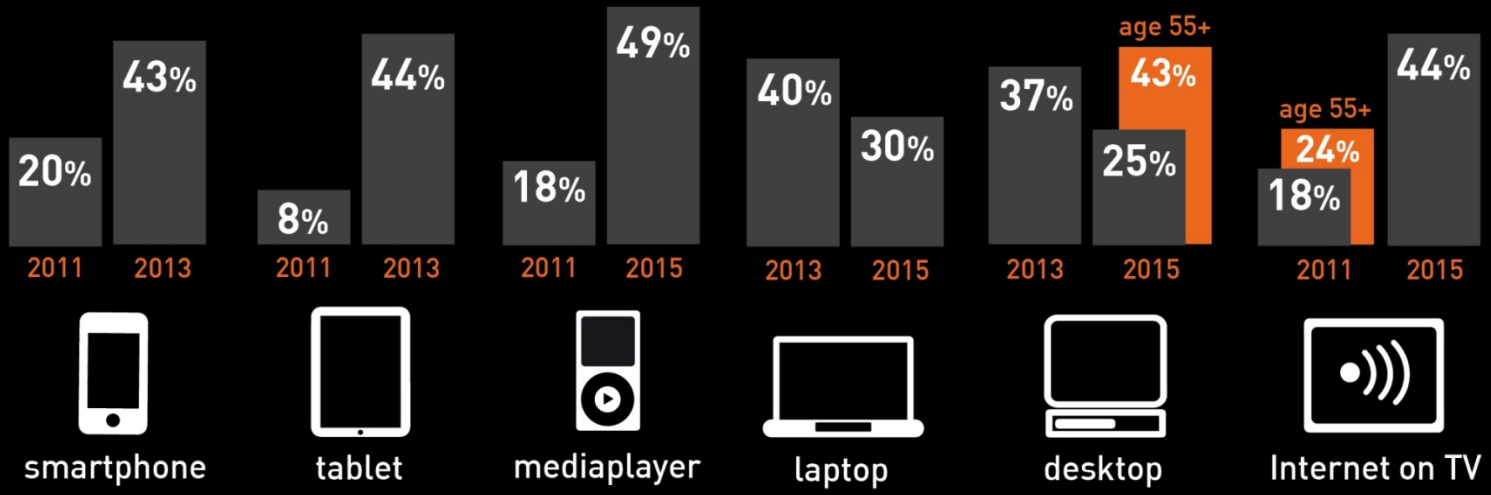
INTERNET OF THINGS

Upcoming technologies

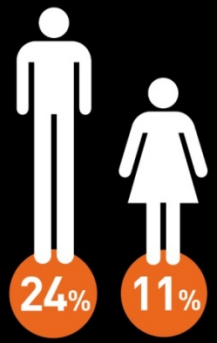
in 2015 **56%** connects lighting to the Internet

in 2015 **59%** connects thermostat to the Internet

Use of devices that are connected to the Internet



Positive attitude towards Internet of Things

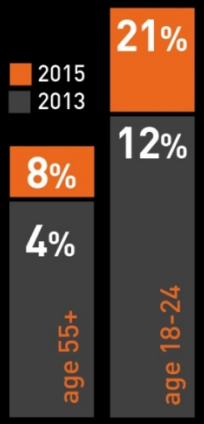


The Internet has changed life concerning:

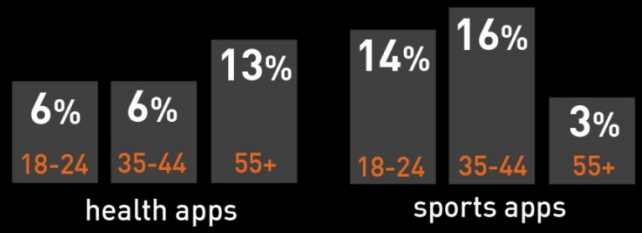
- **59%** banking / administration
- **38%** social life
- **25%** shopping
- **22%** news consumption

The Internet and health

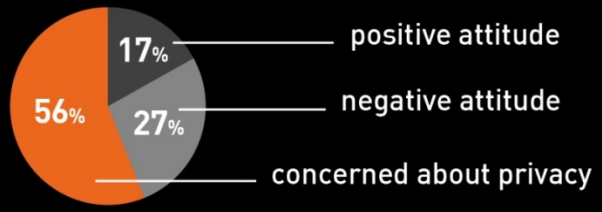
Use of apps for measuring health/sports



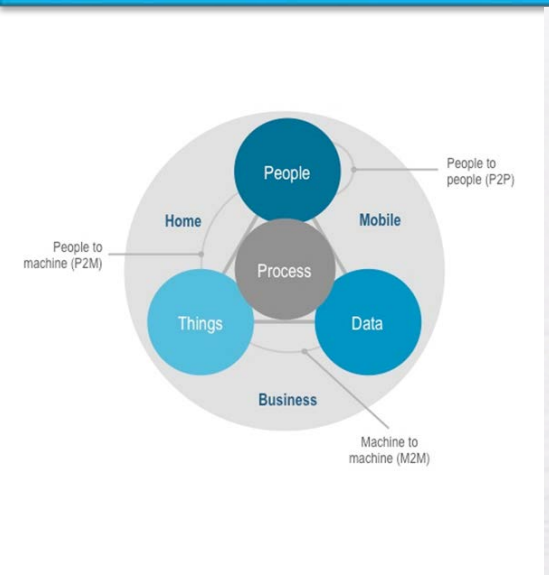
Sort of apps people will use in 2015

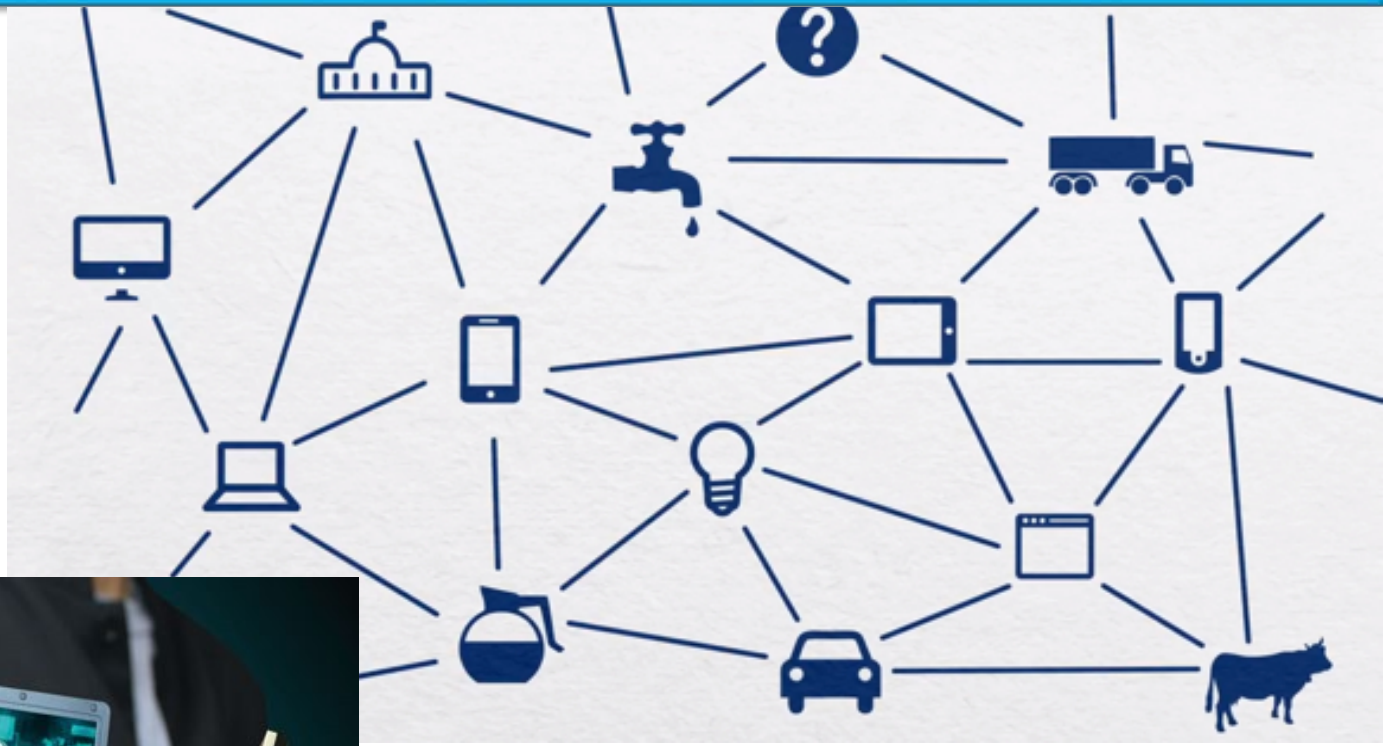


Online monitoring by doctors



All of these illustrations, in part, may be representative of the Industrial Internet or the IoT (Internet of Things) or the Internet of Everything (IoE)





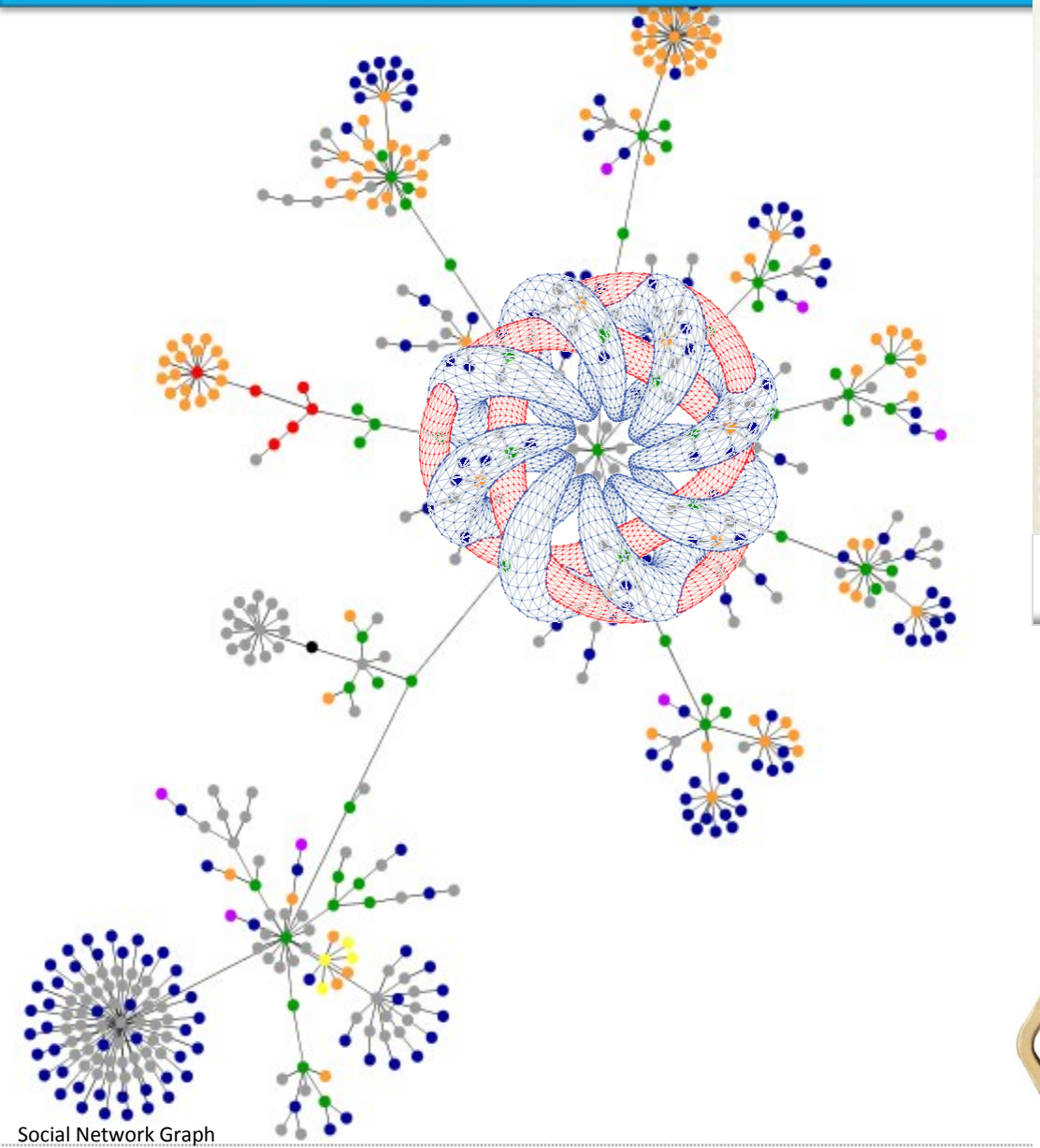
Robot-aided Manufacturing Harley-Davidson

It is difficult to include the innumerable elements and all dependencies in context of the user and the connectivity (required at the point of use).

The key characteristic of IoT

CONNECTIVITY

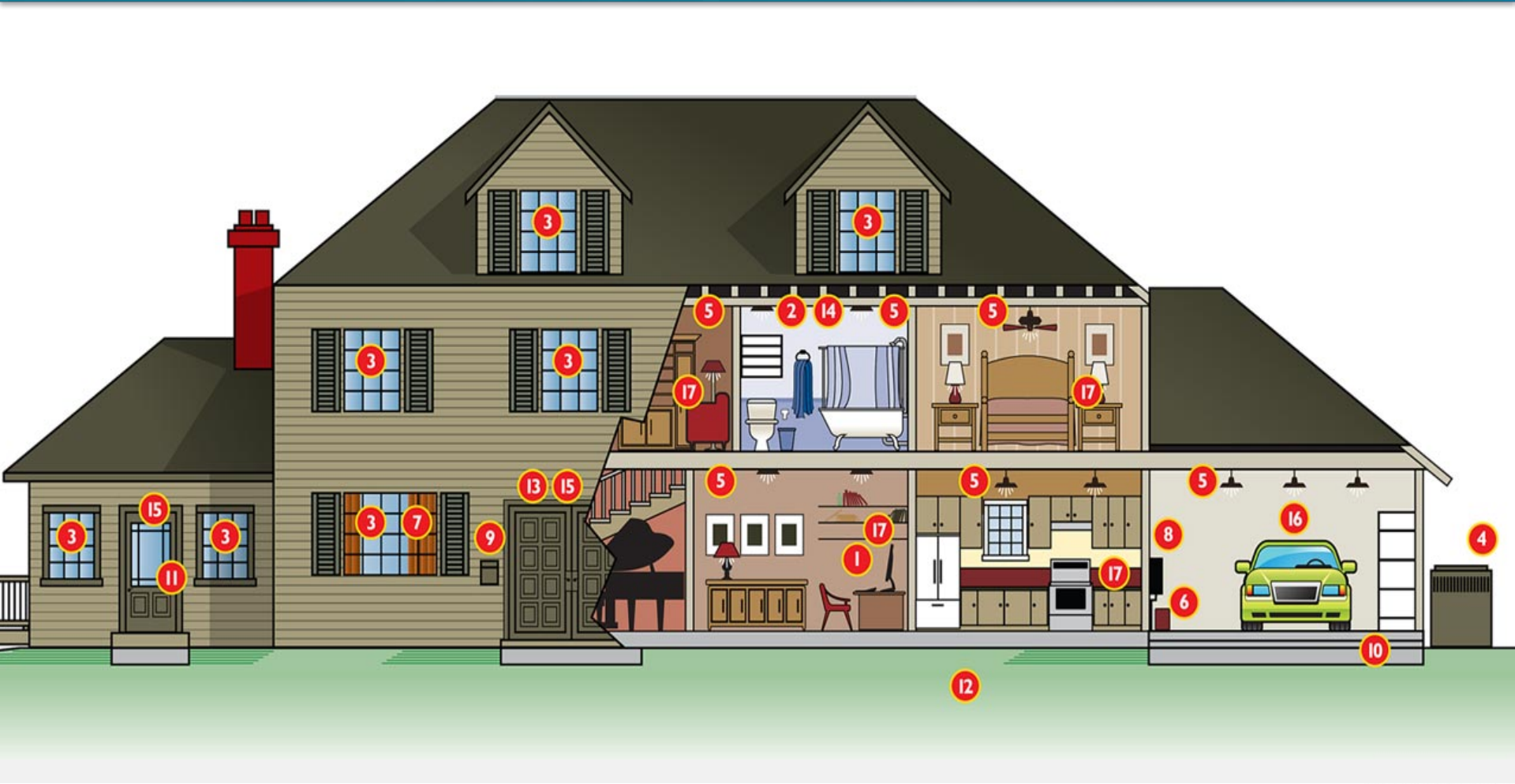
key for the Internet of Things



Social Network Graph

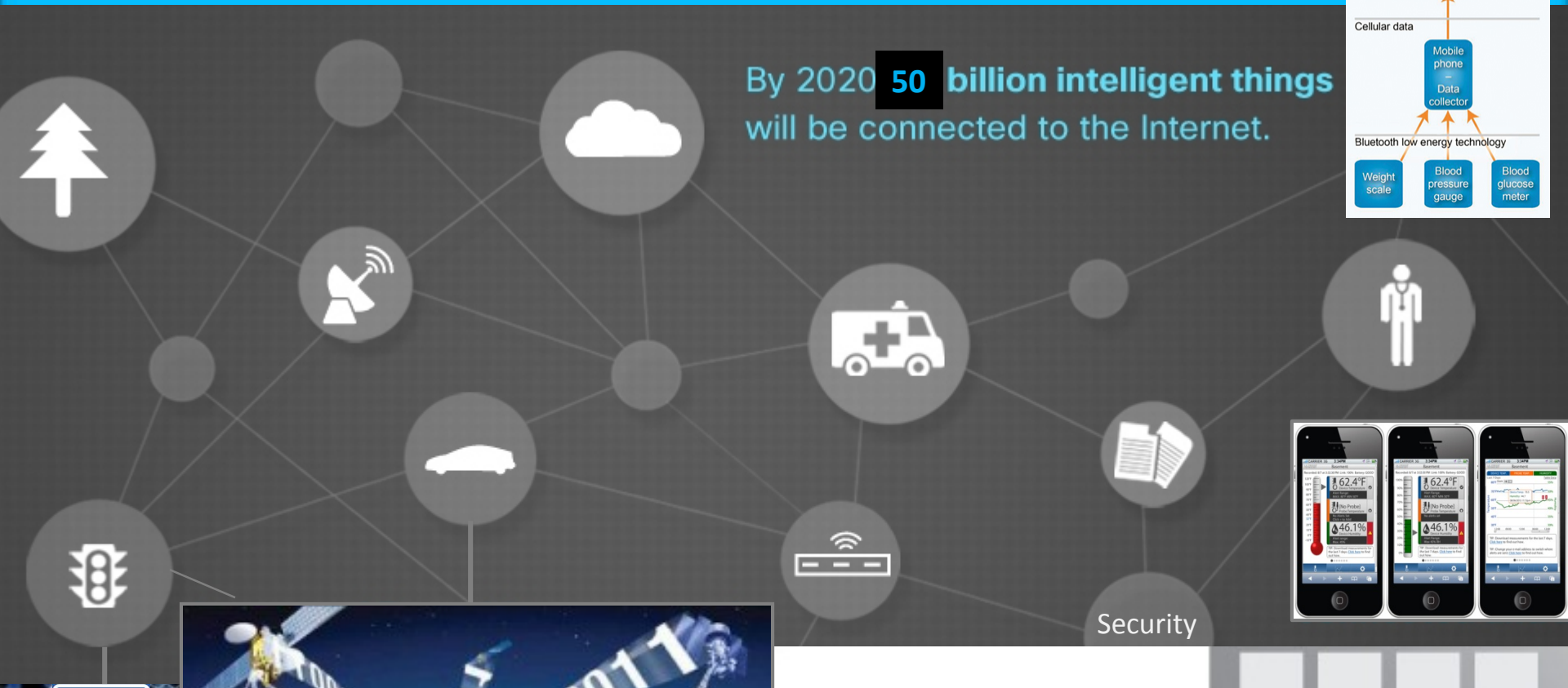
"Attempting to define precisely what is included or excluded is a fruitless exercise. It is a matter of emphasis and focus. "

CONNECTED inside

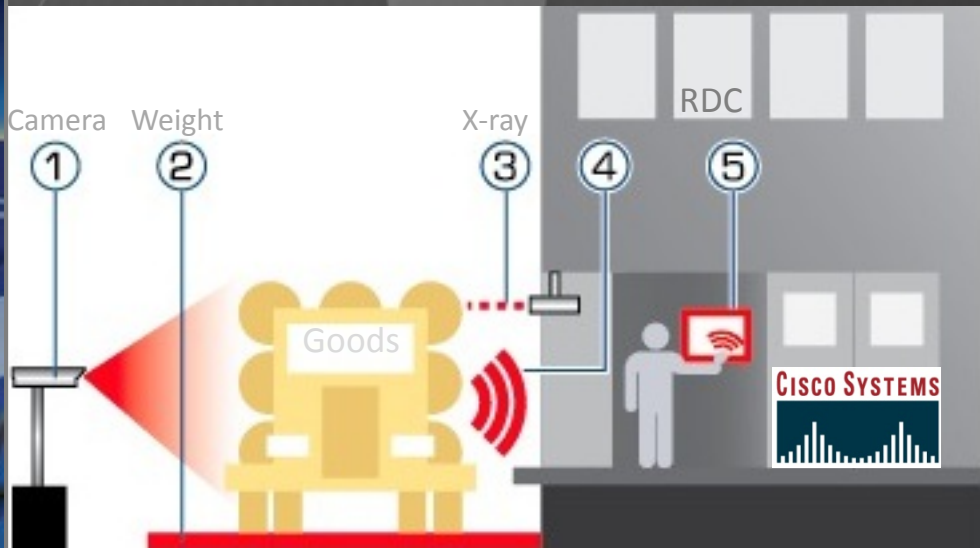


1	Ambient Intelligence Agent (AmI) Control	6	Automatic Pet Feeder	12	Lawn Moisture Sensor
2	Light Sensor	7	Motorized Drapes	13	Face Recognition Sensor
3	Windows and Door Control	8	Automatic Watering	14	Motion Sensors
4	HVAC Control	9	Mailbox Sensor	15	Door Sensors
5	Lighting Control	10	Driveway Sensor	16	AmI Interface with Car
		11	Security System	17	AmI Interface with Smart Phone

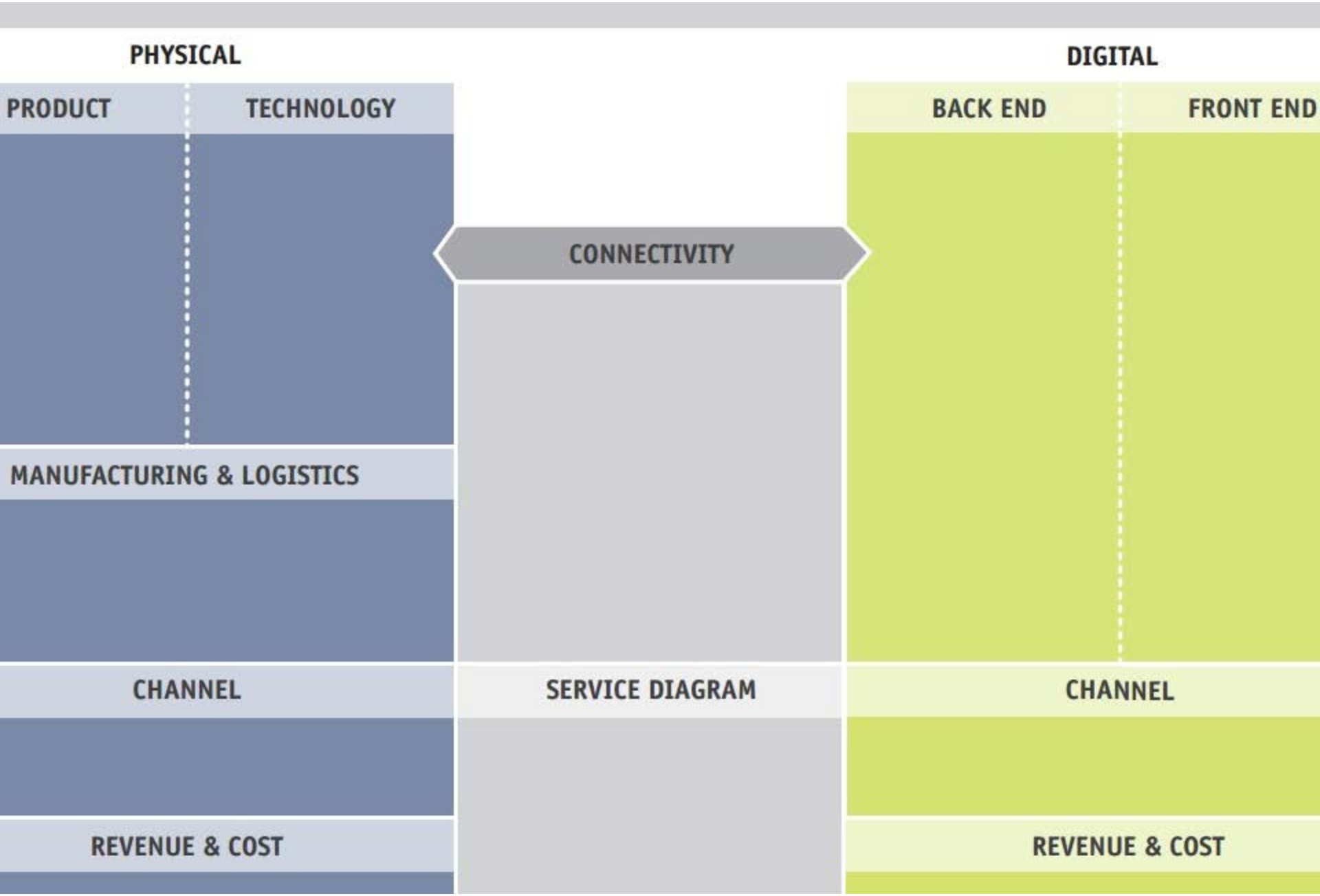
CONNECTED outside



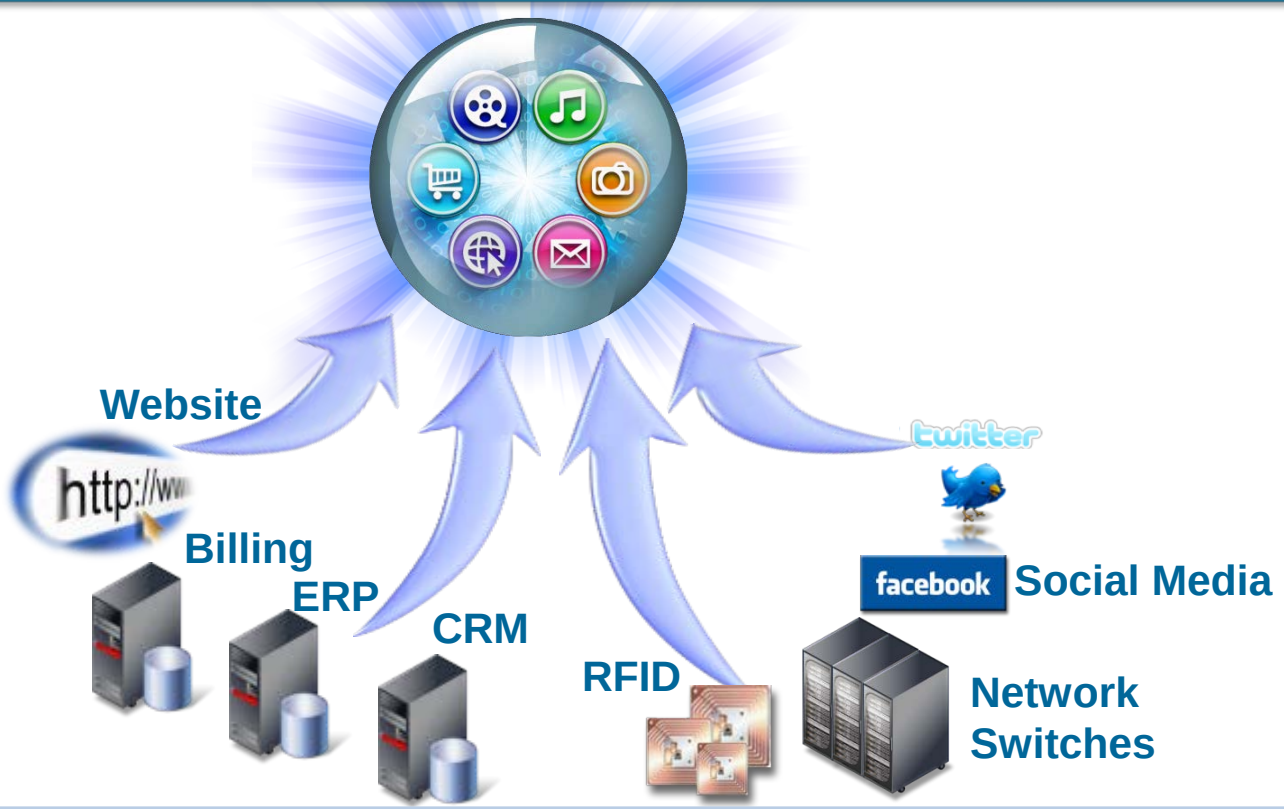
Security



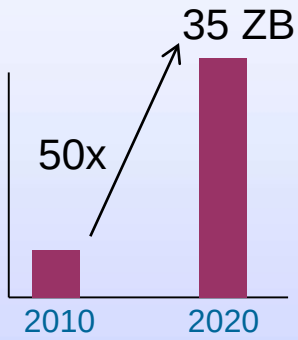
CONNECTED → BITS (DIGITAL DATA) to ATOMS (THE PHYSICAL WORLD)



CONNECTED → ALL DATA



Volume



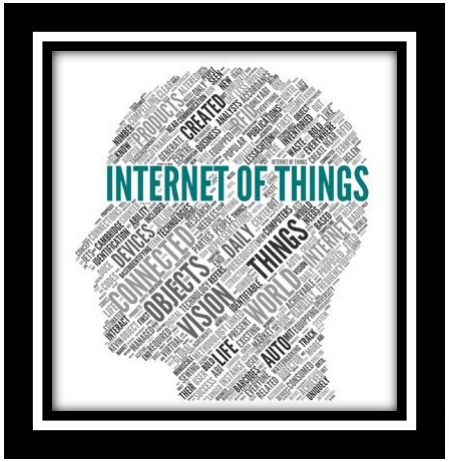
Velocity

30 billion +
RFID sensors

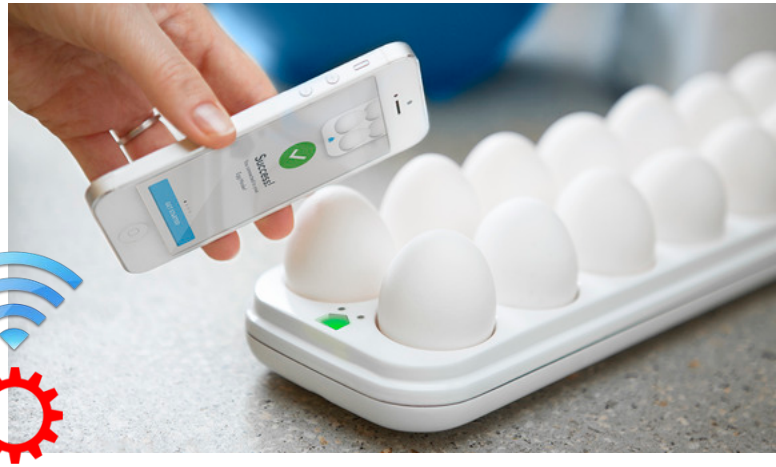
Variety

80% of data
unstructured

Vast numbers of people continue to extend the concepts of connectivity



CONNECT



EGG MINDER by Rafael Hwang • QUIRKY + GE

★ 2003 - the industrial internet ideas in my book chapter.
MIT Library → http://dspace.mit.edu/handle/1721.1/41908

★ 2003 – framework of analytics (published paper in 2007).
MIT Library → http://dspace.mit.edu/handle/1721.1/41906

★ 2007 – context, semantics, connectivity (published paper in 2012).
MIT Library → http://dspace.mit.edu/handle/1721.1/41902

★ 2007 – illustration of industrial internet in my working paper.
MIT Library → http://dspace.mit.edu/handle/1721.1/41900

★ 2008 – illustration published by European Supply Chain Group.
MIT Library http://dspace.mit.edu/handle/1721.1/57508

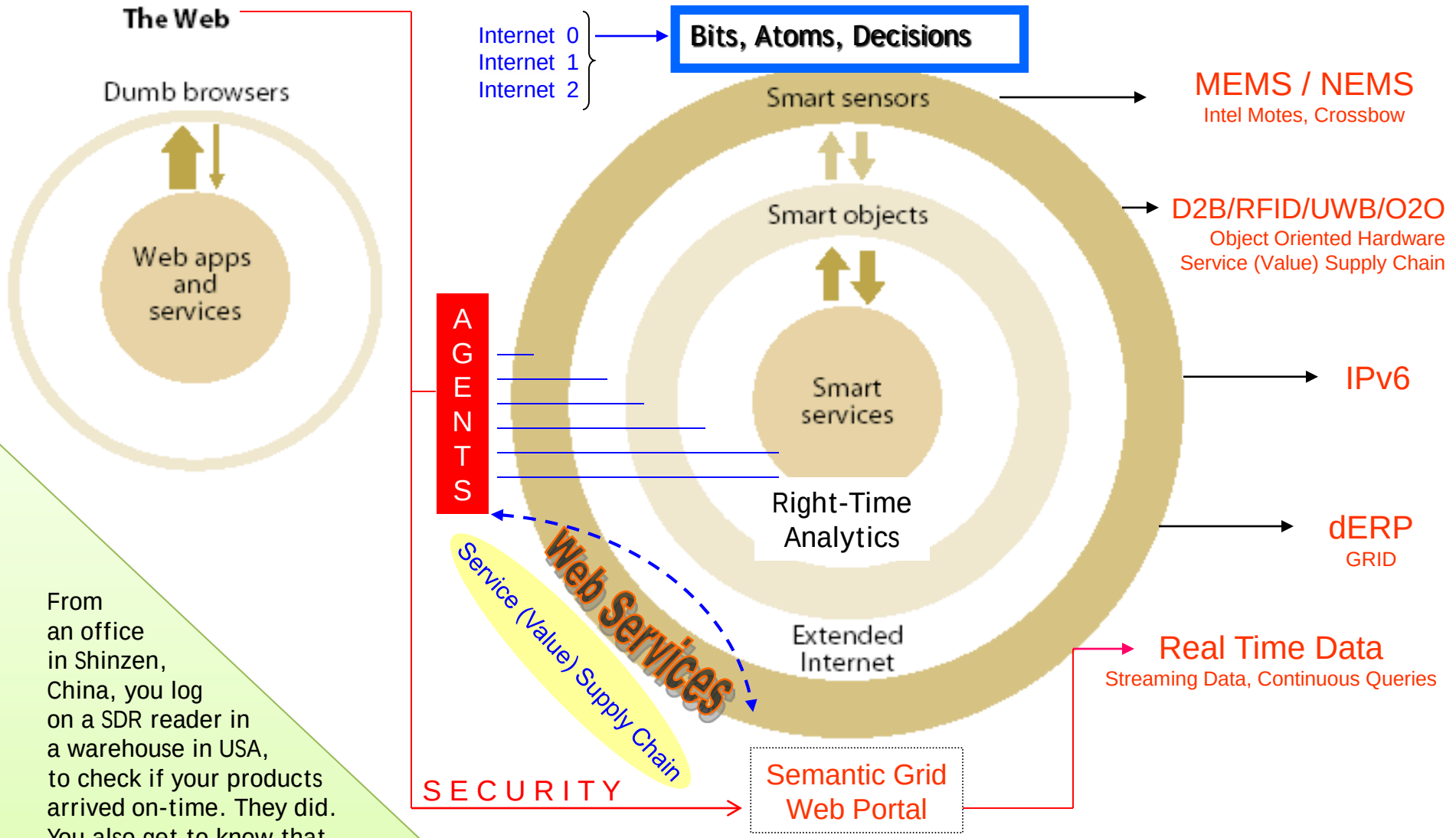
References to some of my earlier thoughts on topics related to the internet of things. A few of the concepts may find some use within the context of the industrial internet products, services and analyses of big data.

My premature suggestions …

The idea of CONNECTIVITY between the edge and the core

Illustration of Industrial Internet circa 2003-08 → Internet 0 Ubiquitous Infrastructure

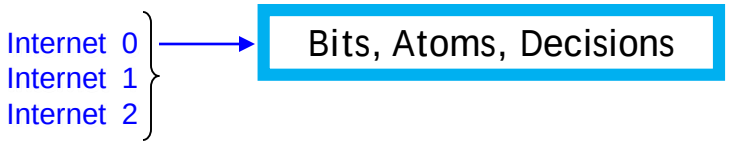
Datta 2003 , Datta 2008



From an office in Shinzen, China, you log on a SDR reader in a warehouse in USA, to check if your products arrived on-time. They did. You also get to know that your distributor in Santiago, Chile and retailer in Espoo, Finland also checked the delivery status, moments before you logged on.

SDR Data Interrogators as Ubiquitous Internet Appliance

Datta 2003 , Datta 2008



Lost in hype ?

This illustration uses the concept of Internet 0, Internet 1 and Internet 2. The purpose was to indicate that small amounts of data (0) can be as important as "big" data in transactions, updates, control parameters, autonomous response and anything else that may be instantiated based on data ("bit dribbling" was the term used by N Gershenfeld & R Krikorian). Internet 1 referred to standard data volume (neither small or too big) and Internet 2 was implied to be the future "fat pipe" carrying high volume of data.

In the opinion of the author, the value and significance of small data (2003) appears to have been overshadowed by the hype/buzz from big data (2013).

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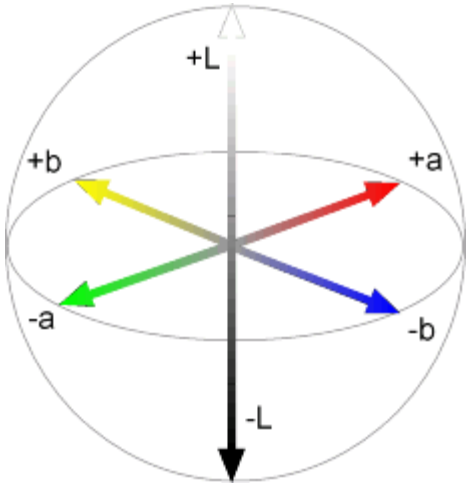
Dimensions of the IoT and Industrial Internet circa 2005



ENVIRONMENT

TIME

- On the move
- Outdoors and indoors
- Night
- Daytime
- **Real-Time**
- **Time Critical**

- **In vehicles**
- On the move
- Outdoors
- Indoors (away from the PC)
- At the PC

DATA

Connect

PLACE

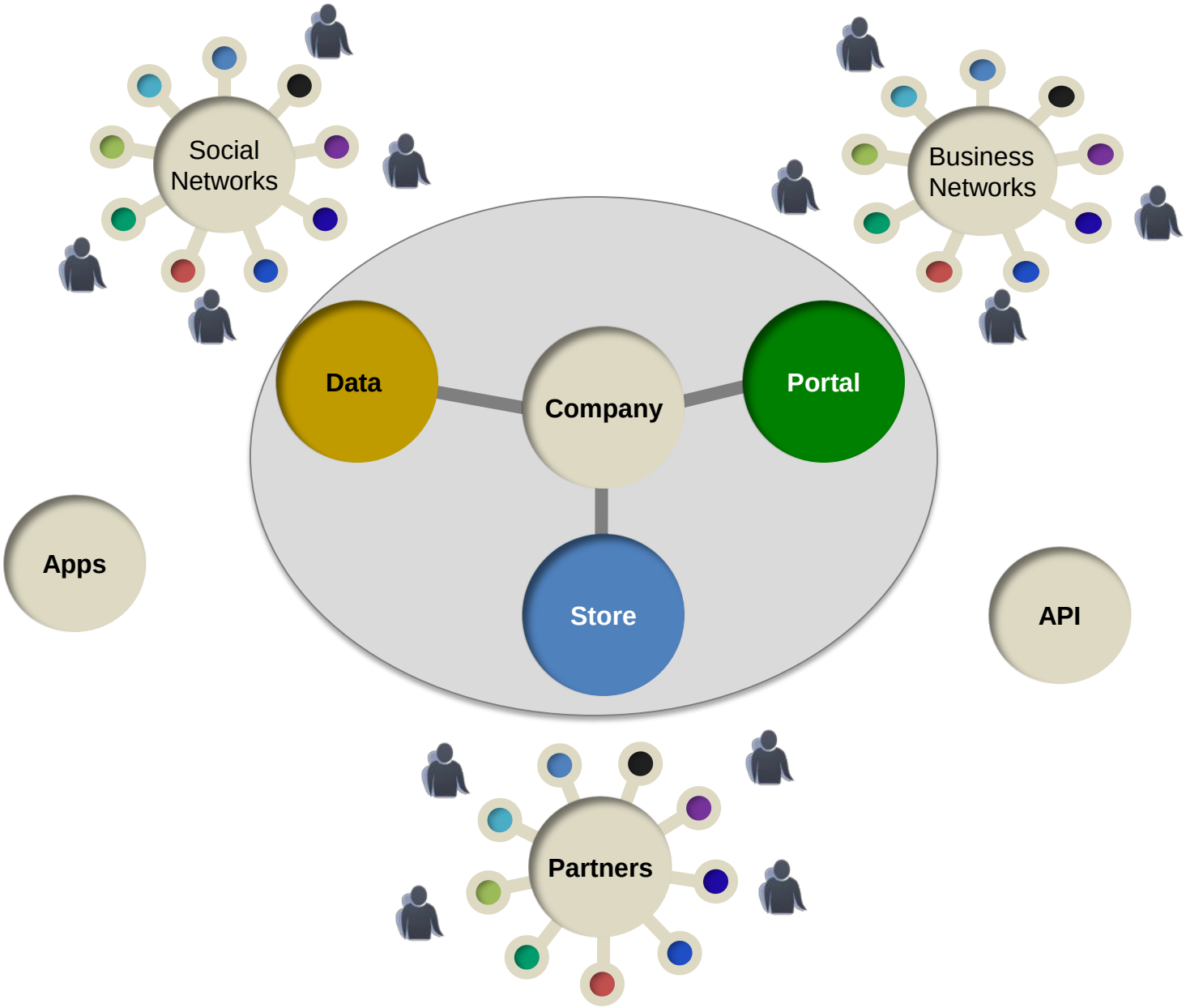
- **Act**
- **Inform**
- **Analytics**
- **Context**

- Between PCs, **Devices, Phones**
- Human to Human (H2H), **speech, language**
- Human to Thing (H2T), using generic equipment
- Thing to Thing (T2T), **M2M, O2O, D2D, V2V, A2A**

THING

(Modified from ITU) Datta, 2005

After a decade – This is the 2013 perspective of edge-core data from www.apigee.com



Anything different?

The Elusive Quest

IoT Standards and Interoperability

Which group may catalyze the move from the austerity of standards to the prosperity from interoperability?

1. Thread

Developed by Google's Nest Labs, ARM and Samsung, it expects to build a low-power mesh network as an alternative to Wi-Fi, Bluetooth and more. It use 2.4GHz unlicensed spectrum, it is built on existing standards, such as IEEE 802.15.4, IETF IPv6 and 6LoWPAN. Therefore, existing devices which use ZigBee / 6LoWPAN can easily migrate. It already connects more than 250 products on the market and has partnered with Mercedes-Benz, Whirlpool and light bulb maker LIFX. Big Ass Fans, Silicon Labs, Freescale and Yale Security are other founding members.

2. Open Interconnect Consortium

Defining the wireless connectivity to enable billions of devices to connect with each other. Set up (7/14/2014) by Intel, Dell and Samsung it also include Atmel, Broadcom, Wind River and others. It is currently focusing on smart home and office technologies but plans to target vertical sectors like automotive and health care. It expects to certify devices compliant with its standards.

3. AllSeen Alliance

Led by the Linux Foundation and Qualcomm plus big names like LG, Sharp, Panasonic, Cisco and Microsoft. There are 51 organisations in this alliance (as of July 2014) pushing for IoT standards.

4. HyperCat

A group of 40 UK-based companies, including IBM, ARM and BT, have developed an IoT standard called Hypercat, an interoperability layer that allows devices, such as lamp posts and smart meters, to interact with each other. Like an address book, it lets applications ask data hubs what types of data it holds and what permission it needs to ask them, making sense of it without human aid. It can browse machines, search by metadata and uses standards such as HTTPS. It was developed by 40 UK-based tech firms, including IBM, Intel and ARM, startups and universities that joined 12 months ago with £6.4m grant from the Technology Strategy Board (TSB) of the UK government.

5. HomeKit

Apple announced a software platform it claims will allow devices, such as locks, lights and thermostats, to be controlled from one app. Partners include Philips, which makes the Hue connected light bulb, iHome, Osram Sylvania and Texas Instruments.

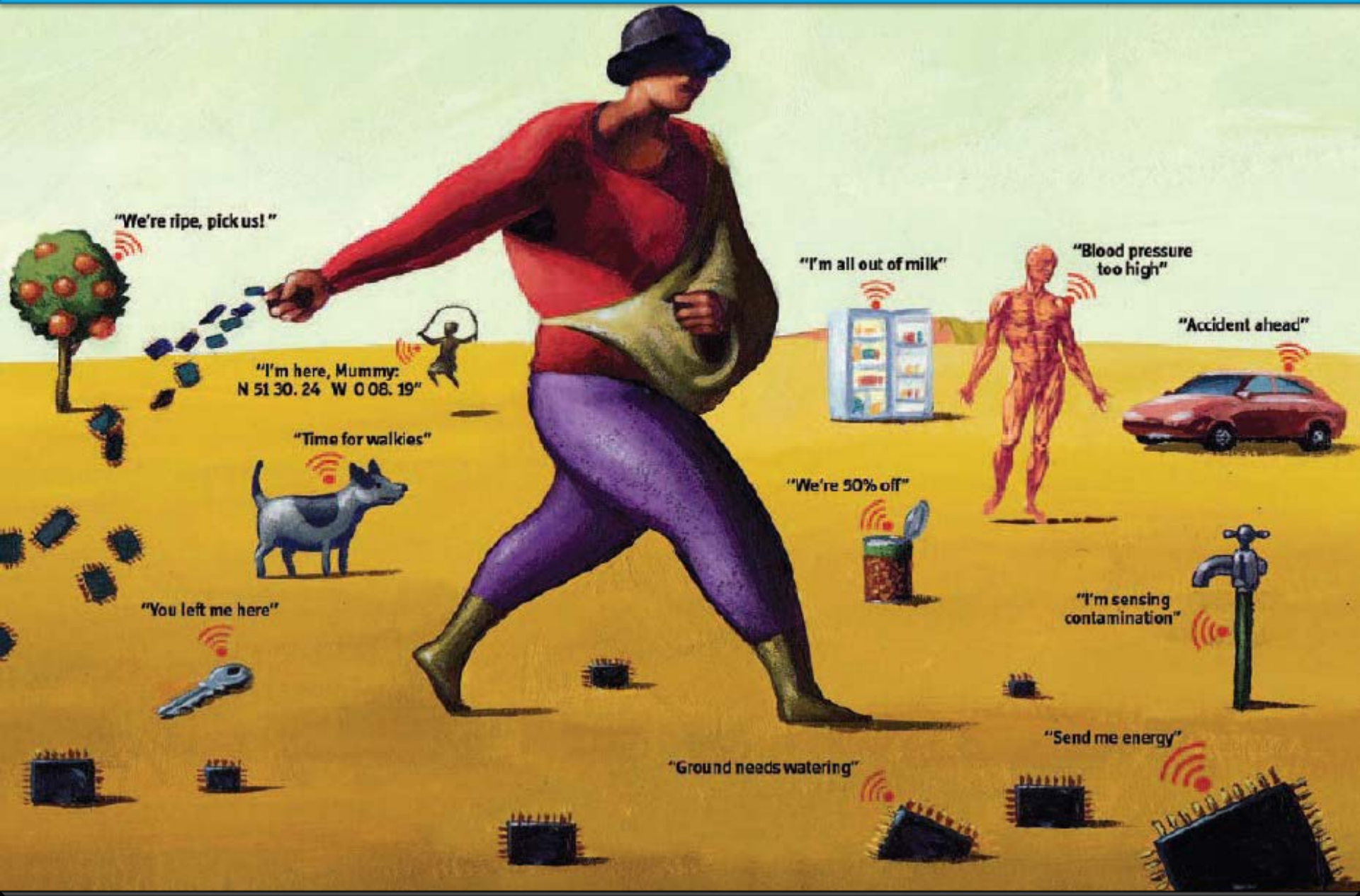
6. Industrial Internet Consortium

Intel, IBM, AT&T, GE and Cisco formed the IIC (03/27/2014) which is managed by OMG and focused on "industrial internet" apps in markets including manufacturing, oil and gas exploration, healthcare and transportation.

Modified from Paul Duffy

Ubiquitous computing scenarios

Fundamental Theme and Salient Feature of the IoT vision is based on CONNECTIVITY



Cartoon copied from a PhD thesis submitted at a Danish university. Wireless sensor networks illustrated as key infrastructure .

CONNECTIVITY powered by MESH NETWORKING

CONNECT

UBER CONNECTIVITY - *transforming the taxi trade*

Push to Talk
Say current location and where you're going. Your voice message will be delivered instantly to all nearby available taxis

Bid to Win
Increase your chance of hailing a cab during peak hours by offering extras tips up front (in addition to regular fare)

Real Time Tracking
View your taxi's location in real-time, push to talk to the driver directly to coordinate pick-up

Reinventing Lifestyle

The JetSmarter App connects you
with a private jet at the tap of a button

Download App

Watch video

Request information

Air Carrier Inquiry

THE APP-LIST

THE UBER OF PRIVATE JETS IS HERE

Summon a private jet to pick you up with the touch of a button.

By Lauren Fisher on Aug 1, 2014 Share:

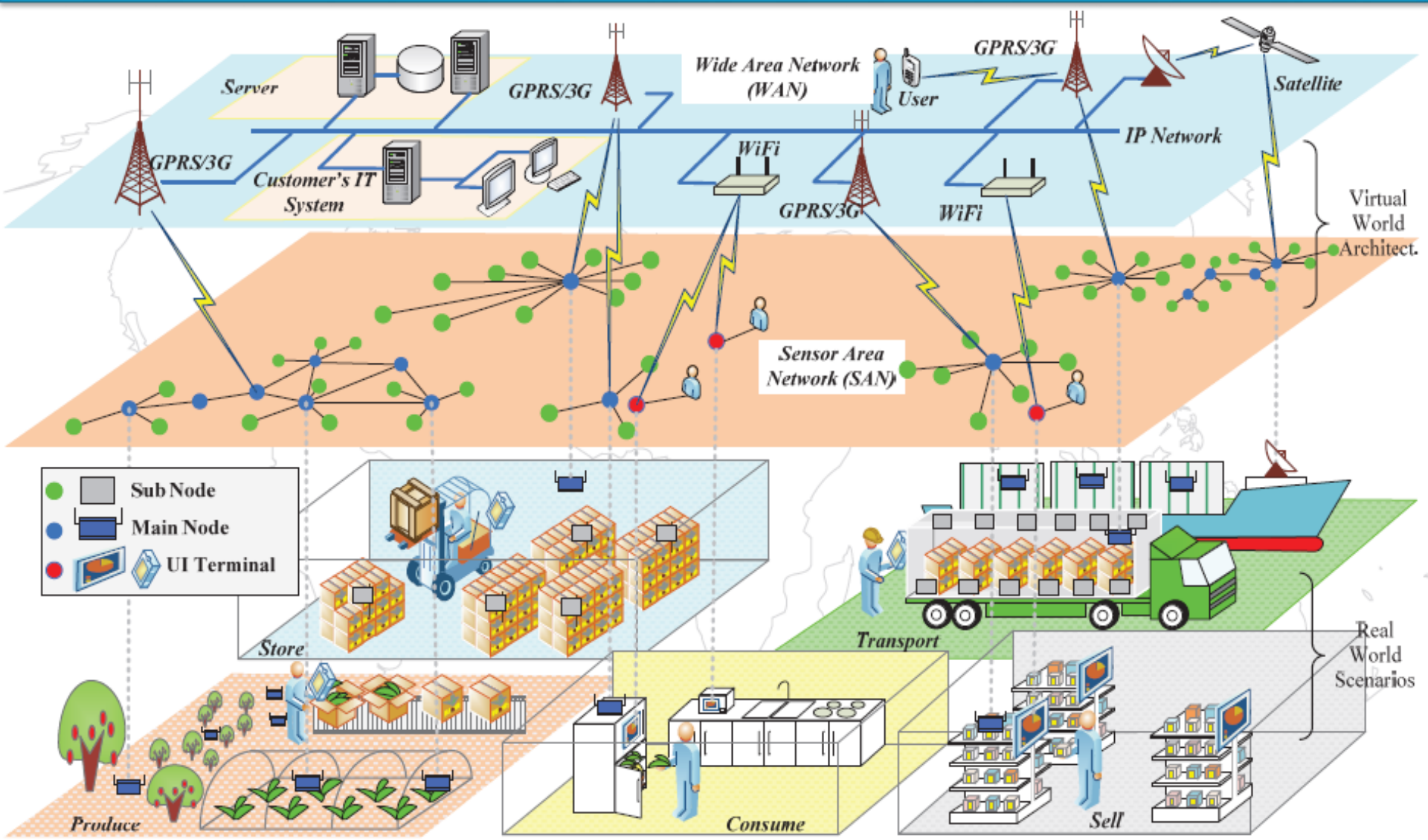
Your ticket to escaping August's insane summer weekend traffic is here. Modeled as the Uber for private jets, Jetsmarter allows app users to charter a plane from anywhere in the world at a moment's notice. The app offers instant pricing, and boasts rates that are 17% cheaper than the Marquis Jet Card, and the option to choose from five different air carrier sizes from 'Very Light Jet' to 'Heavy Jet'. Flights are available to anywhere, from New York to Tokyo, and can be booked by the hour. The ultimate in luxury travel, Jetsmarter takes Uber's genius vision to the next level. For a cool $3K, you can really can be in the Hamptons by cocktail hour.

Jetsmarter app is free and available for download here.

IoT Inter-domain integration scenarios

- CONNECTIVITY
- INTEROPERABILITY
- INTEGRATION
- INTELLIGENCE
- SENSE-RESPONSE
- ACTUATORS
- SMALL DATA / BIG DATA
- ANALYTICS
- AUTONOMOUS
- ECOSYSTEMS
- STANDARDS
- ECONOMIC IMPACT

Connectivity generates data from/about distributed devices, locations, sensors, status



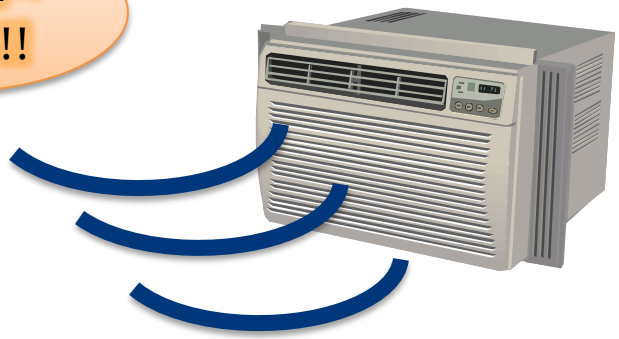
Asking correct questions in the context of the problem is key to unlocking value from data analytics. It may suggest solutions or trigger autonomous responses to adapt, optimize, transact or execute within a system or between multiple system of systems.

IoT Energy Management

Energy efficiency

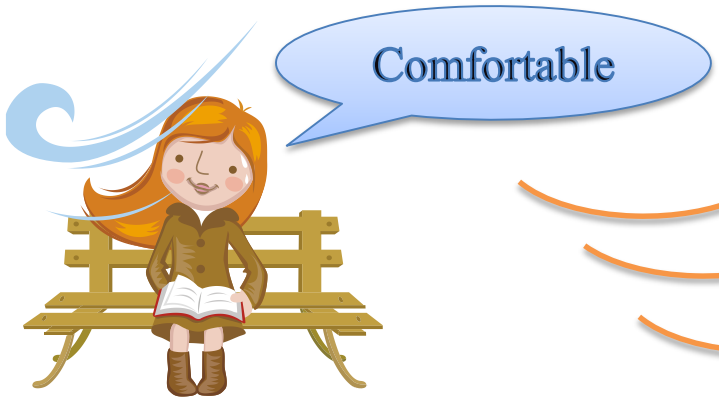
Energy Efficiency - *answers, not numbers* - Customer Satisfaction

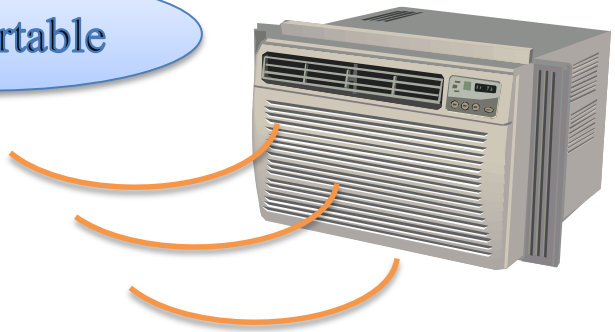
BEFORE



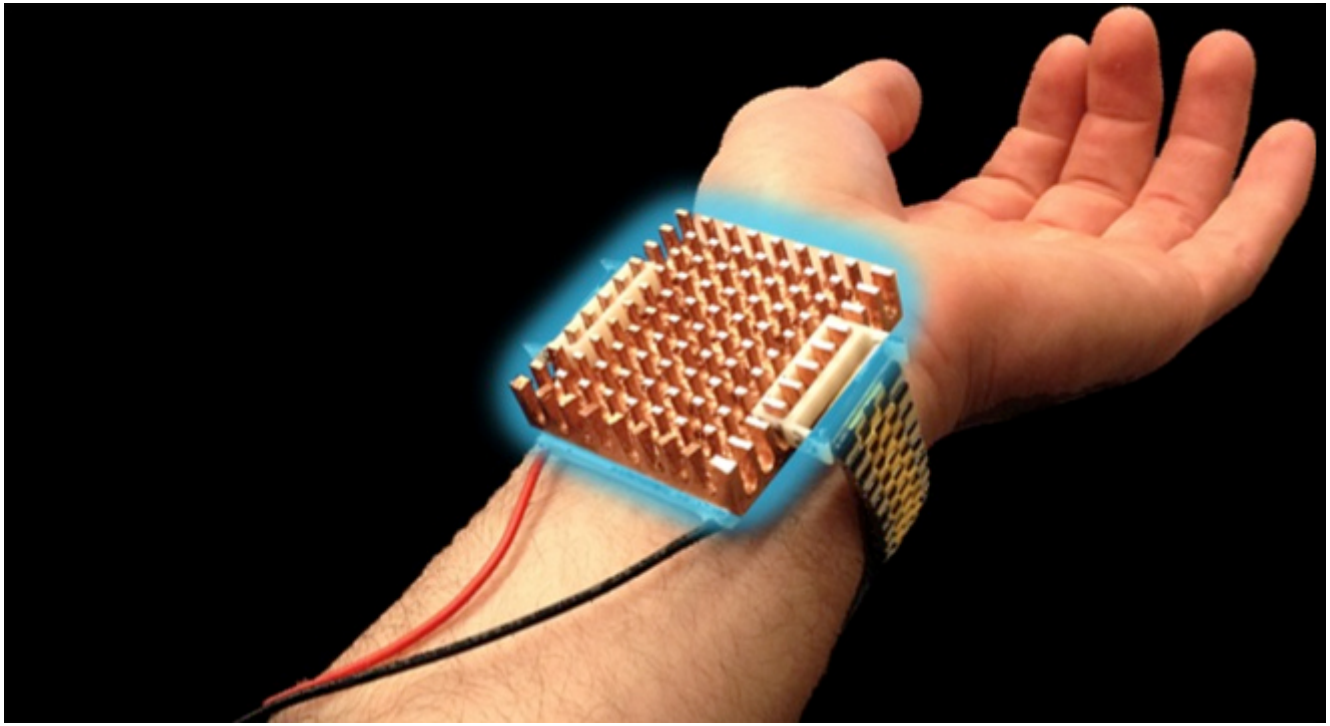
Optimize

AFTER



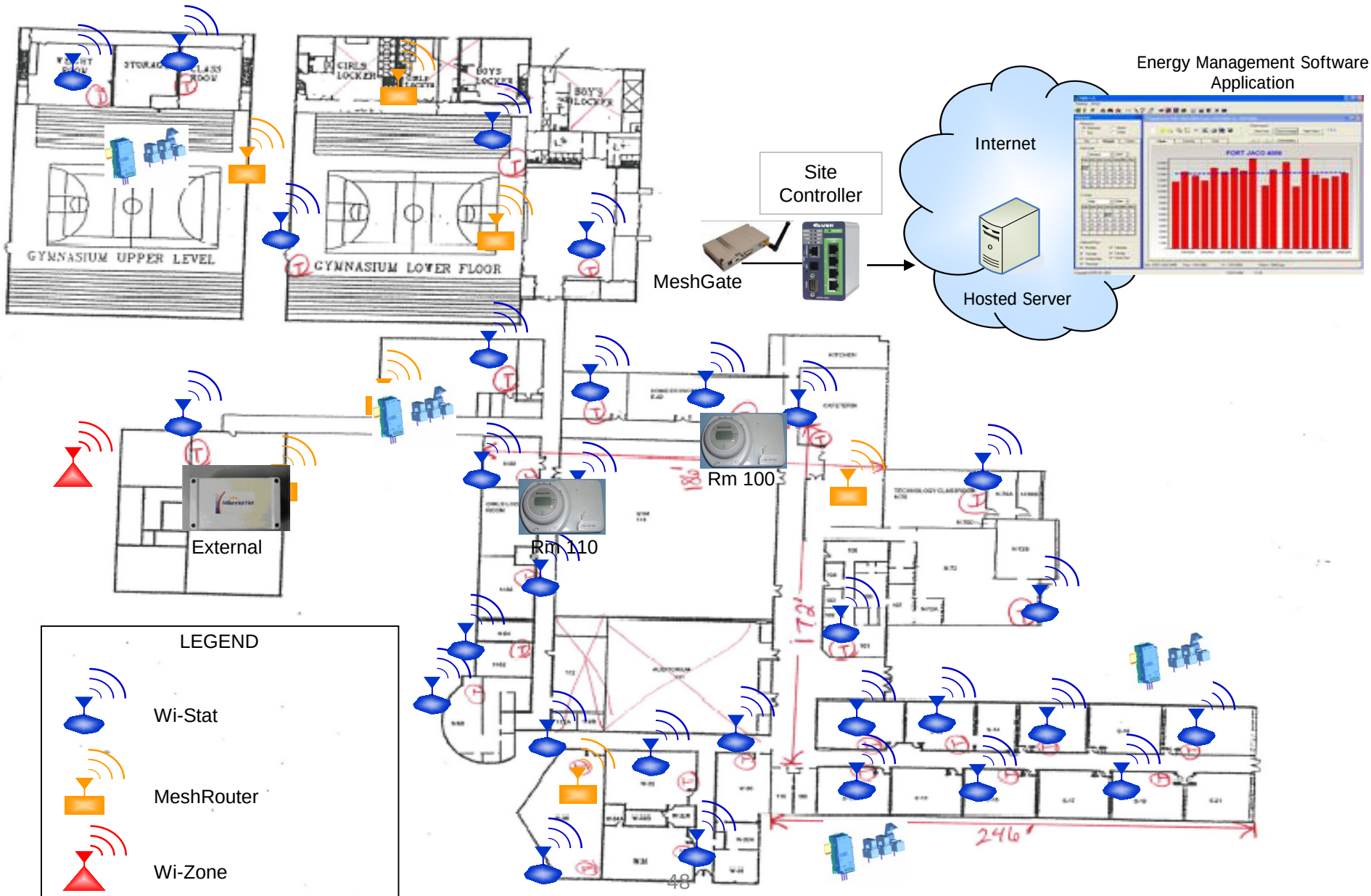


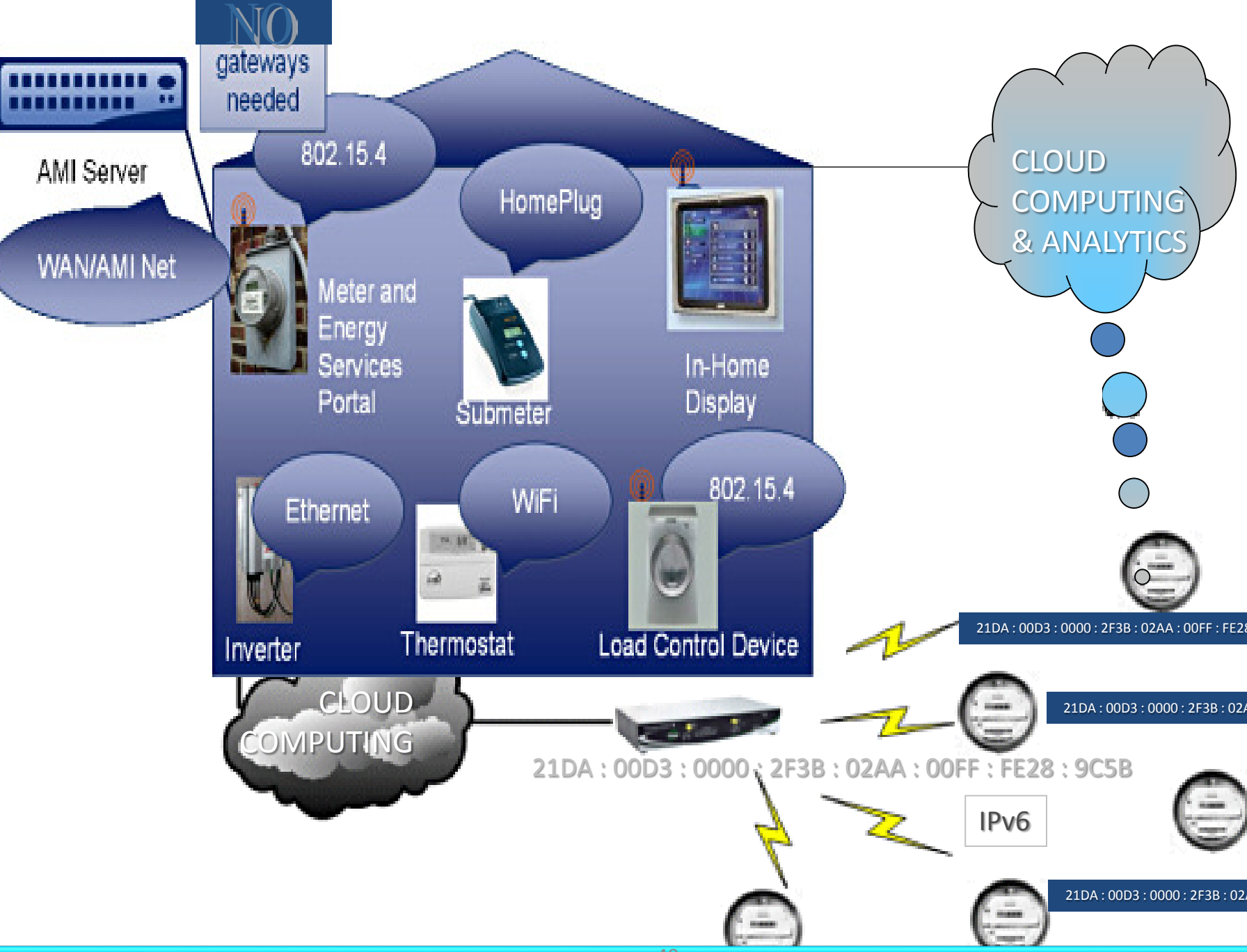
Why cool the house, just cool yourself with WRISTIFY



WRISTIFY by Sam Shanes, MIT undergraduate

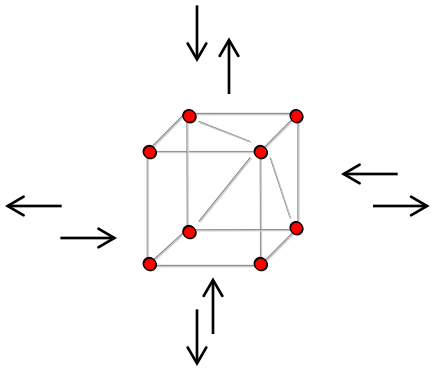
Energy Management System using Wireless Sensor Network

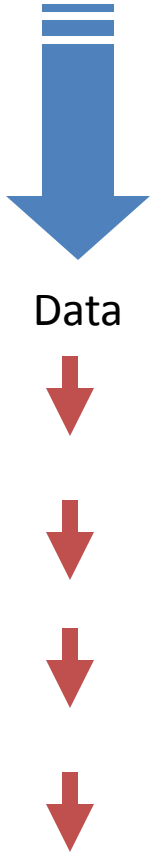




MITOCHONDRIA

Wireless Sensor Mesh Networks Integrated with Monitors, Devices & Places





meters readers sensors tools

mall school factory buildings

Zone 1

Zone 2

Metropolis

Area

Sub-Station

Station

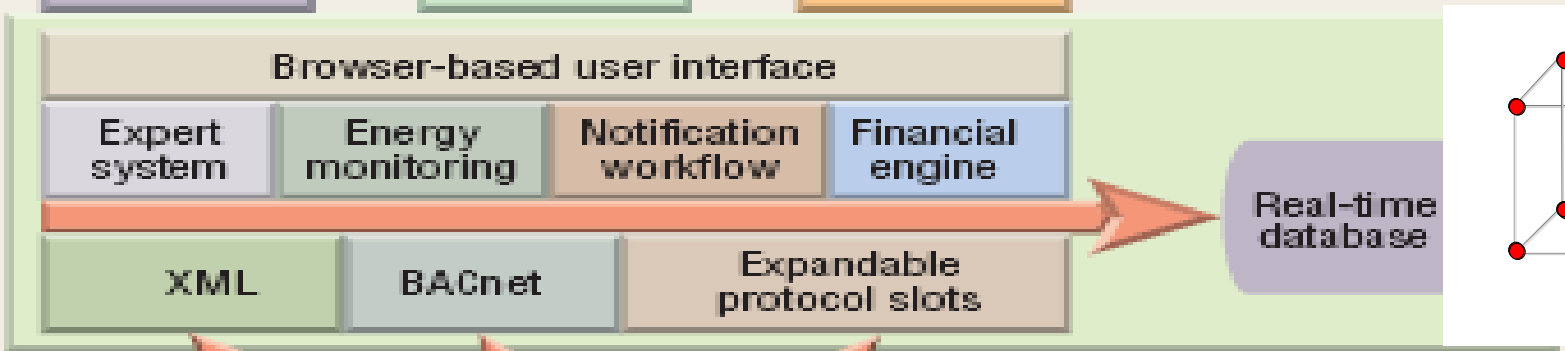
Data

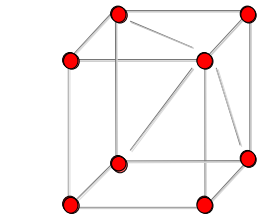
Decisions

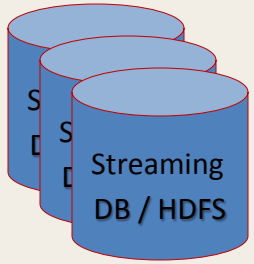
Feedback

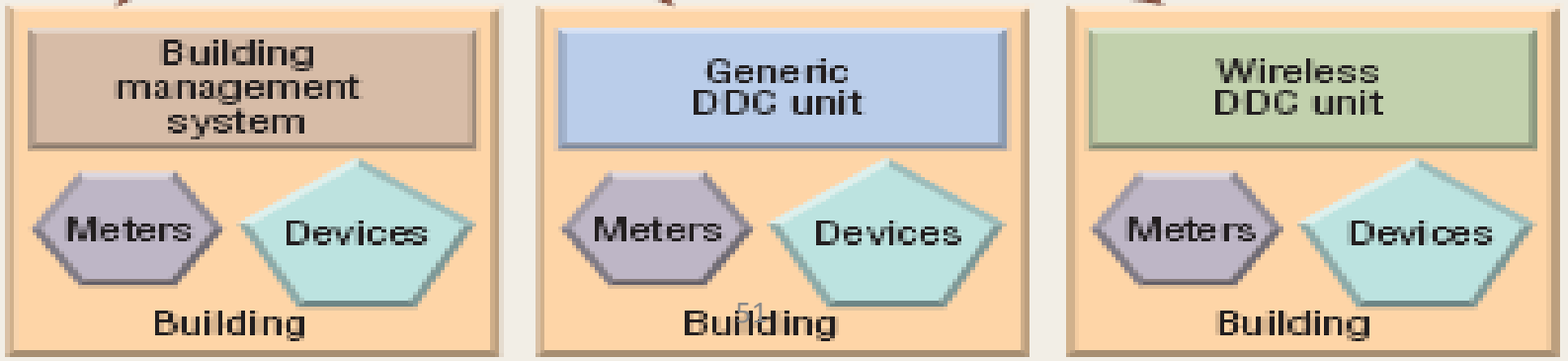
ENERGY EFFICIENCY

Field Devices: Systems Integration



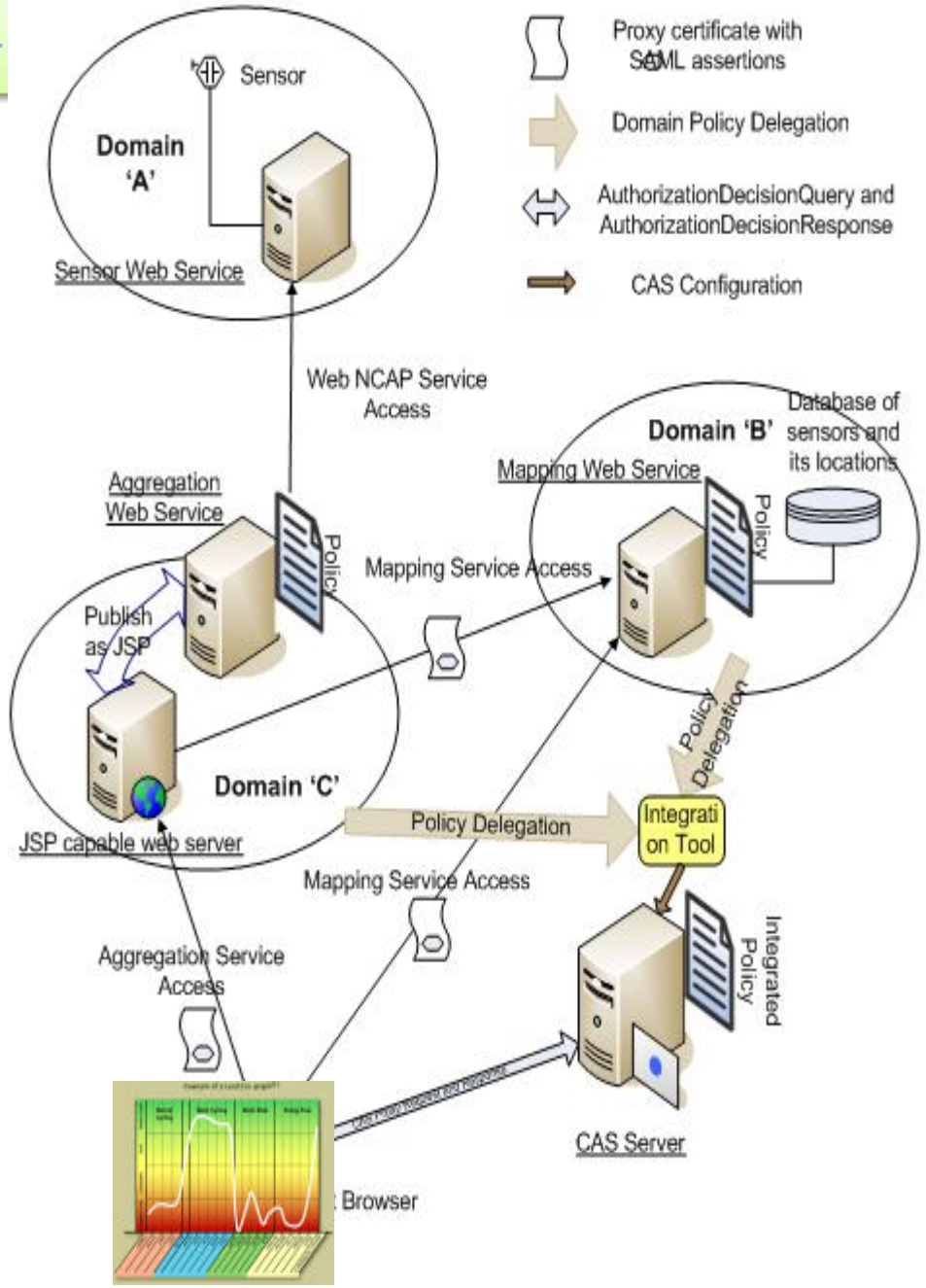






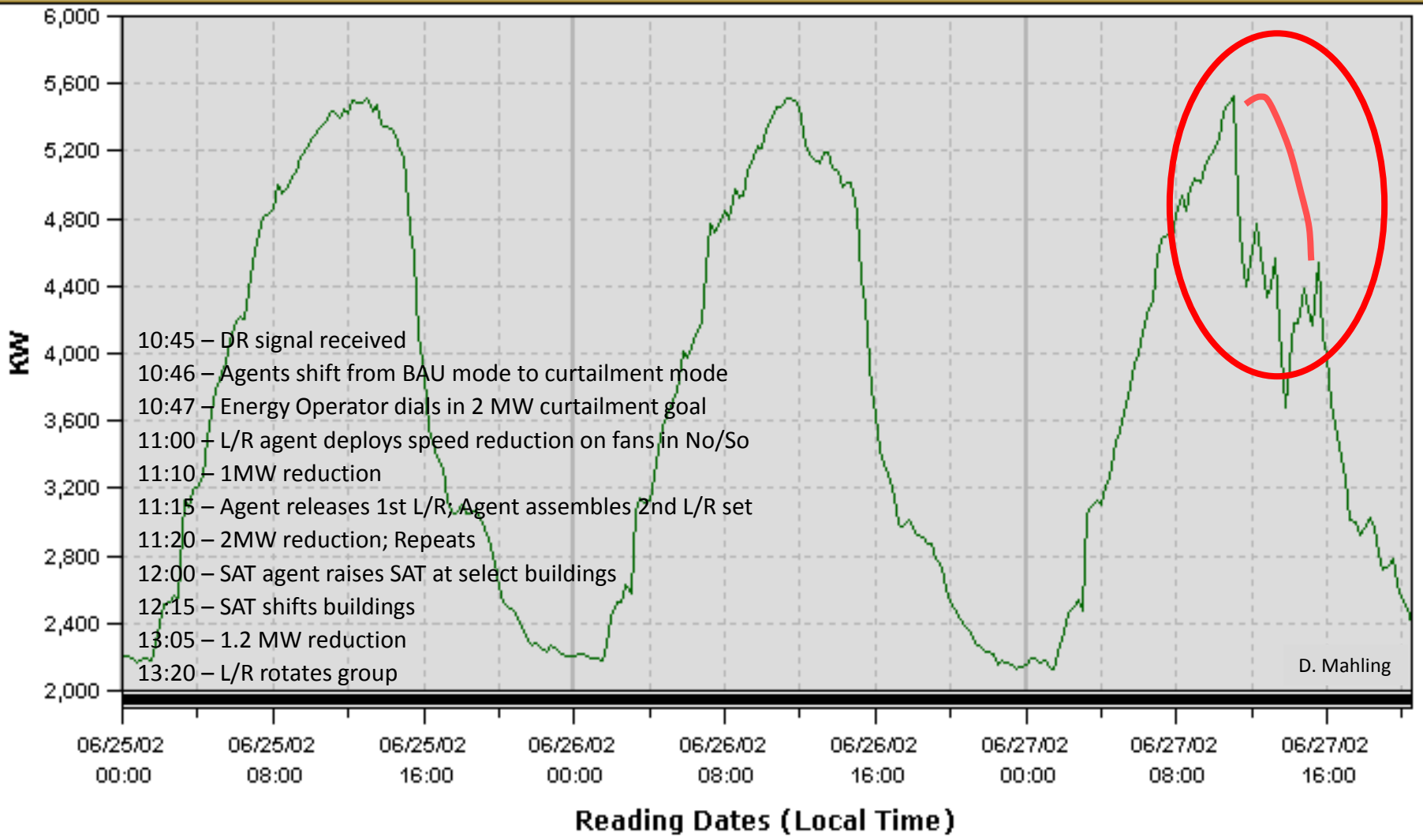
Intelligent reports using data

- Analysis of system efficiency
- Early warning of system exception
- Analysis for power consumption
- Analysis of environmental sensor
- Reports for warning and data



ENERGY EFFICIENCY - granular data enables demand response, load balancing & usage regulation

Energy Load Balancing – Automated Demand Response



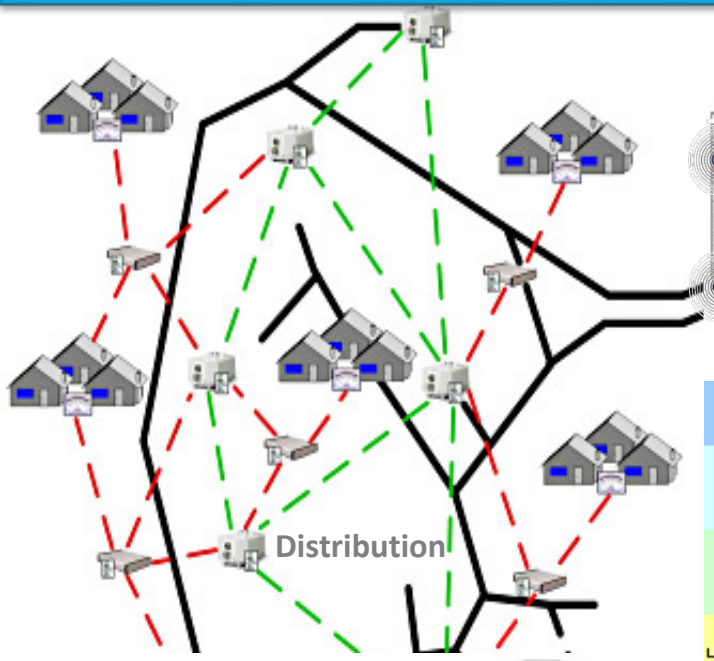
Graph Legend

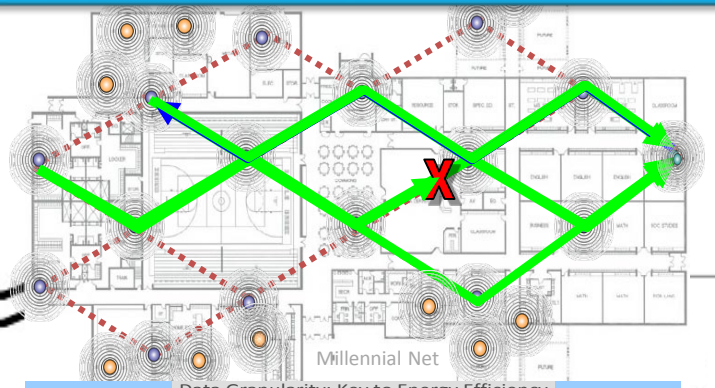
Bank of America : Northern CA

Northern CA -> Demand 15 Minute (KW)

- Signal to building system - curtail 2 MW for ~4 hrs across 78 sites
- Base load for 78 retail branches approximately 10 megawatts (MW)
- Signal received at 10:45am [15 min ahead of start time 11am]
- Curtailment commenced at 11am and completed at 4pm

Energy Efficiency – Consumption, Distribution, Production – Data Visibility





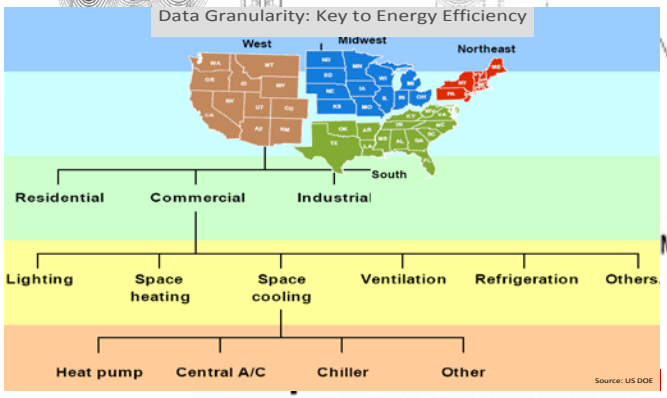
External Users

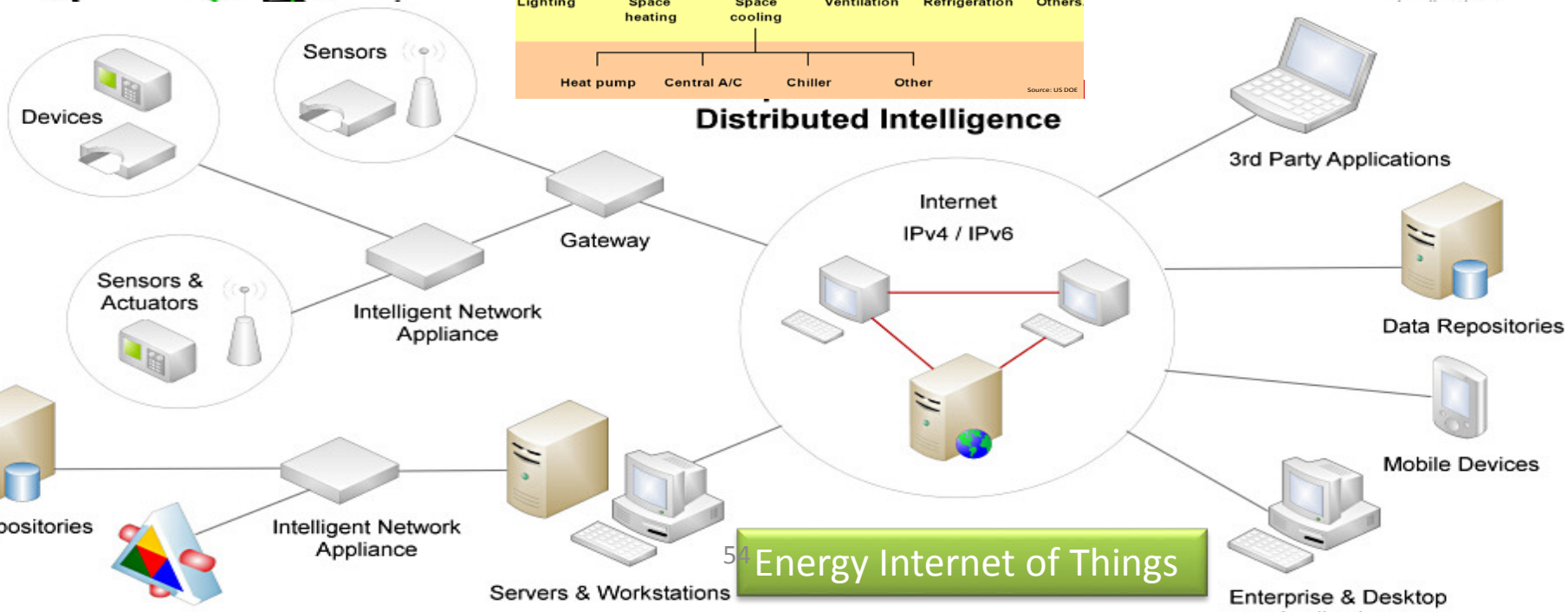
Energy Decision Support

Internet

Mobile Devices

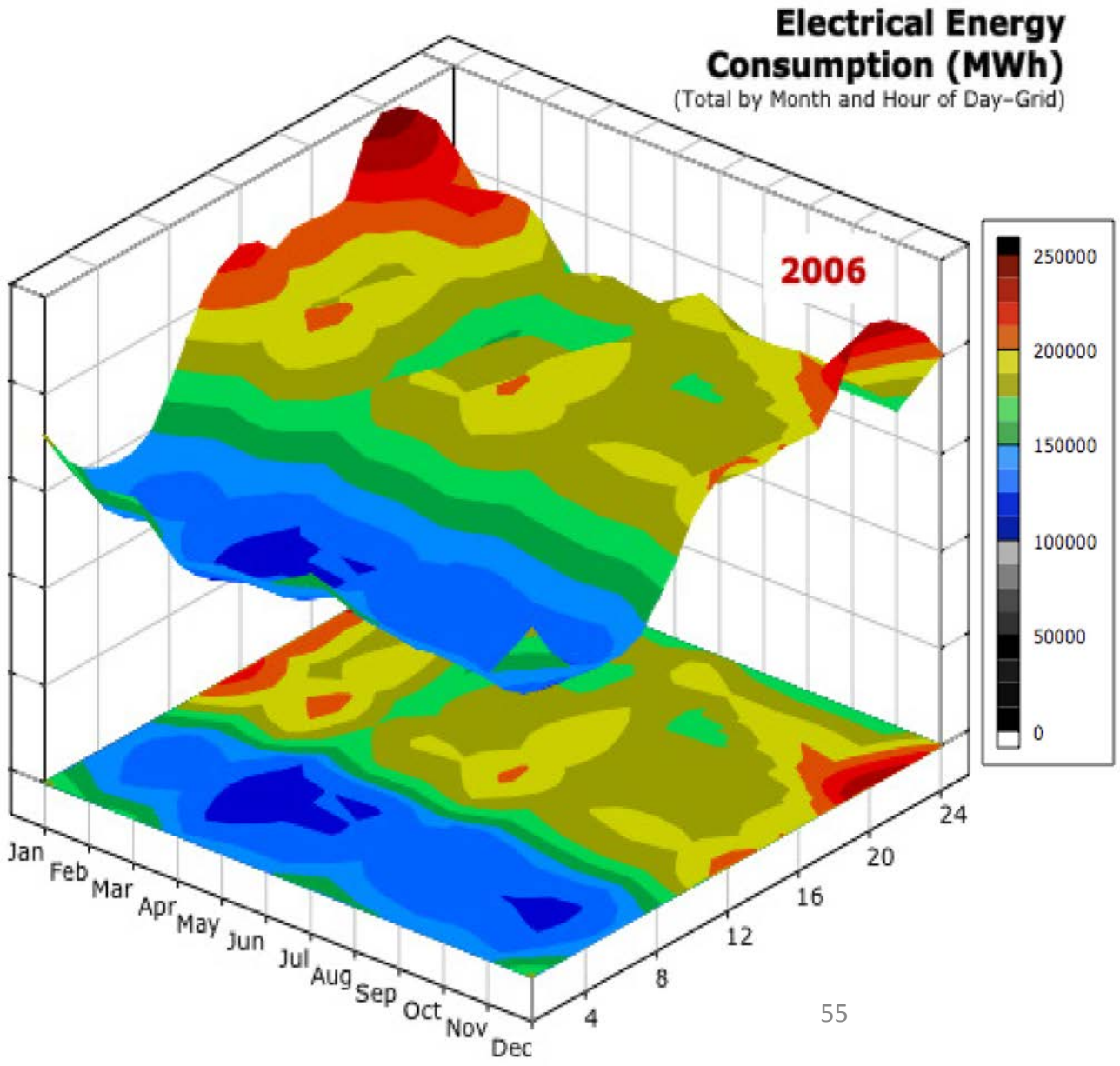
Enterprise End-User

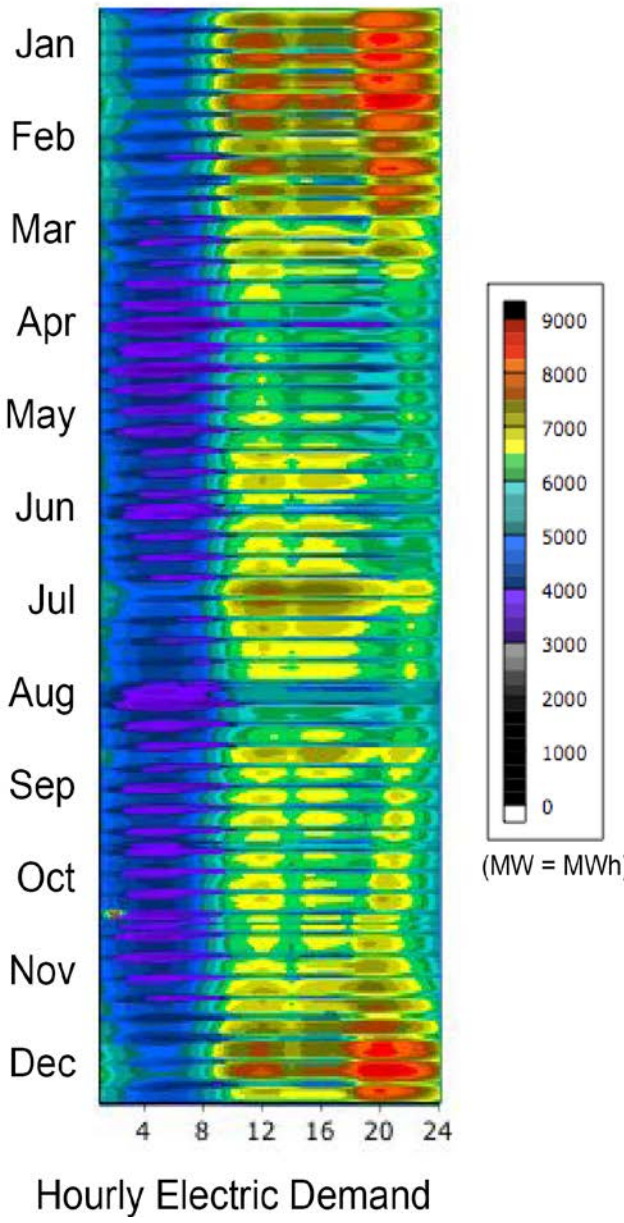




Energy Internet of Things

Energy Efficiency – Consumption, Distribution, Production – Country Data

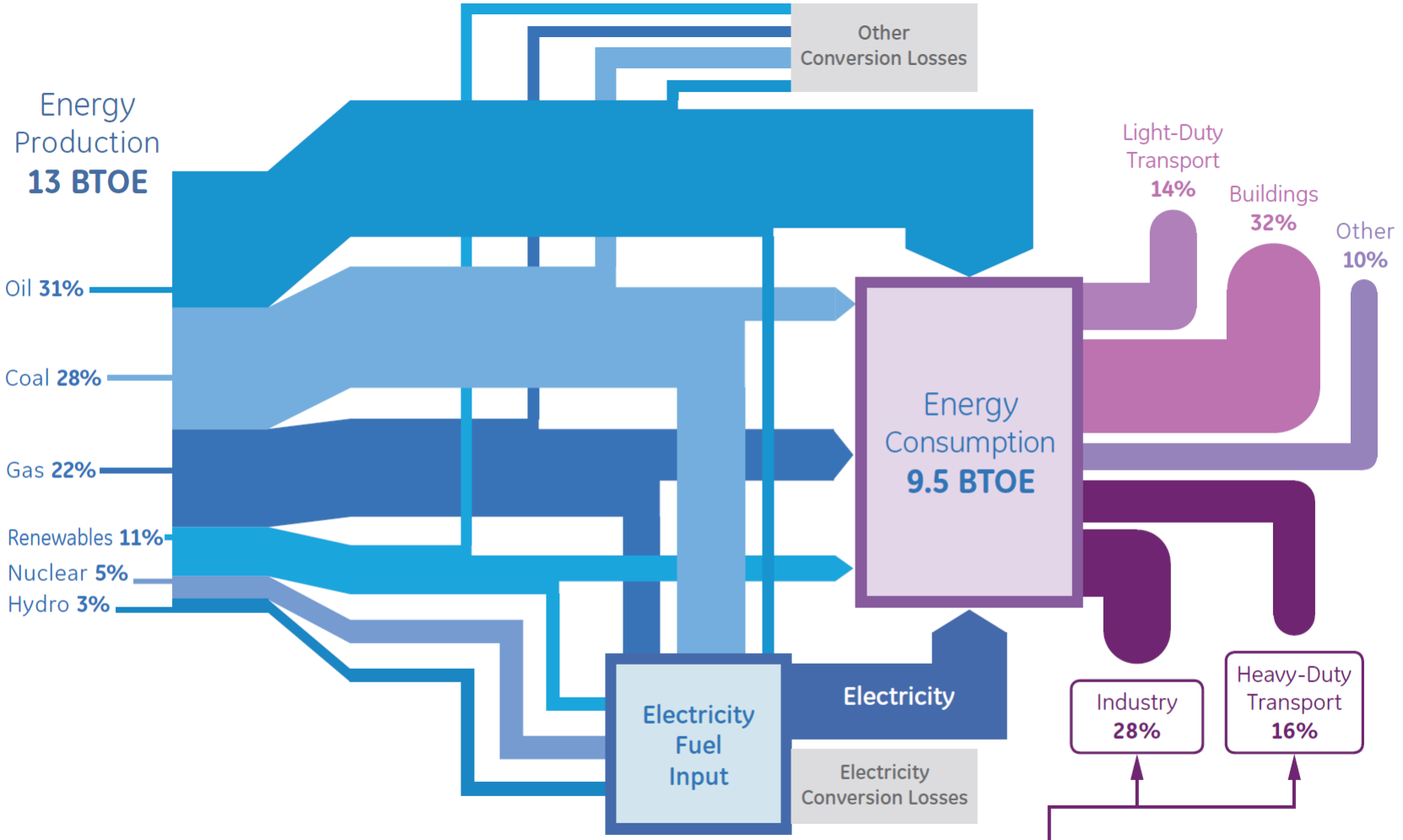




Source: MIT Portugal

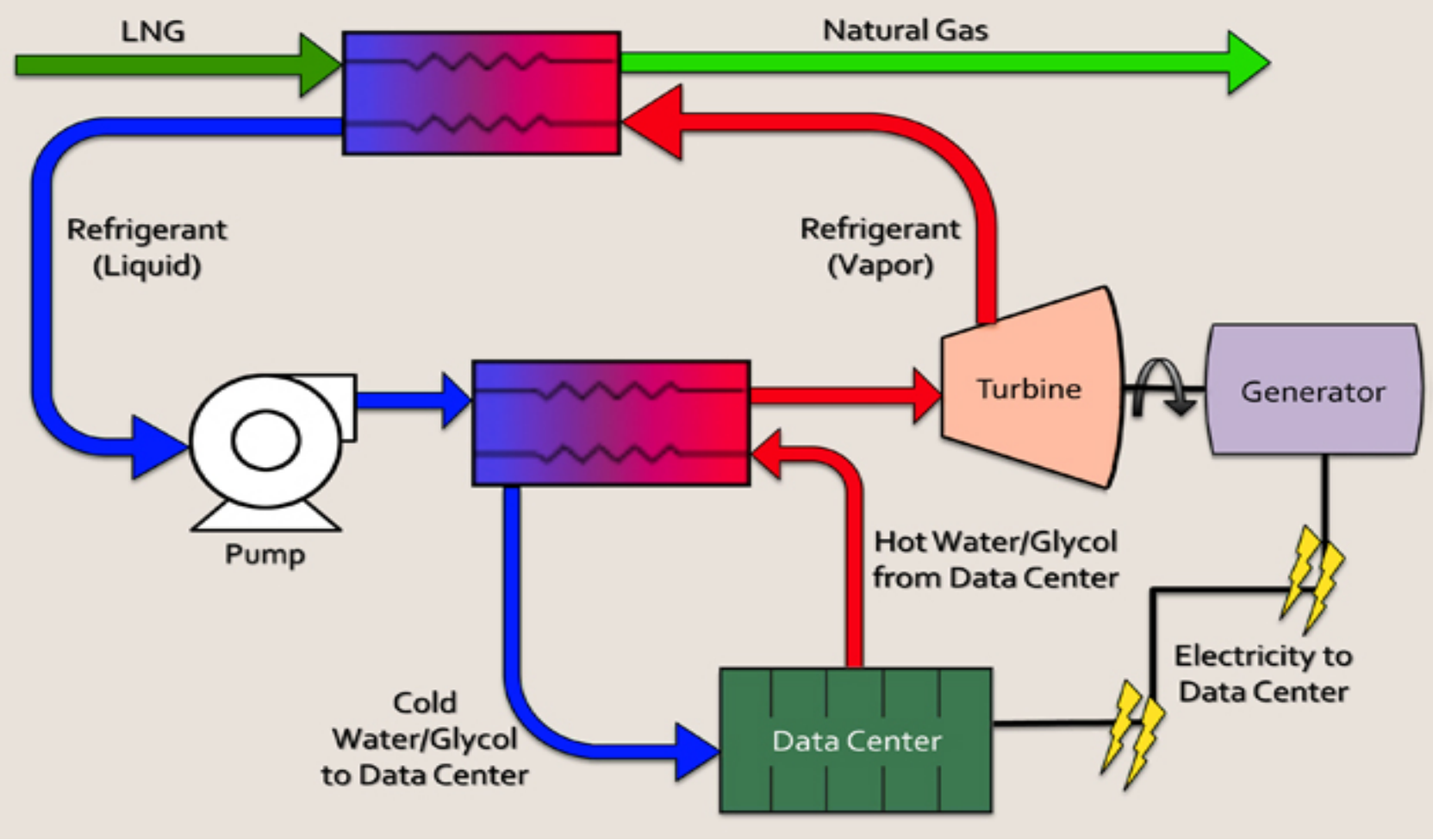
ENERGY EFFICIENCY IoT ● optimization of energy management

Dr Peter Closson Evans (GE Global Strategy and Analytics, 2013)



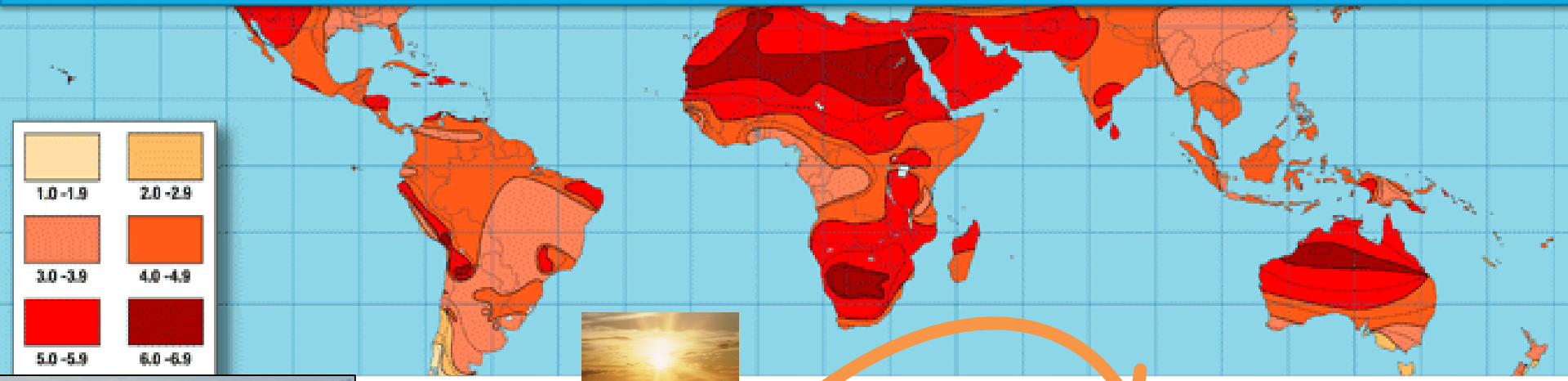
Connectivity between energy production & energy consumption reduces energy waste

ENERGY RECLAMATION – Is this an efficient model ?



Cool data centers use “cold” produced when converting stored liquid gas into pipeline-ready gas. Build Data Centers adjacent to LNG terminals at ports – not in the Arctic Circle (TeraCool).

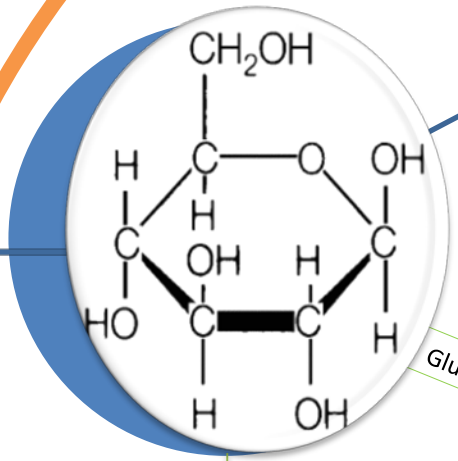
ENERGY as a SERVICE – Sunshine as a Service (SaaS)




Ivanpah Solar Energy Plant

Micro Algae

Cyano Bacteria



Glucose

Glucose

Liquid Fuel Generator

C 4
C 5

Butanol
Pentanol
Liquid Fuel

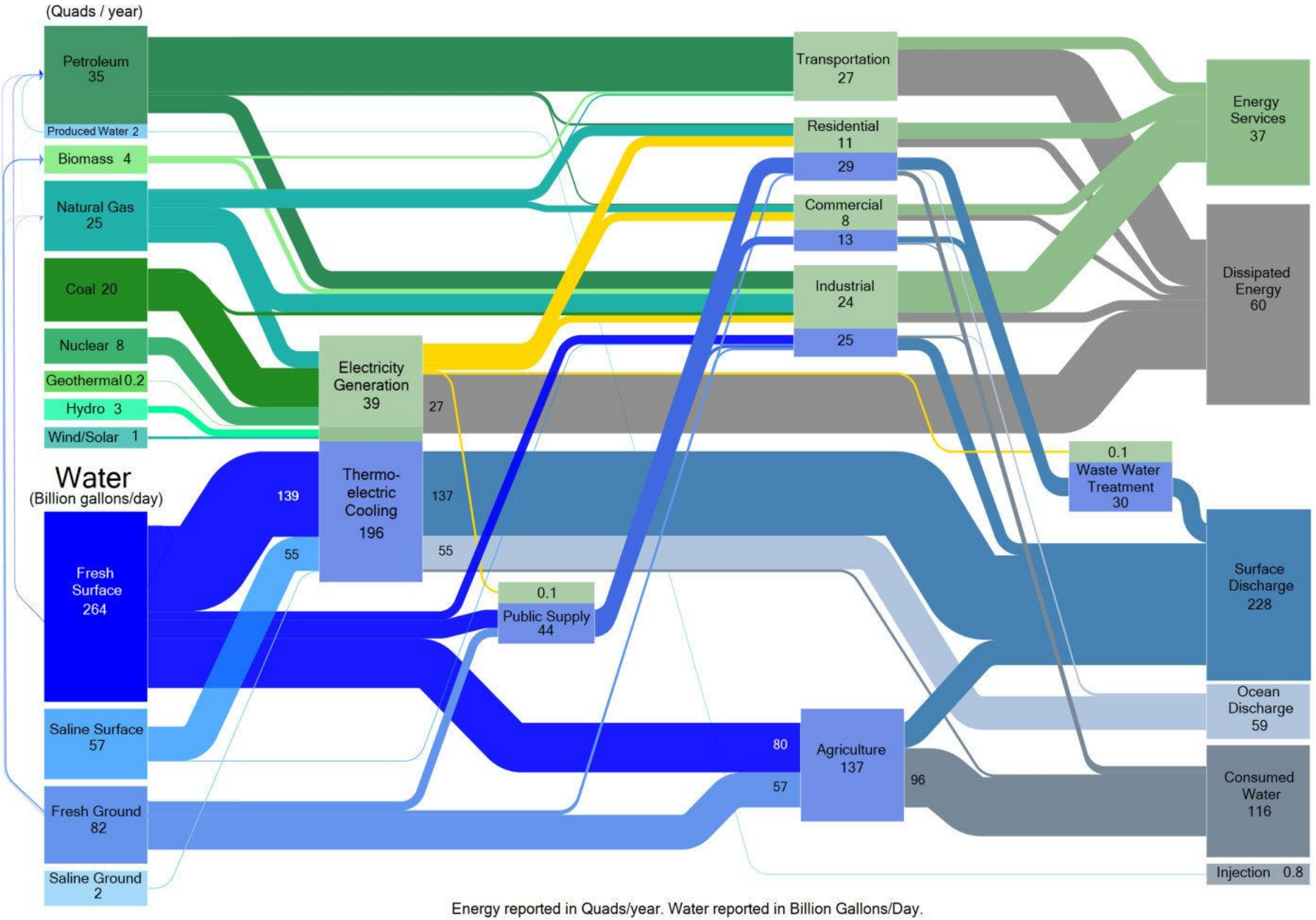
Low Insolation Commodity

C 6

Glucose
Non-perishable Energy Security

Energy Cottage Industry – The Social Business of Off-Grid Power

ENERGY and WATER – IoT and Smart Cities to converge the management



Energy reported in Quads/year. Water reported in Billion Gallons/Day.

IoT Domain Specific Scenario

Aircraft Maintenance

Classical Triple Control System – Redundancy increases complexity, system size & power consumption

Actuators

Sensors

Actuator Control Electronics

Each ACE votes on redundant actuator commands

Pilot Inputs

Column

All data communicated on redundant data buses

Each PFC votes on redundant sensor/pilot inputs

Primary Flight Computer

Add “on the ground” issues to the issues “in the air” and we are looking down a financial drainage system

19,975 commercial aircraft globally

205 million man-hours to service annually*

Dr Peter Closson Evans (GE Global Strategy and Analytics, 2013)

Aviation may harbor vast inefficiencies which presents enormous opportunities for economic growth

Classical Triple Control System – Redundancy increases complexity, system size & power consumption

Actuators

Sensors

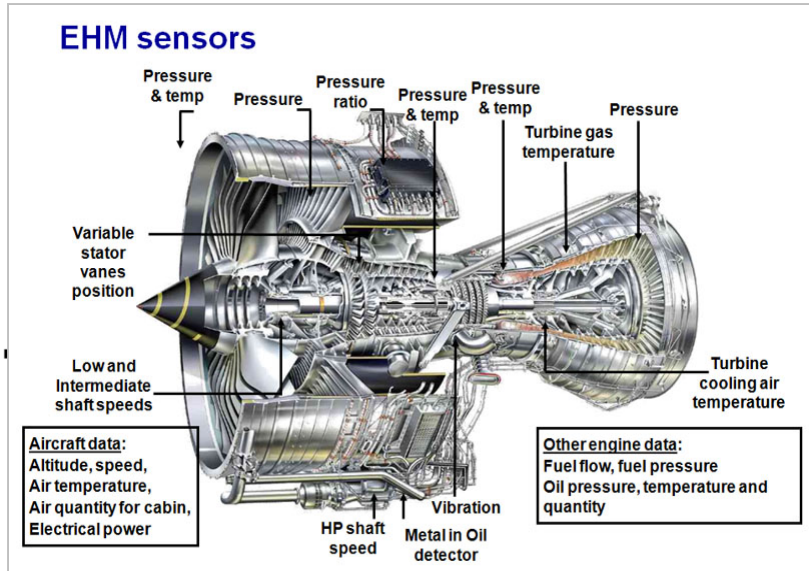
Actuator Control Electronics

Pilot Inputs

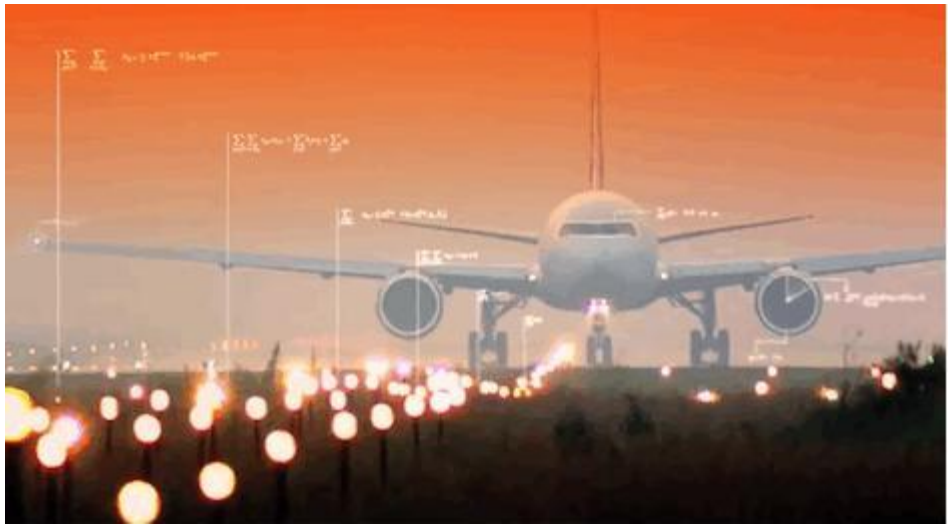
Column

Primary Flight Computer

IoT connectivity will make it possible –
An airplane pulls up to the gate and data from sensors automatically downloaded.



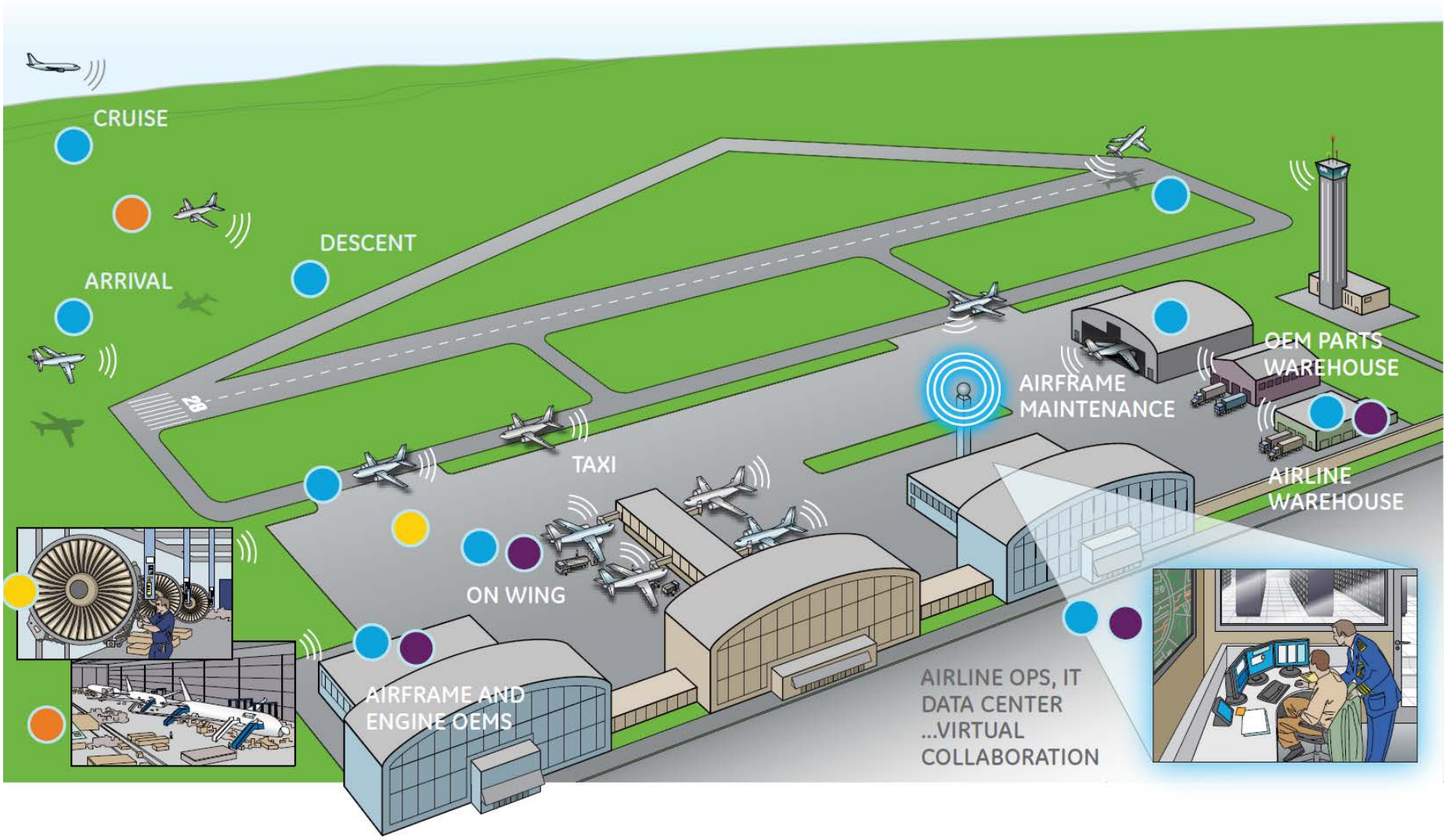
Aero & Astro – Aircraft Maintenance and Diagnostics IoT connectivity will re-shape maintenance (MRO)



An airplane lands and data from sensors automatically downloaded to local and global maintenance centers. Reduces downtime, predicts potential inventory of spare parts from in-flight data and optimizes performance.

Aviation – Aircraft Diagnostics and Maintenance

IoT will optimize asset optimization, security and visibility of work in progress



Service Quality | Asset and Facility Optimization | Fleet and Network Optimization | Asset Performance

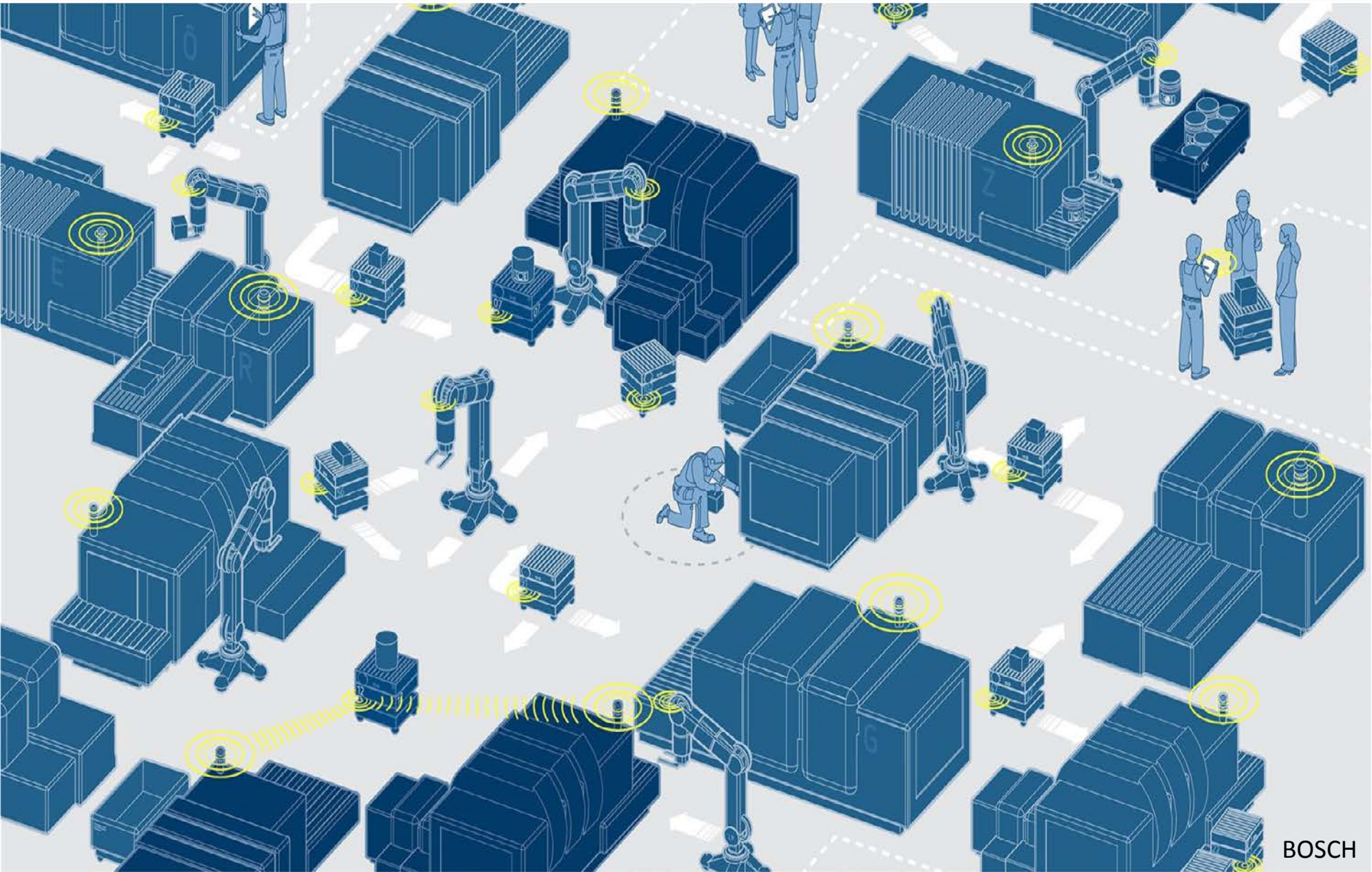
Dr Peter Closson Evans (GE Global Strategy and Analytics, 2013)

IoT Domain Specific Scenario

Smart Manufacturing

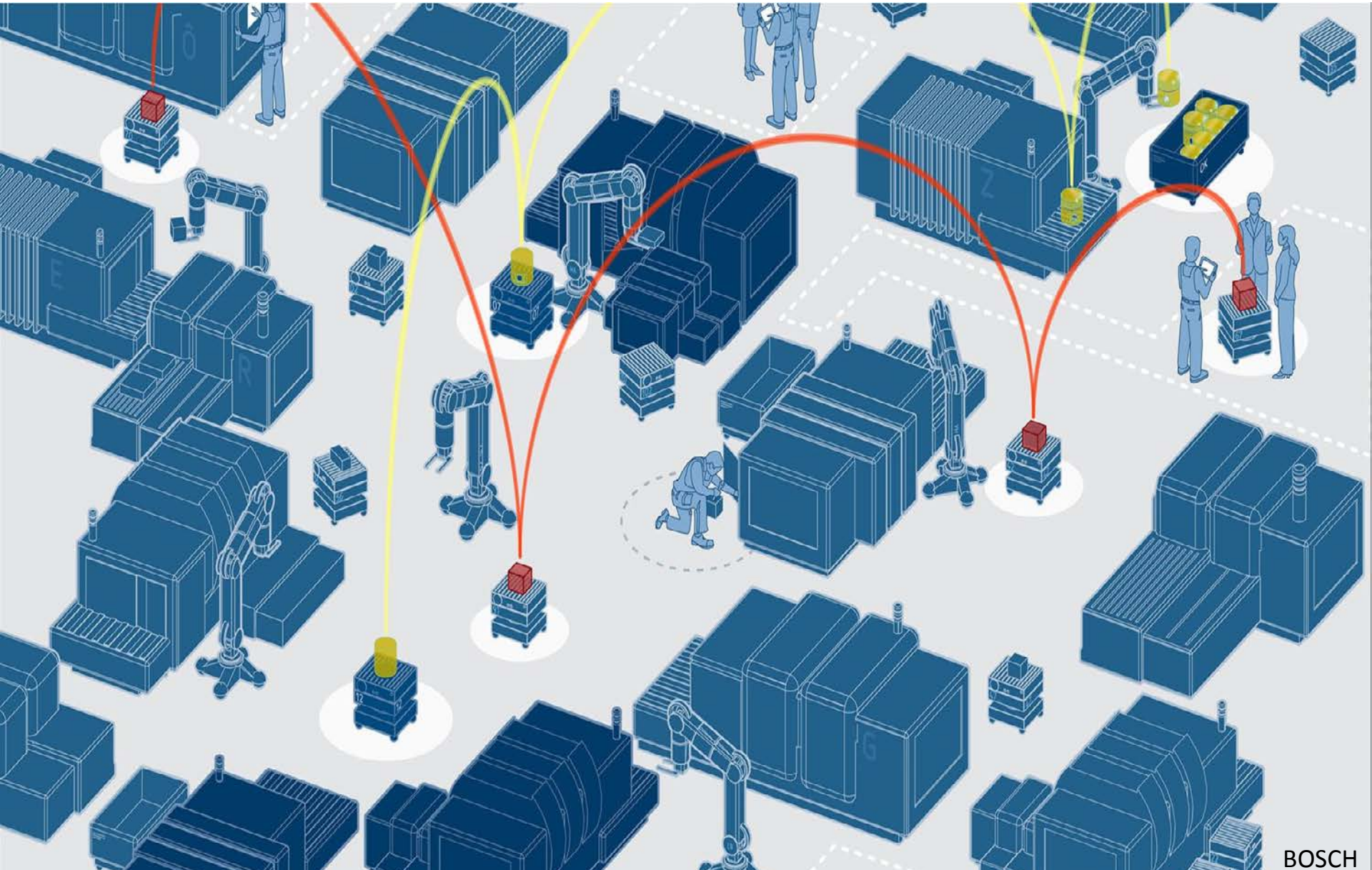
Smart Factory

Improves Agility in Manufacturing



Smart Factory

Improves Flexibility for Variant Configuration



BOSCH

V2VIN
IoT Domain Specific Scenario

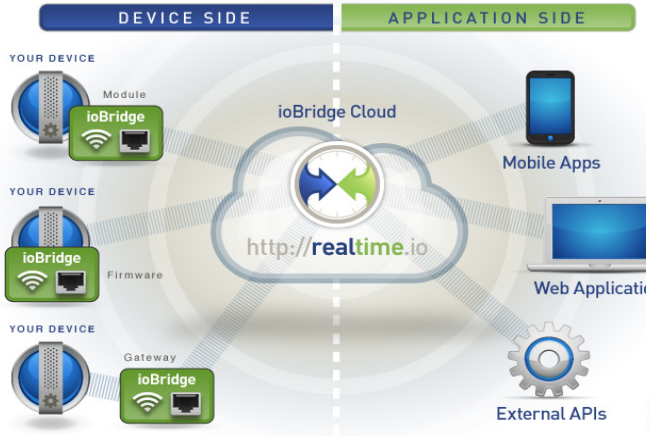
Connectivity, Communication, Integration, Automation

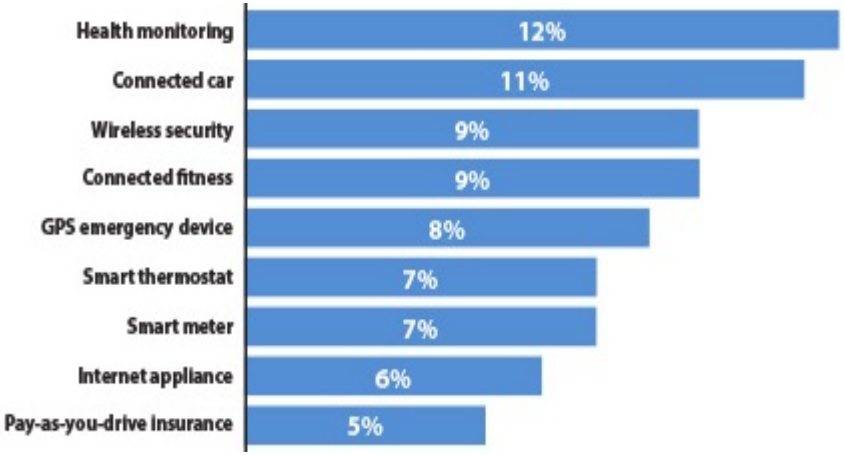
Vehicle 2 Vehicle, Infrastructure and Network (VIN)

Industrial Internet of service delivery: flow of information proportional to connectivity

...more numerous, valuable, and relevant connections with other cars,

Industrial Internet / IoT service delivery – functionality is proportional to integration





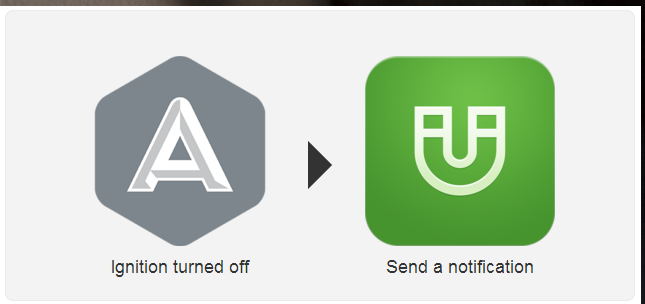
Reduce emissions by 15% and save ~1 billion liters of fuel each year (in Germany alone)

jalopnik.com/audi-will-save-fuel-by-turning-every-light-green-in-fro-1540311906?rev=1394456766

How? By synchronizing vehicle speed with traffic lights online to eliminate stop and start at red lights. Demonstrated in Las Vegas using Audi A6 navigating 50 sets of traffic lights. Testing is underway in Verona with 60 traffic lights. In Berlin, select Audi customers are driving cars fitted with online traffic information that can link up to a total of 1000 traffic lights.

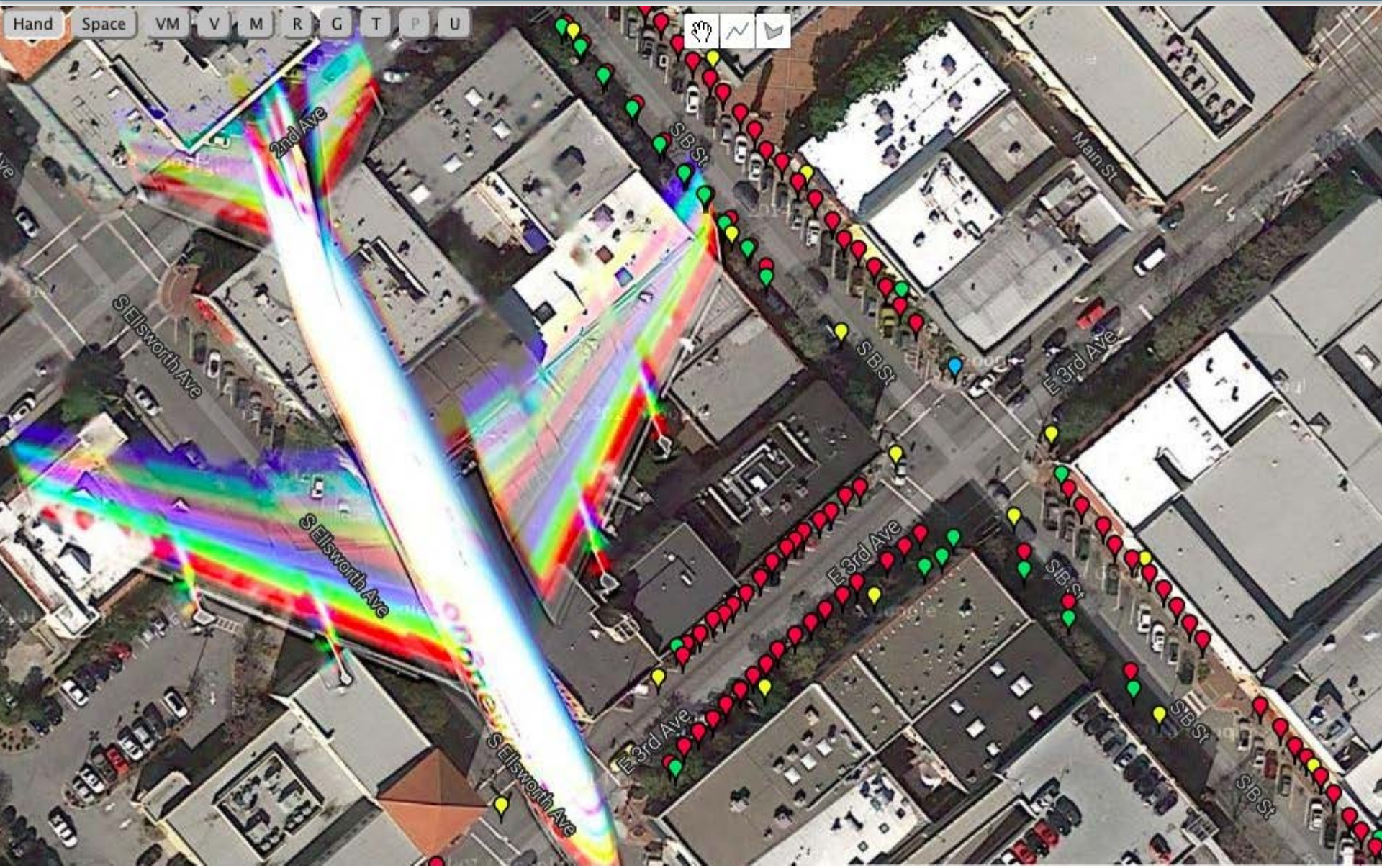
CAR TALKS TO CLOUD

For auto diagnostics, jealous spouses, concerned parents, geo-fence fanatics and auto shut-off for theft prevention



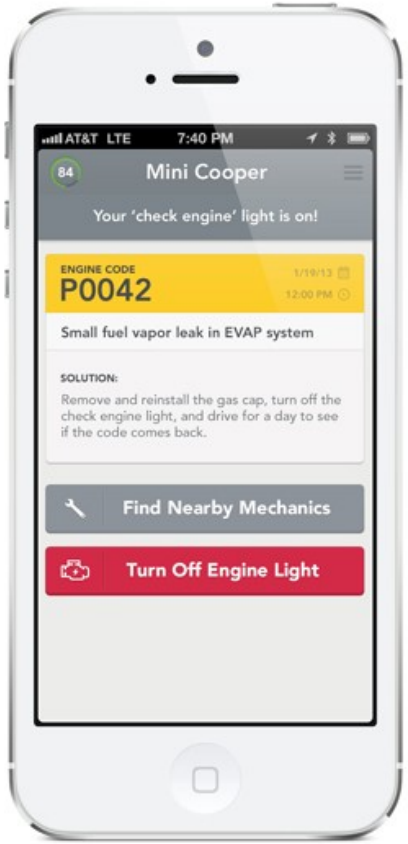
Notes: Add your parents push.co account to your IFTTT account to enable this recipe.

Industrial Internet ← IoT Services → Parking Spaces Talks to Cars



Google Earth photo of a plane flying over downtown San Jose, CA. Parking space sensors showing available car parking spaces using Parker™ by Streetline (Photo courtesy of Zia Yusuf, President & CEO, Streetline Inc)

Industrial Internet – IoT – Services Ecosystem → Convergence



Automobile Big Data - Services vs Privacy

Industrial
Internet
IoT
Services
Ecosystem
Convergence

The Korea Herald ENGLISH EDITION

Samsung Electronics to provide telematics service to Tata Motors

Published : 2014-02-14 20:31
Updated : 2014-02-14 20:31

A model poses with a Tata Motors Zest vehicle during the 12th Auto Expo 2014 in Noida, India, on Feb. 7. (Bloomberg)

Samsung Electronics will provide Tata Motors with infotainment programs as its first step into the smart car business.

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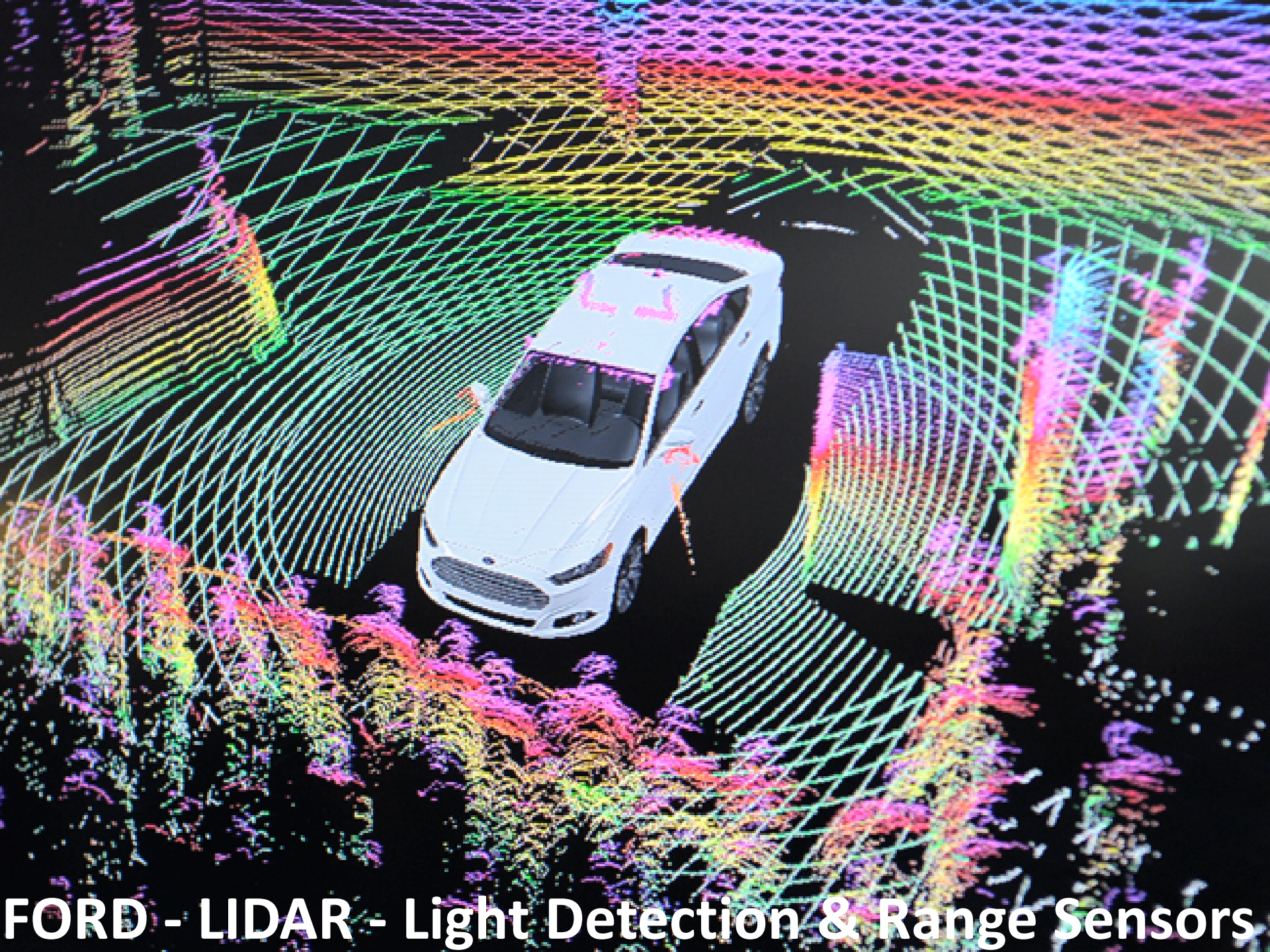
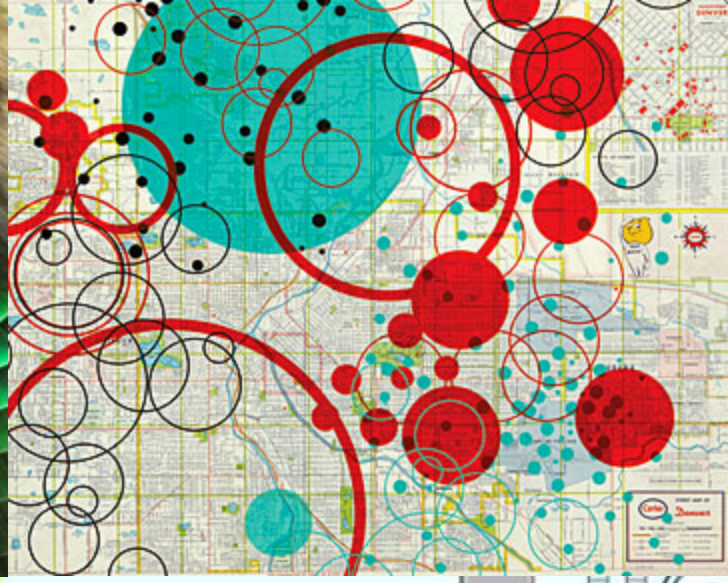
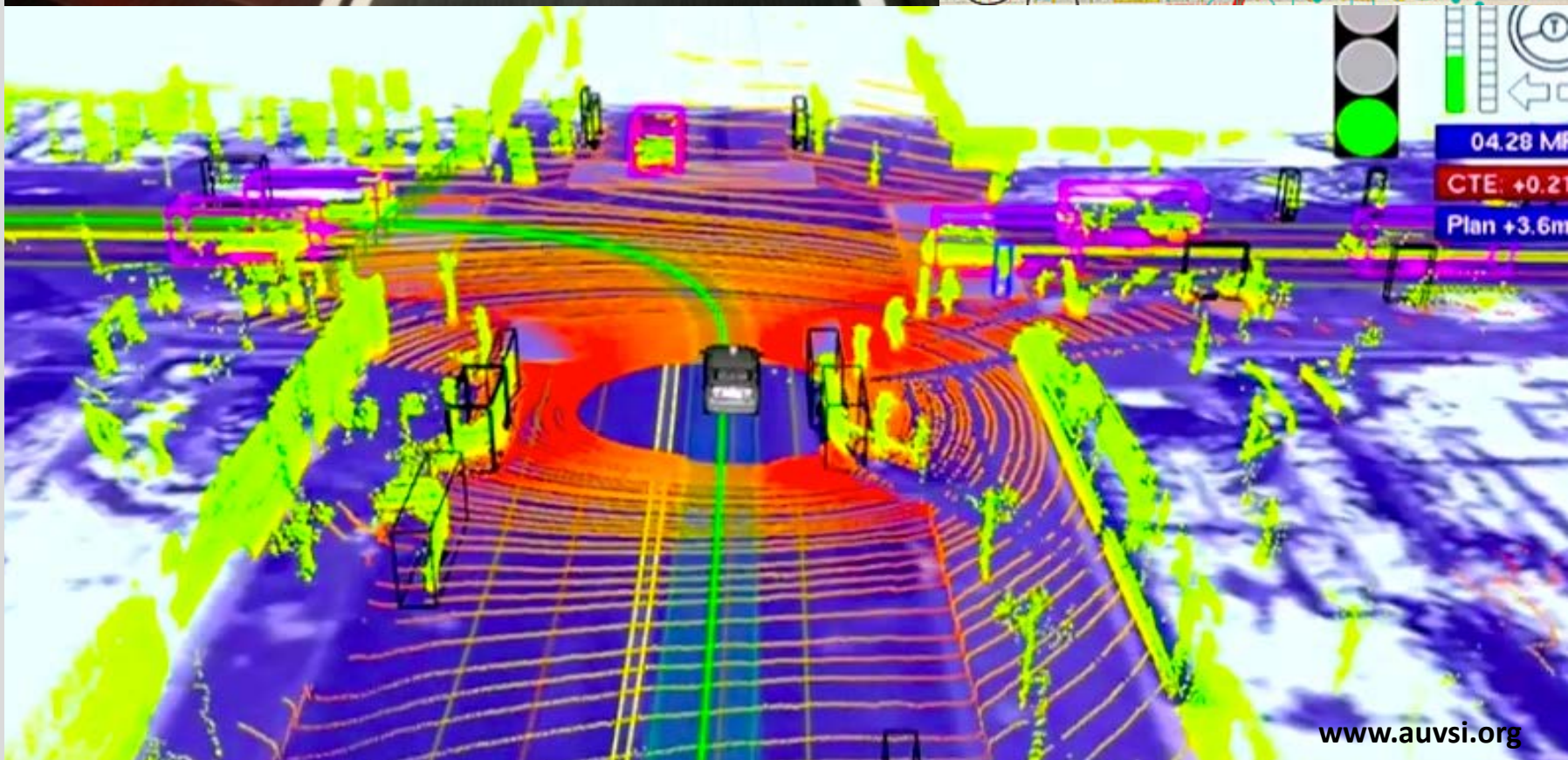

FORD - LIDAR - Light Detection & Range Sensors

AUTONOMOUS VEHICLES





www.auvsi.org

Convergence → When these boxes start dissolving then the SMART WORLD will start evolving

Mobile e-commerce

Supply chain management

Emergency assistance

Mobile communications

Inter-modal transportation

A SMARTER PLANET begins with SMART CITIES

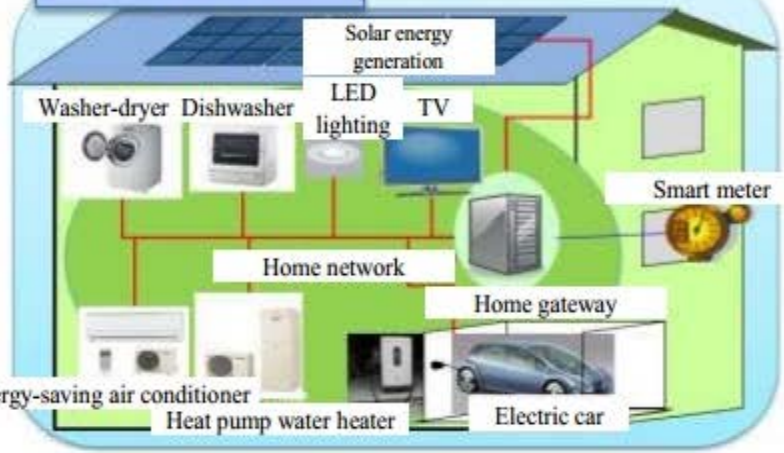
Control center

Control center that optimizes supply and demand of energy for the region

A new transport infrastructure integrated with the energy network

Drastically lowering carbon emissions and providing solutions for traffic accidents and traffic jams, by exchanging information between EVs and electric buses.

Smart houses



Electric bus (to be changed into streetcars in the future)

Electric buses with replacement-type batteries. Multiple buses will be connected to become a streetcar in the future.

METI
Ministry of Economy, Trade and Industry

India invests $20 million for smart cities linked to transport

NATIONAL INDUSTRIAL CORRIDOR AUTHORITY TO BE SET-UP

SMART CITIES ALONG INDUSTRIAL CORRIDORS PROPOSED

The Union Finance Minister Shri Arun Jaitley while presenting his first Budget in Parliament today, announced that a National Industrial Corridor Authority, with its headquarter in Pune, is being set-up with an amount of Rs. 100 crore, to coordinate the development of industrial corridors with smart cities linked to transport connectivity. The Finance Minister has also announced that the Amritsar Kolkata Industrial Master Planning will be completed expeditiously for the establishment of Industrial Smart cities in seven States in this corridor.

IoT Domain Specific Scenario

NADA.ORG

NERDS AGAINST DRINKING ACCIDENTS

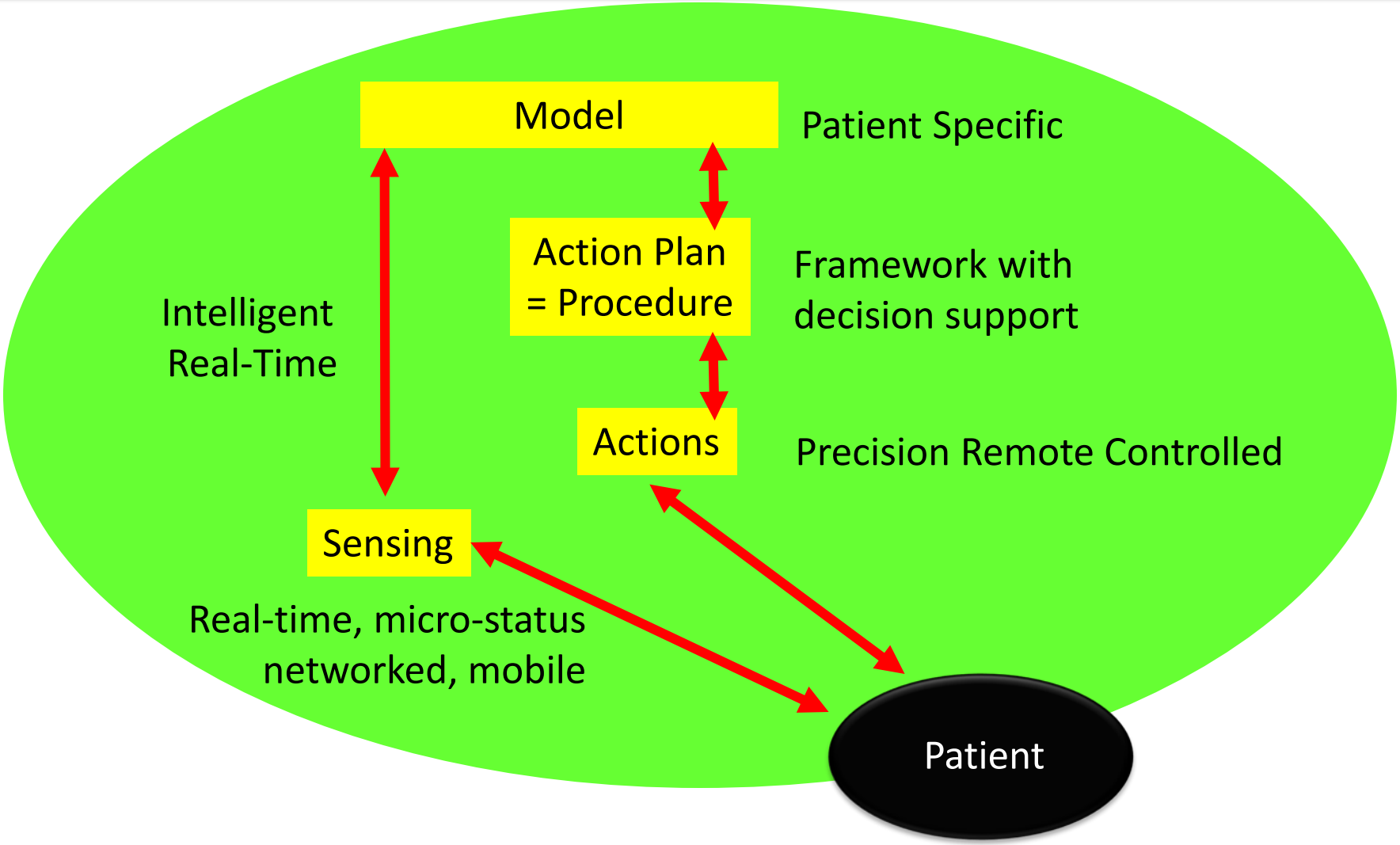
Drinking and Driving are not synonymous

Integrated breathalyzer with retina scan, facial identification, biometric ignition and smartphone

IoT Domain Specific Scenario

Medical Device Integration

One Remit of CIMIT – Sense, ***then***, Respond – Future Integrated Healthcare Monitoring



The distinction between healthcare and other industry is in differentiation of scalability. Patient centricity as a service is not scalable but patient centric infrastructure (architecture) is scalable.

Autonomous Control of Morphine Infusion Pump – Medical Device Integration Model

Infusion Pump

Capnometer

Patient Simulator
Ventilator

Intelligent Monitor

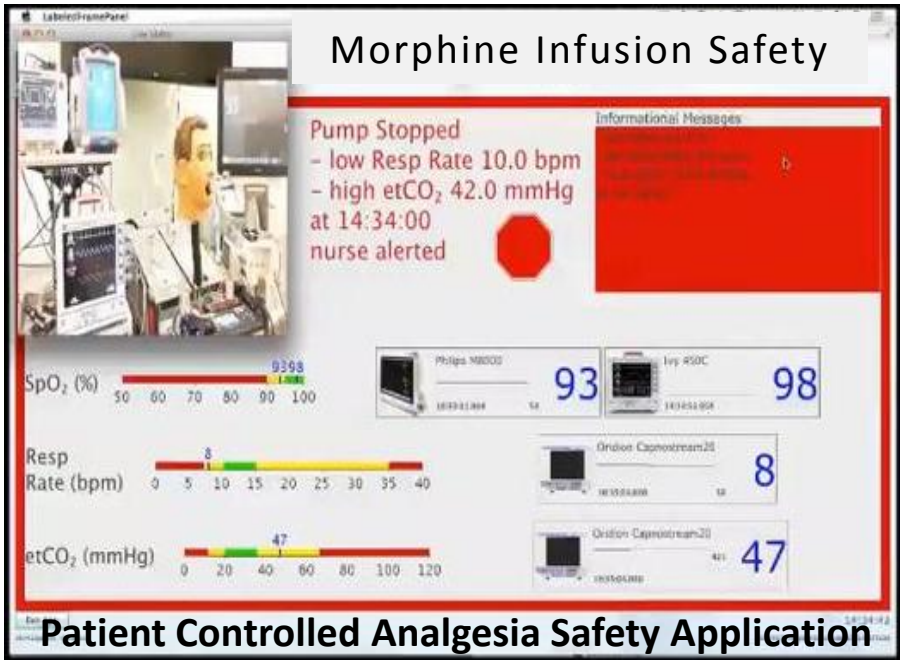
- ↓ O_2 Saturation
- ↓ Respiratory Rate
- ↑ end-tidal CO_2

Connected Data
Collective Analysis
Automated Response

Vital Signs Monitor

Simulator connected to vital signs monitor

Fluke ProSim 8 connected to intelligent monitor



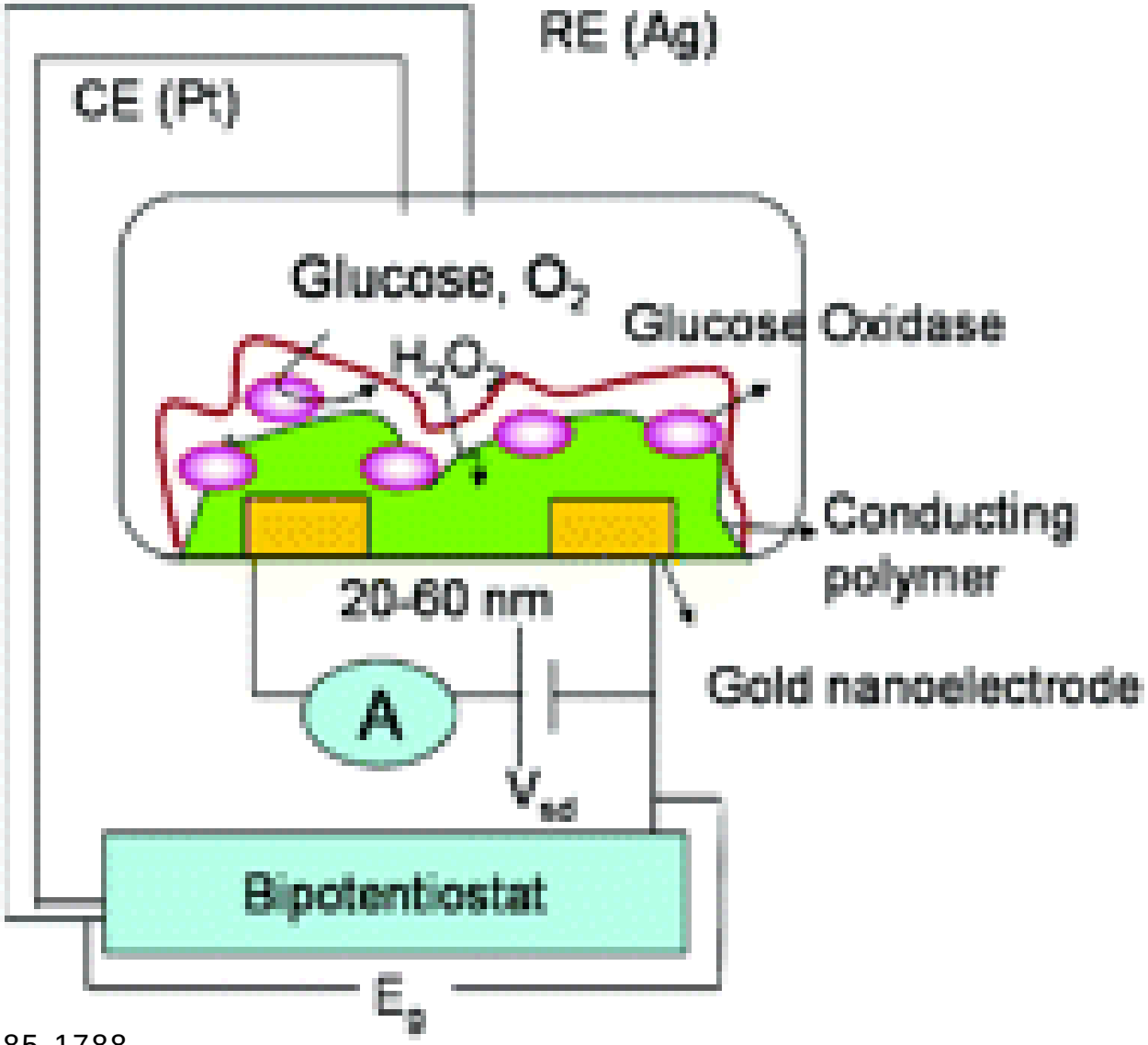
Patient Controlled Analgesia Safety Application

Julian Goldman MD (MDPnP.org and Partners.org)
Massachusetts General Hospital, Harvard Medical School
Harvard – MIT Center for Integrative Medicine and Information Technology

IoT Domain Specific Scenario

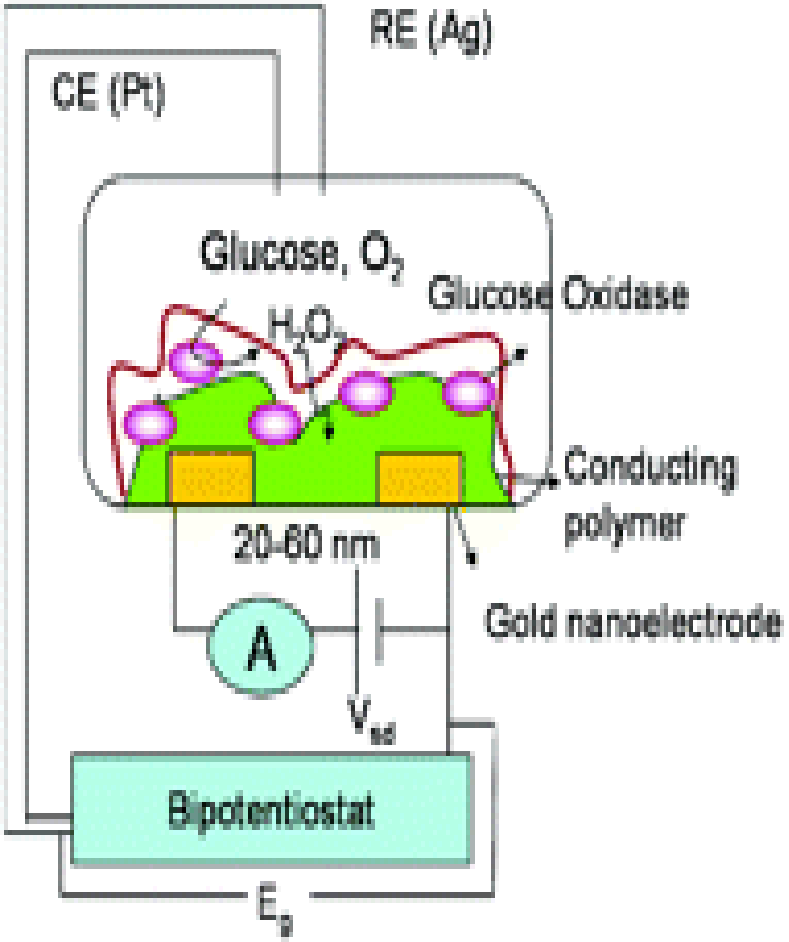
Health Monitoring

Domain Specific Anchor for Internet of Health and Wellness – Glucose NanoSensor



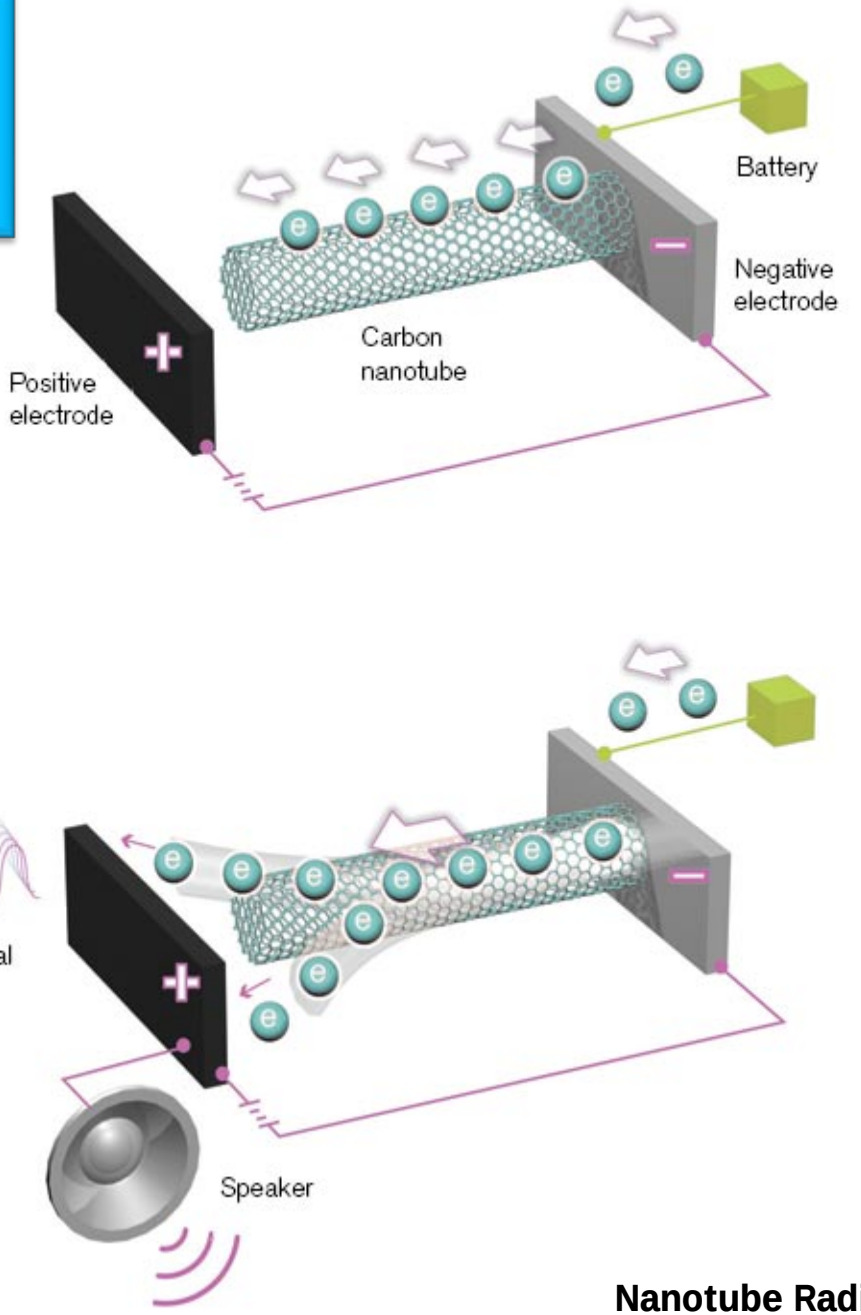
NanoLetters (2004) 4 1785-1788

The Industrial Internet
The Industrial Internet of Things
The Industrial Internet of Healthcare



Blood Glucose Nano-sensor

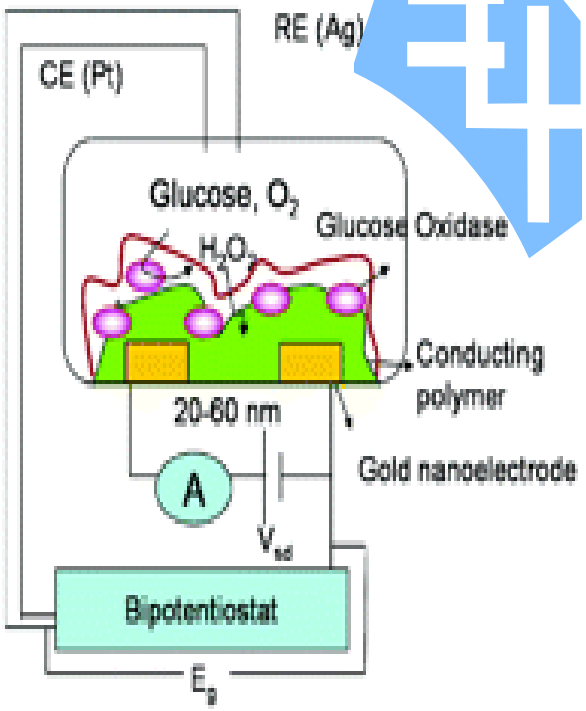
NanoLetters (2004) 4 1785-1788



Nanotube Radio

NanoLetters (2007) 7 3508-3511

Integrated Glucose NanoSensor NanoRadio



Hypothetical (S. Datta)

Diabetes affects 25.8 million people

8.3% of the U.S. population

DIAGNOSED

18.8 million people

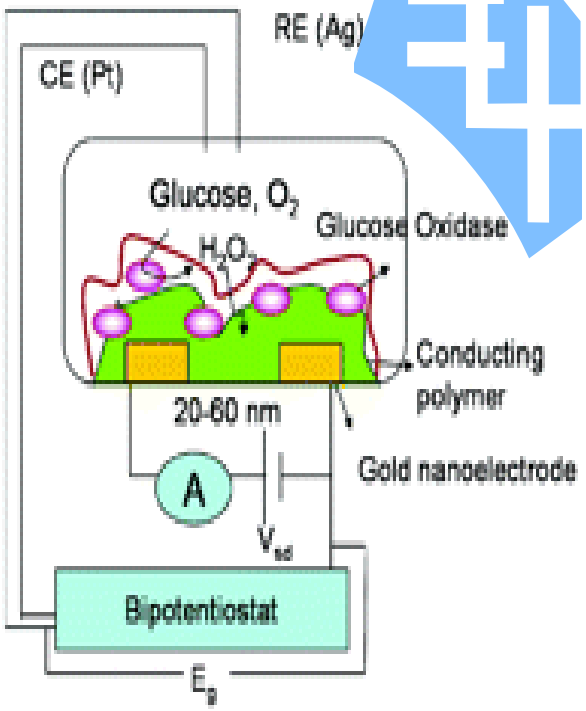
UNDIAGNOSED

7.0 million people

http://www.cdc.gov/diabetes/pubs/pdf/ndfs_2011.pdf

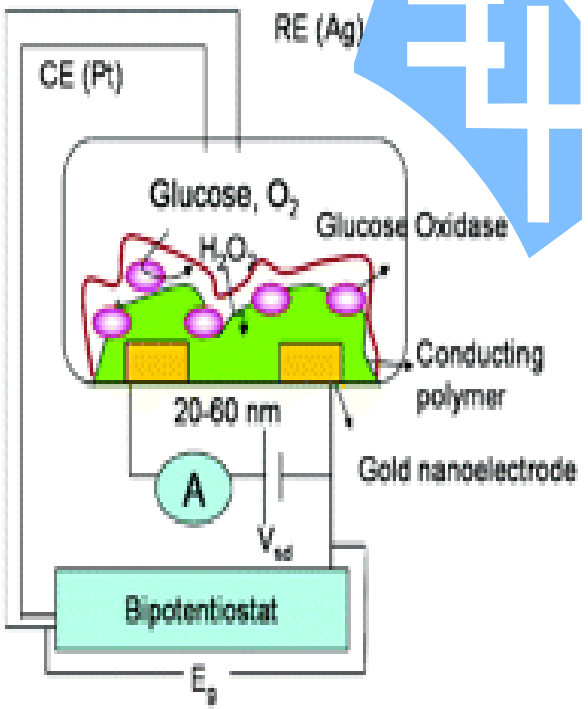
Internet of Things - Remote Heath Monitoring

May I implant a glucose nano-sensor nano-radio chip on your shoulder? You are fat. You could become diabetic.



Glucose NanoSensor NanoRadio ecosystem of health-care monitoring

About 30 million individuals in US affected by diabetes



1. Implanted wireless sensor transmits blood glucose data from home or office or airport (WiFi/WAN/gateway)

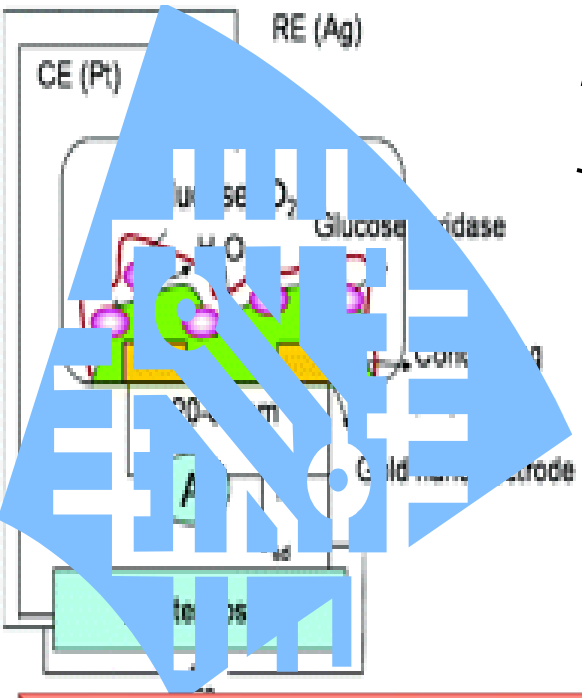
2. Data travels from you to your hospital or clinic (MAN)

3. Blood glucose data updates risk and patient profile

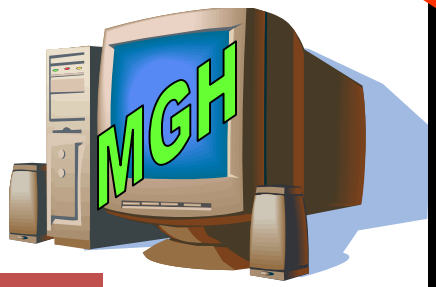
4. If you need medical attention or insulin or other treatment then auto-responder sends message or calls

http://www.cdc.gov/nchs/fastats/diabetes.htm

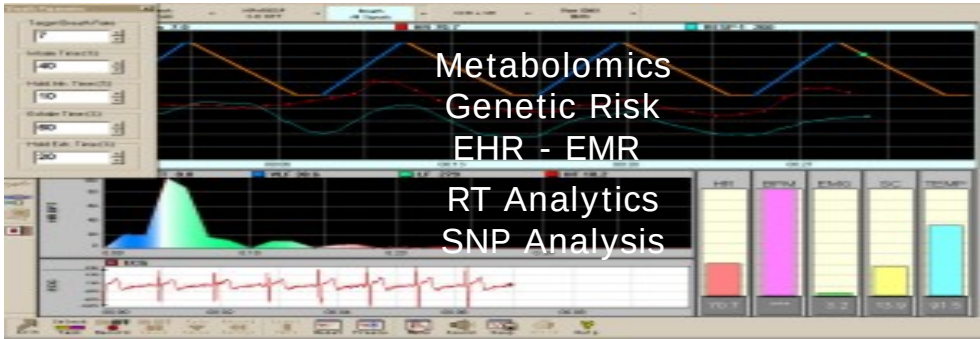
Helene Langevin Joliot-Curie



802.11b
WiFi
802.11g

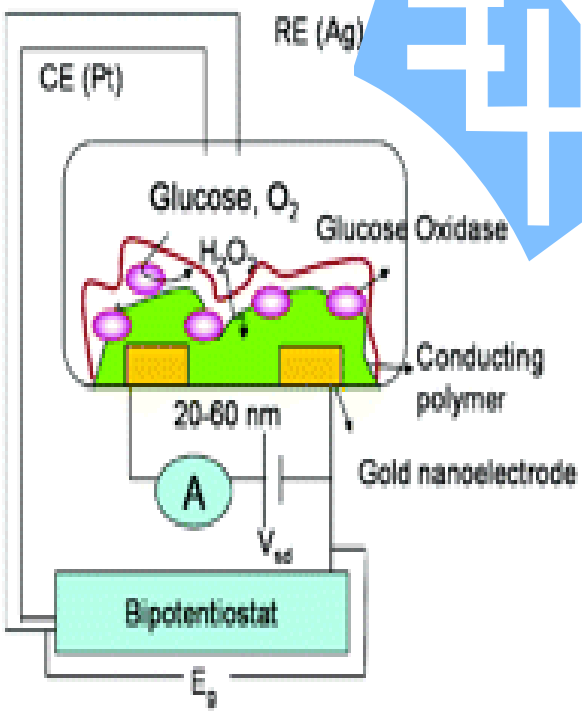


802.16a

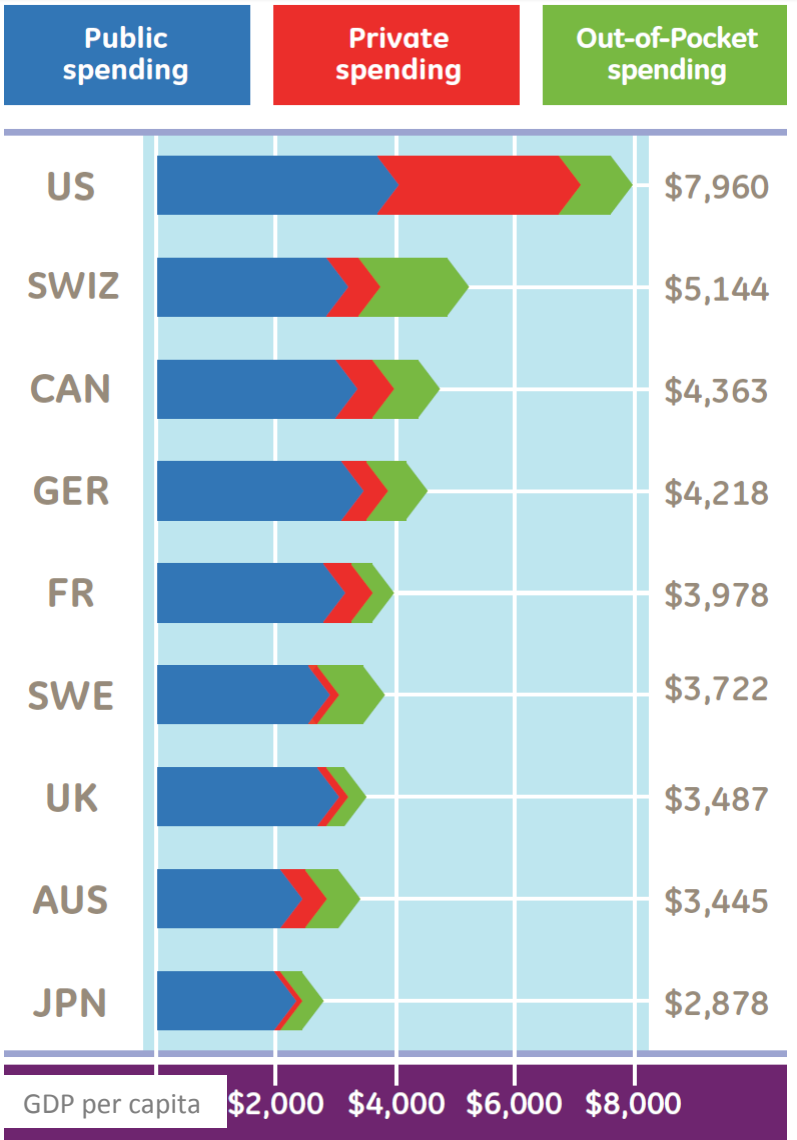


Improved healthcare services, savings, create jobs from new products, new services and potential to create as well as capture new emerging markets of billions (BRICS)

Glucose NanoSensor NanoRadio ecosystem of health-care monitoring may have a major economic impact

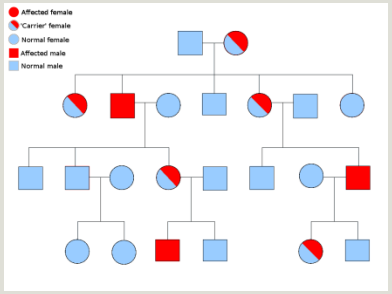


Healthcare Spending →



http://www.cdc.gov/nchs/fastats/diabetes.htm

Human Genomics in the IoT era - Is your genome connected to mine?



Genome

Transcriptome

Proteome

Metabolome

Microbiome

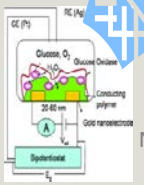
Epigenome

Exposome

Social graph

Biosensors

Imaging



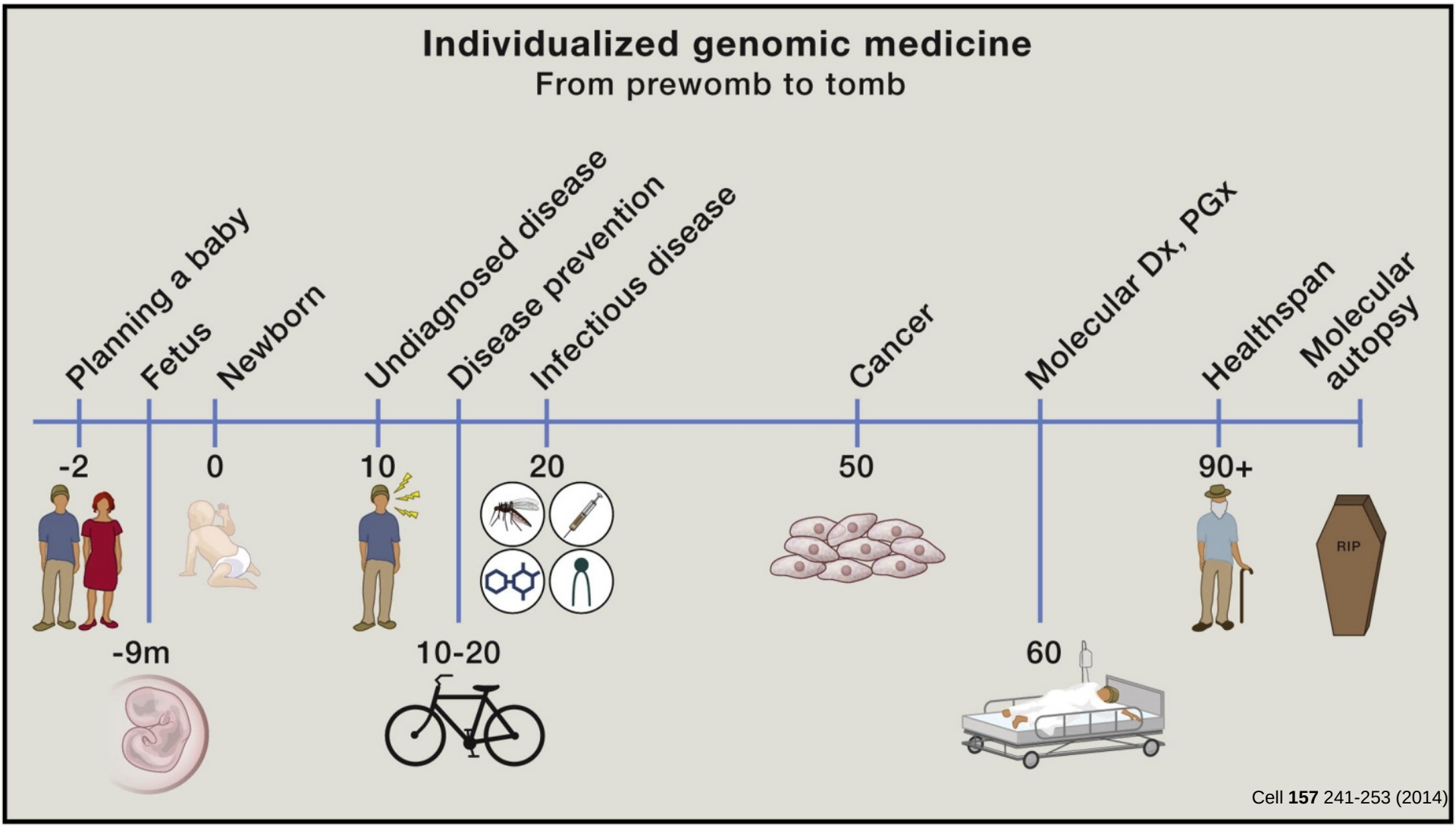
Glucose
NanoSensor
NanoRadio

Cell **157** 241-253 (2014)

Mendelian Inheritance in Man: A Catalog of Human Genes and Genetic Disorders by Victor A. McKusick

Human Genomics in the Age of the IoT

Designer Drugs Transmitted in the Wireless Hospital



Cell **157** 241-253 (2014)

IoT Domain Specific Scenario

Early Detection and Prevention

Sensor enabled wearables - appropriate attributes may improve preventive medicine

Hands-Free
- Voice / gesture control

Always-On
- Low power consumption
- Instant wake
- Background working / sensing

Environment -Aware
- GPS
- Accelerometer
- Compass
- Camera
- Microphone
- Other Sensors

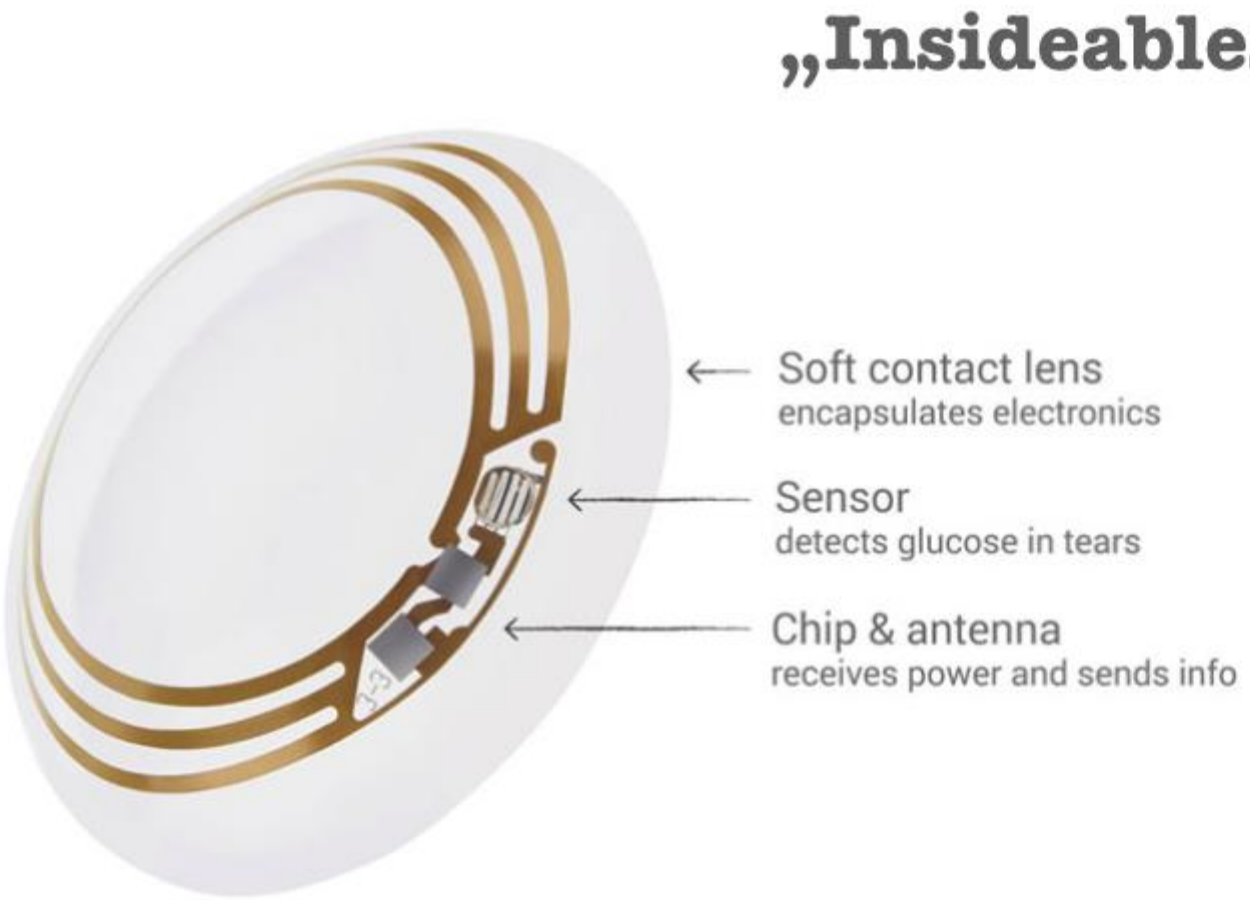
Connected
- Wi-Fi
- 3G / 4G
- Bluetooth
- NFC

Attention-Getting
- Less distracting when receiving alerts / reminders / messages

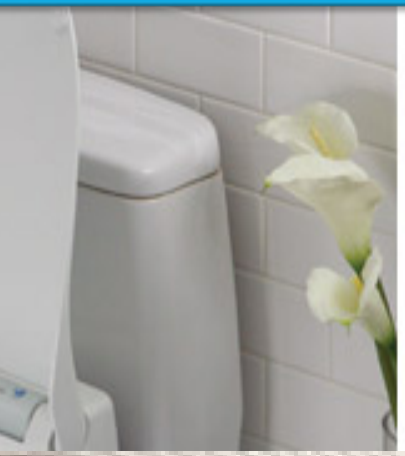
Development Platform
- 3rd party apps
- API partners
- Accessories

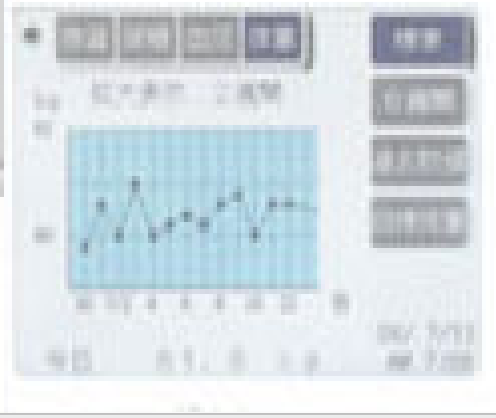
MIT

Glucose Sensors can reduce the morbidity due to Glaucoma



Pay-Per-Pee Home Health – IoT Wireless Toilet Bowl Connected to Health Informatics





Weigh-scale, BMI, FOBT, urine analysis, sugar, ketone body analysis, blood pressure monitor, pulse oximeter, networked to phone via WiFi and/or Bluetooth with biometrics and face recognition for secure communication with physician and hospital or clinic, globally.

Walgreens Specials - $1.99 for 24-pack Diet Coke • $1.99 for Bone Density • $1.99 Mammogram

PDEXA SCAN
BONE MINERAL
DENSITY PROFILE

Value Network Ecosystem Testbed

Walgreens – Retail Healthcare
GE – Equipment
Cisco – IPv6 Routers
AT&T – Data Transmission
Intel – MIPS
IBM – Data Analytics
Samsung – Diagnostic Apps
Walmart – Grocery Supply Chain

Low Cost of Healthcare in India leaves billions in the dust without access to healthcare

Cancer Treatment

$2,900 HCG Oncology, India

$22,000 U.S. average

Kidney Dialysis

$12,000 Deccan Hospital, India

$66,750 U.S. average

Fast Forward → Penny Per Person Per Use Per Day

$1 - Bone density

$1 - Mammogram

at the corner of Happy and Healthy in every zip code in India, China, Indonesia

data transmitted to specialists and reports sent to individuals, doctor and clinic

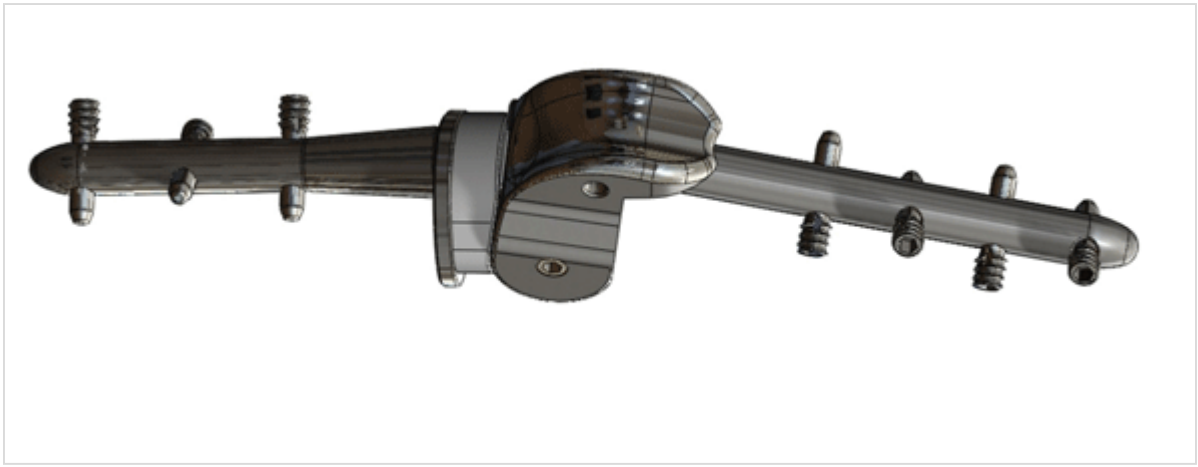
The micro-revenue earnings potential with 10% penetration for population of 3+ billion & aging!

IoT Domain Specific Scenario

3-D Printing in Healthcare

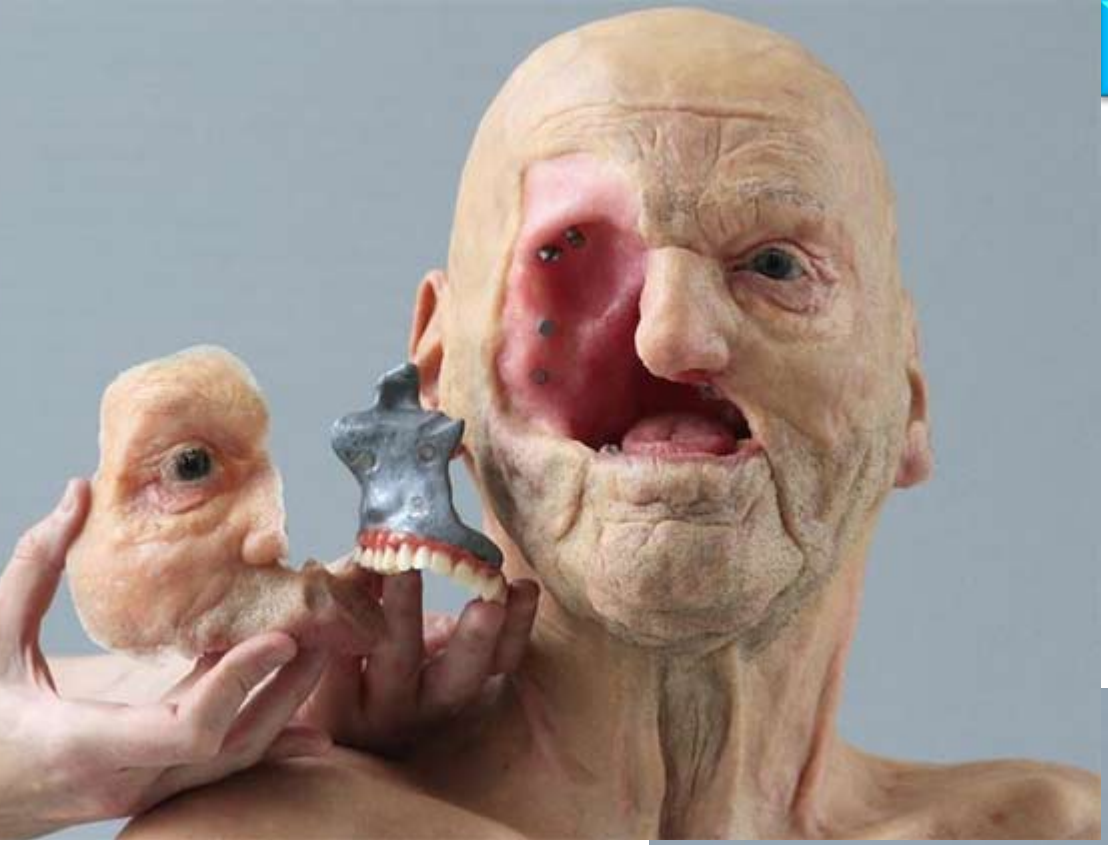
Innovation in manufacturing and digital design

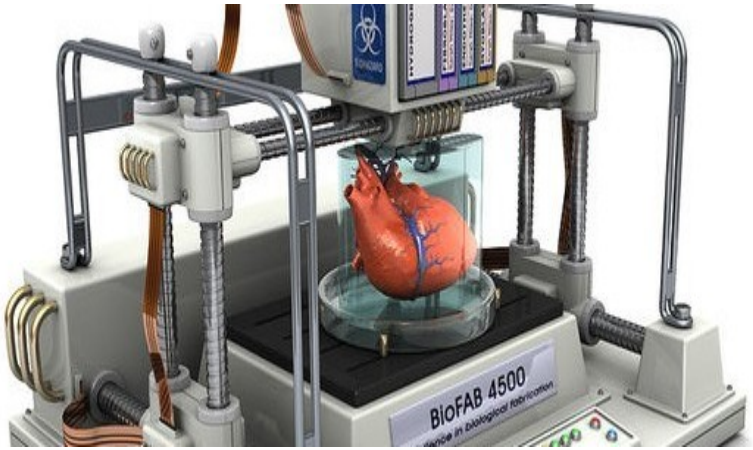
3-D Printing
Design of Prosthetics and Orthopedic Imaging



Cyrano L. Catte II (above) is the first feline to receive a total knee arthroplasty (TKA). Femoral and tibial components were created with a direct metal laser sintering (EOS).

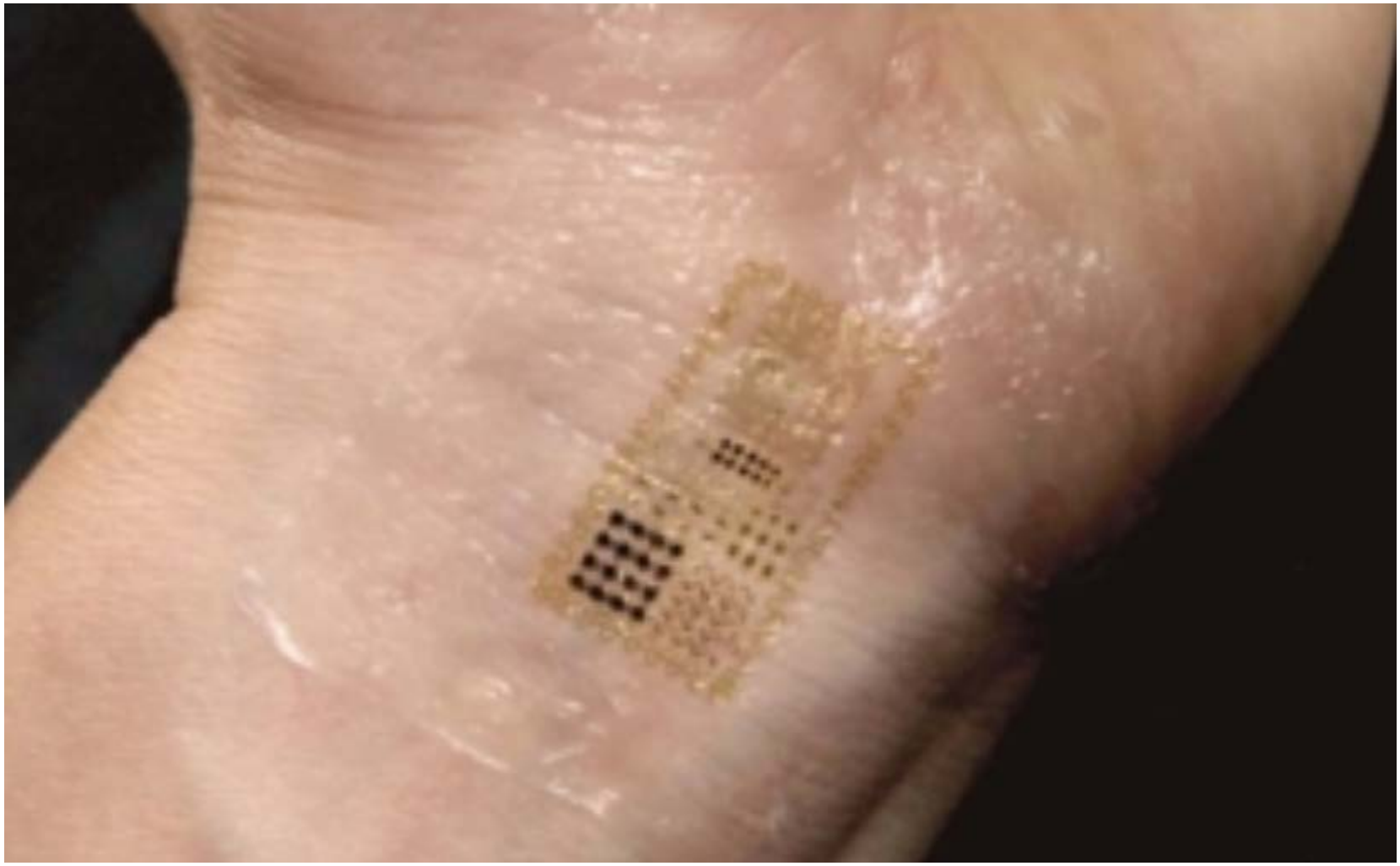
3D Printing of Medical Devices





http://bit.ly/3D-Print-A-Tooth
http://bit.ly/3D-Print-Medical-Devices

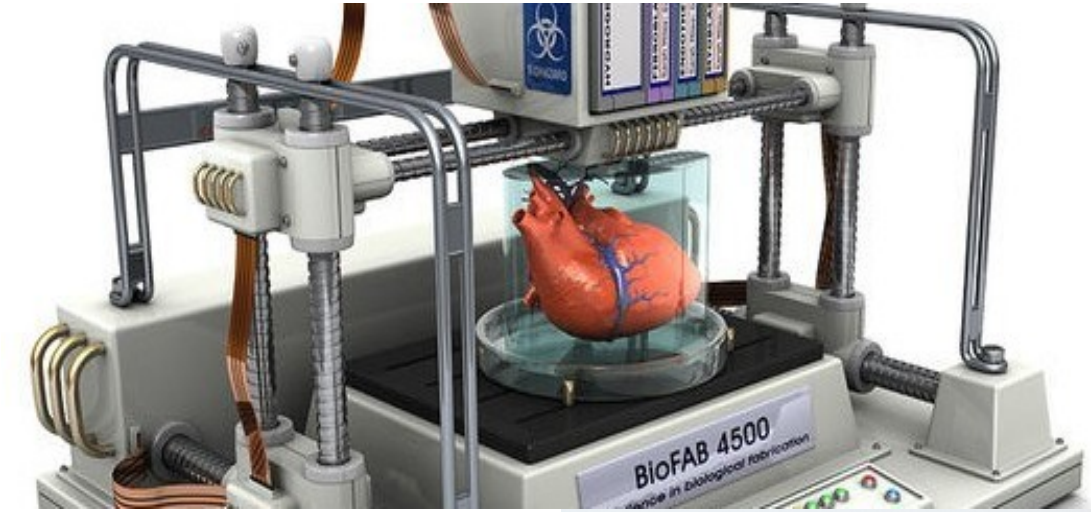
Artificial Skin with embedded sensory surface talks to smart phone via capacitive sensing using Touchcode app adapted for 3D printed i-Skin

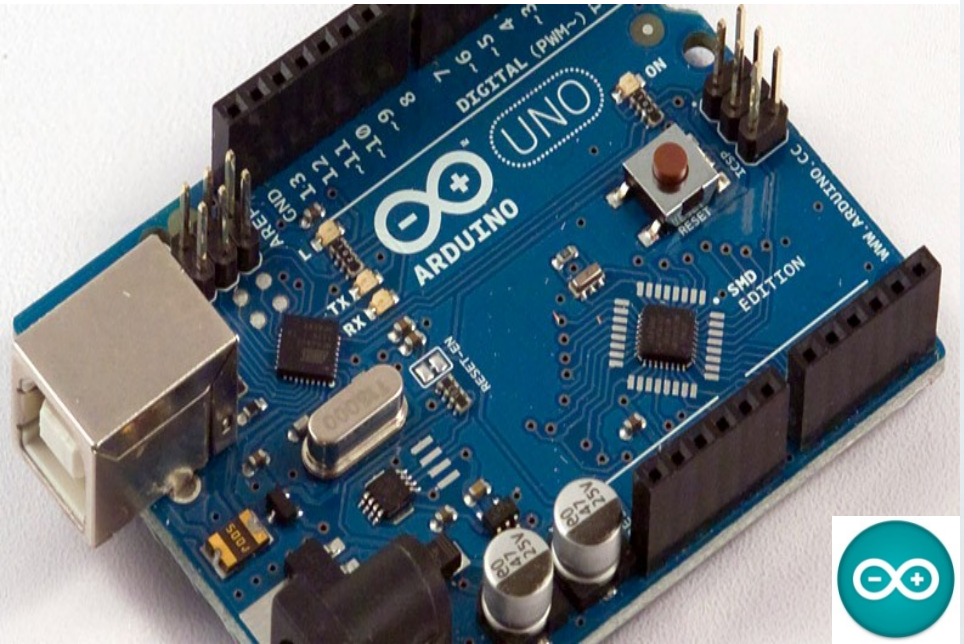


Your *medicine* can inform your doctor about its kinetics, bio-availability and any side effects. It can alert your pharmacist about potential over-dose if multiple medications contain same or similar active ingredients. Your medicine can query and adjust dosage.

Paradigm Shift – Disrupt Healthcare Economics

3D Printed Medical Devices + OS Hardware / Software

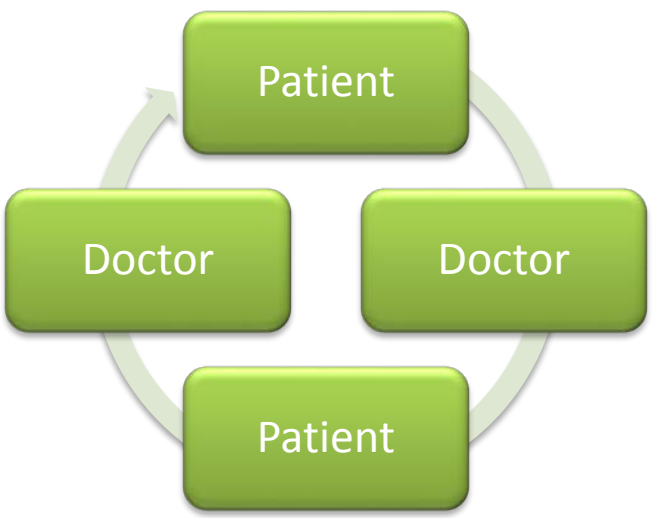


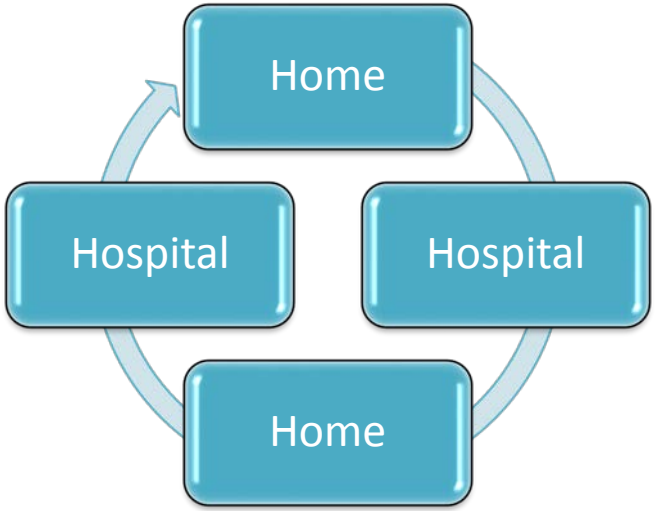


IoT Domain Specific Scenario

Healthcare Management

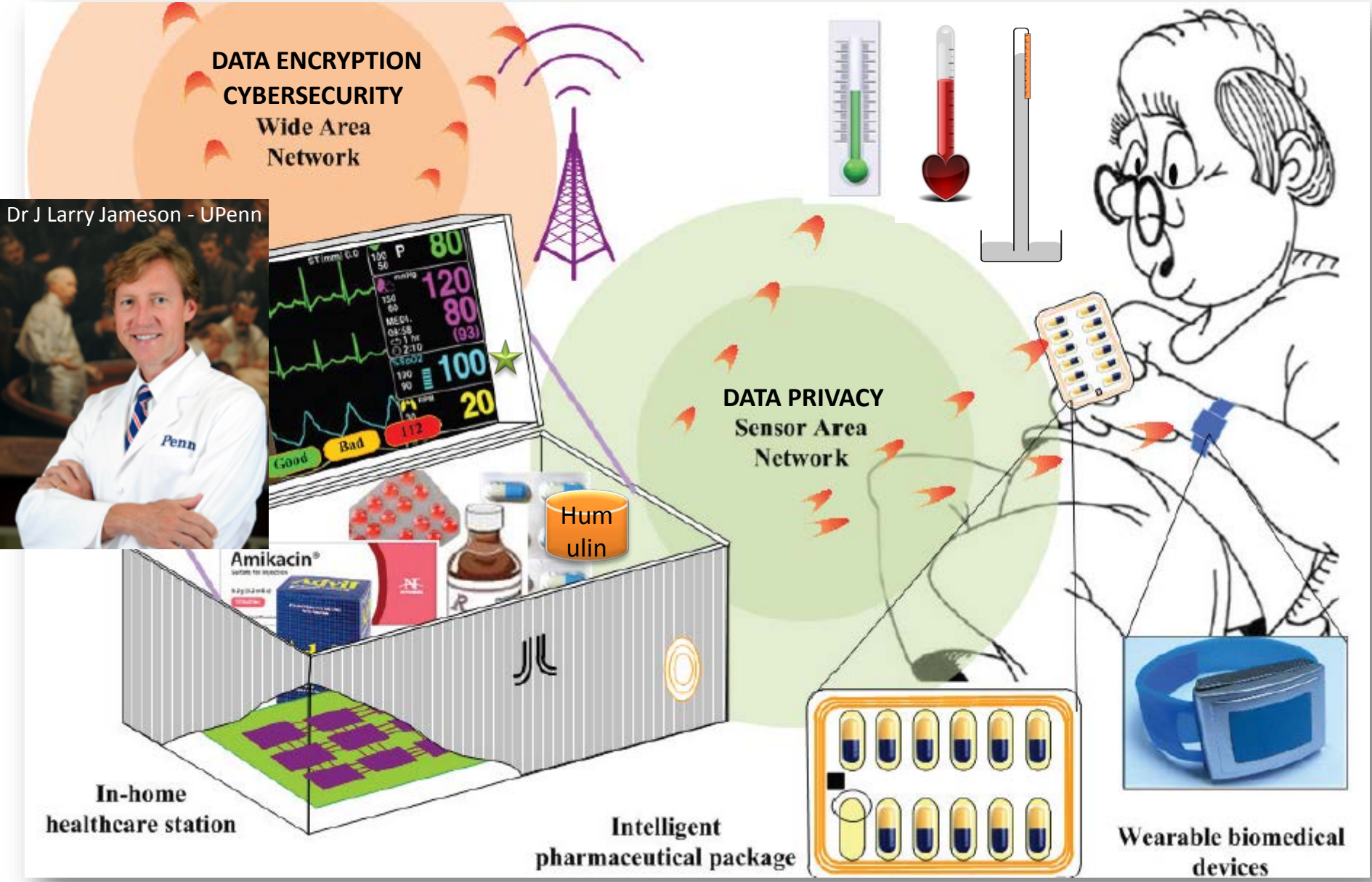
Healthcare Management - Fundamentally Closed Loop & Quintessentially Patient Specific





The buzz of "innovation" in healthcare often fails to differentiate between tools and services. Tools and technologies used to deliver healthcare are easy targets for innovation, modularity and scalability. This is innovation in health related tools, ***not healthcare***. Innovation in healthcare is about ***delivery*** of healthcare which is a closed loop management system uniquely focused on one patient (not scalable) and relevant tools must converge at the point of care. The infrastructure (data, transmission, security, privacy) to deliver healthcare may be scalable but innovation to enhance the quality, functionality and reliability of the infrastructure may or may not have an impact on the QoS of healthcare delivery at POC (point of care).

Harry at home with hypercholesterolemia : Hi Dr Jameson - Do I need Lipitor today?



Dr J Larry Jameson: Thanks for avoiding KFC. Your LDL-VLDL ratio looks good. No Lipitor today.

IoT Healthcare Management - Fundamentally Closed Loop & Quintessentially Patient Specific

HOSPITAL

2. Robot dispatch alerts 911

Robot dispatch And 911

EHR

3. ER - Smart alarms utilize cloud data and EHR

Home Monitor

Cloud

1. Fall Detected at home Randall doesn't get up

PCP

4. Surgery

4. PCA risk of injury Reduced; reduce alarm fatigue

Datalogger

HOME

Safety Cert of interop

7. Discharge

6. Real-time blue button

Key:

- Current
- June
- Proposed
- Patient movement

Dr Julian Goldman MD
MDPnP – MGH – HMS

Healthcare Management at the Point of Care – Convergent? Transparent? Secure?

Patient Record – can you see the history from a prior visit in a different hospital?
Patient Data – monitoring device data – does it converge on a real time dashboard?
Patient Profile – created specifically using history + device data + genetic background
Patient Symptoms –
Recommended Tests –
Patient Profile – update with symptoms and test data from labs
Patient Diagnosis –
Patient Prescription – link to pharmacy, check for cross reactivity, side effects, allergy
Patient Discharge – follow up plan, outpatient schedule, in-home care plan
or
Patient Hospital Admissions – ward assignment, nurse-physician team, family circle
Patient Progress – tests? surgery? therapy?
Patient Discharge – follow up plan? in-home care? rehab?
Patient Billing – insurance plans, co-payments

To improve the lives of people, the buzz of "innovation" in healthcare must shift from easy targets (tools, wearables, printables) to embrace the (often chaotic) systems perspective to organize, optimize and better orchestrate a seamless delivery of end-to-end healthcare which results in a measurable increase in the quality of life of the patient or person (if applicable to preventative medicine through remote monitoring).

IoT Domain Specific Scenario

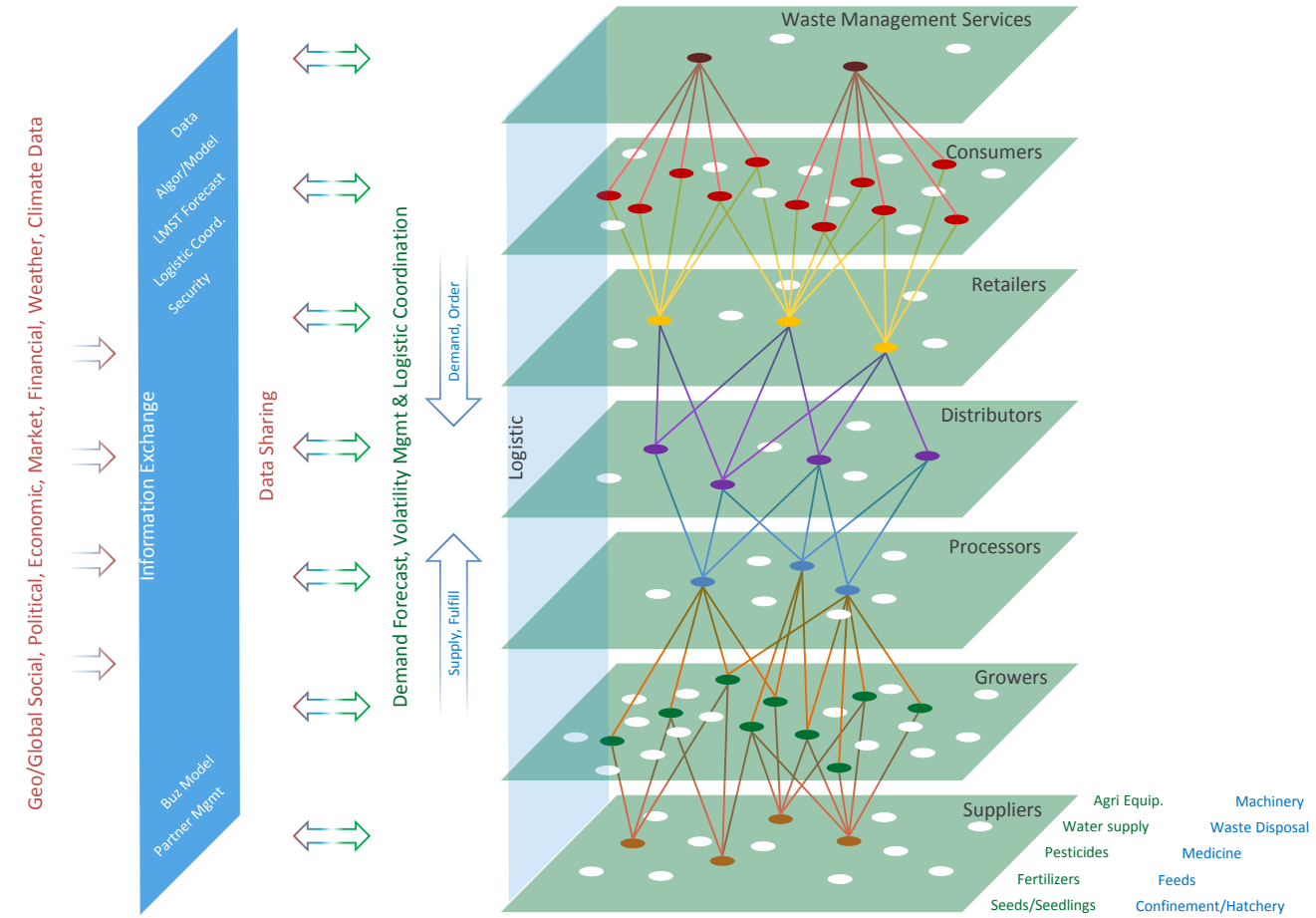
Real Time Precision Farming Platform

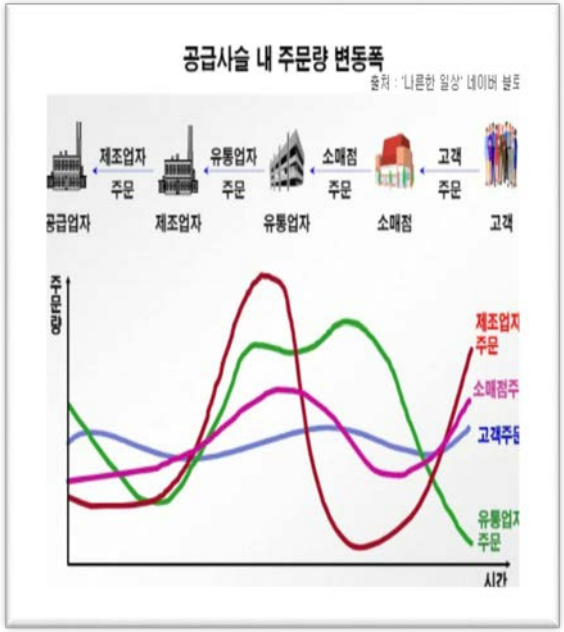
Precision Farming - Supply Network Planning - Decision Systems Support

Value Network	Service Supply Chain	Food Supply Chain	Big Data Economy

Performance: Reduce response time & Avoid out of stock

Cost: Optimize logistic, reduce inventory & avoid over-production



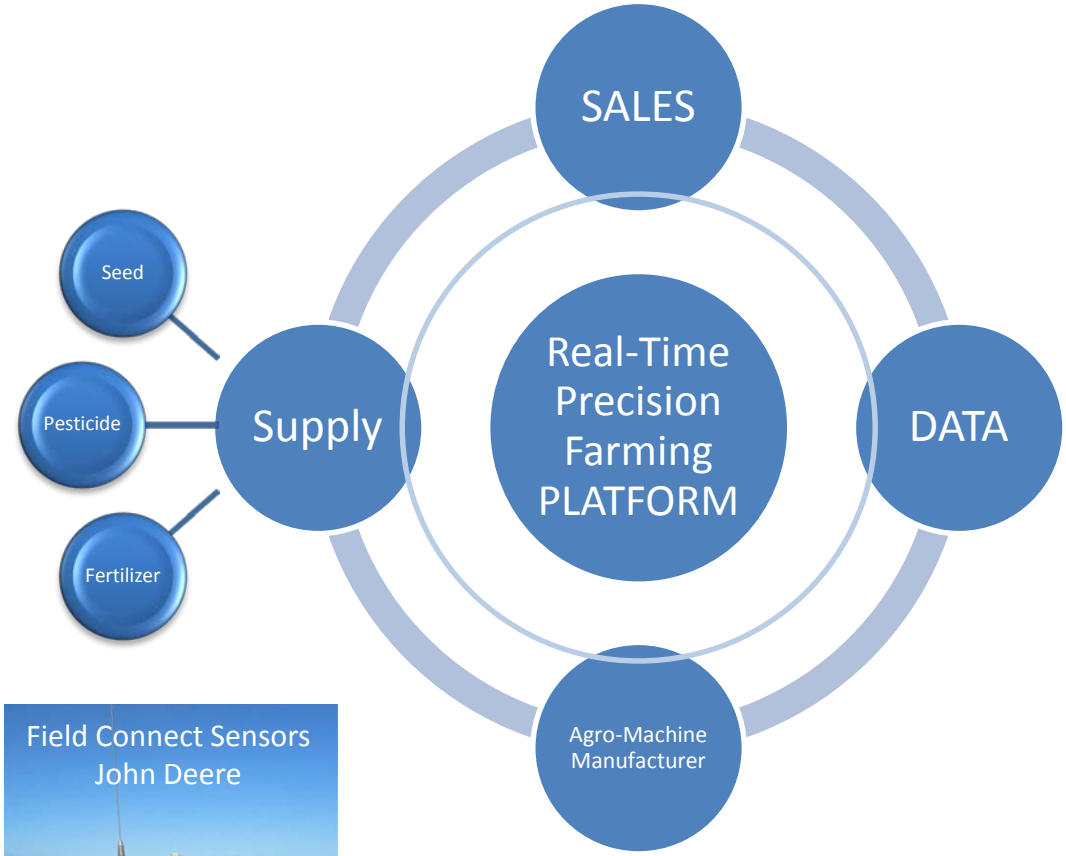


End 2 End Platform - convergence of ecosystem of inter-dependent systems

The potential convergence of Precision Farming ecosystem
- Seed to Mouth (S2M)
- Farm to Fork (F2F)

with other ecosystems, such as:
- Smart Cities
- Autonomous Transportation and operations management for trusted and secure supply chain network of partners. Compliance with SOX-409 type regulations and DHS e-manifest are a part of this scenario. Additional links to energy and environmental systems are also obvious. Food safety, security, nutrition, availability and consumption are inextricably linked with global health, malnutrition, infant mortality and healthcare, in general.

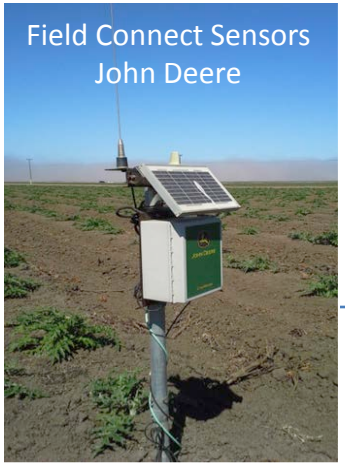
Retail Supply Chain – Sourcing / Distribution / Warehouse / Transportation
Track & Trace – Commodity Traders – Risk Management – Regulators (FDA)



-Measure, understand and apply
-Impact of data on quality & yield

-Weather data
-GPS micro-localization data
-Soil chemistry (GCMS) specifics
-Seed (sterile unless cultivated)
-Fertilizers (catalytic vs toxicity)
-Protection (pesticide, herbicide)
-Storage, shelf-life and waste
-Country of origin - goods supply

Leverage data to run long and short term simulations to plan for "what if" to optimize profit
- Weather patterns
- Demand uncertainty
- Export and import
- Tariff, cost, excise
- Regulatory policy



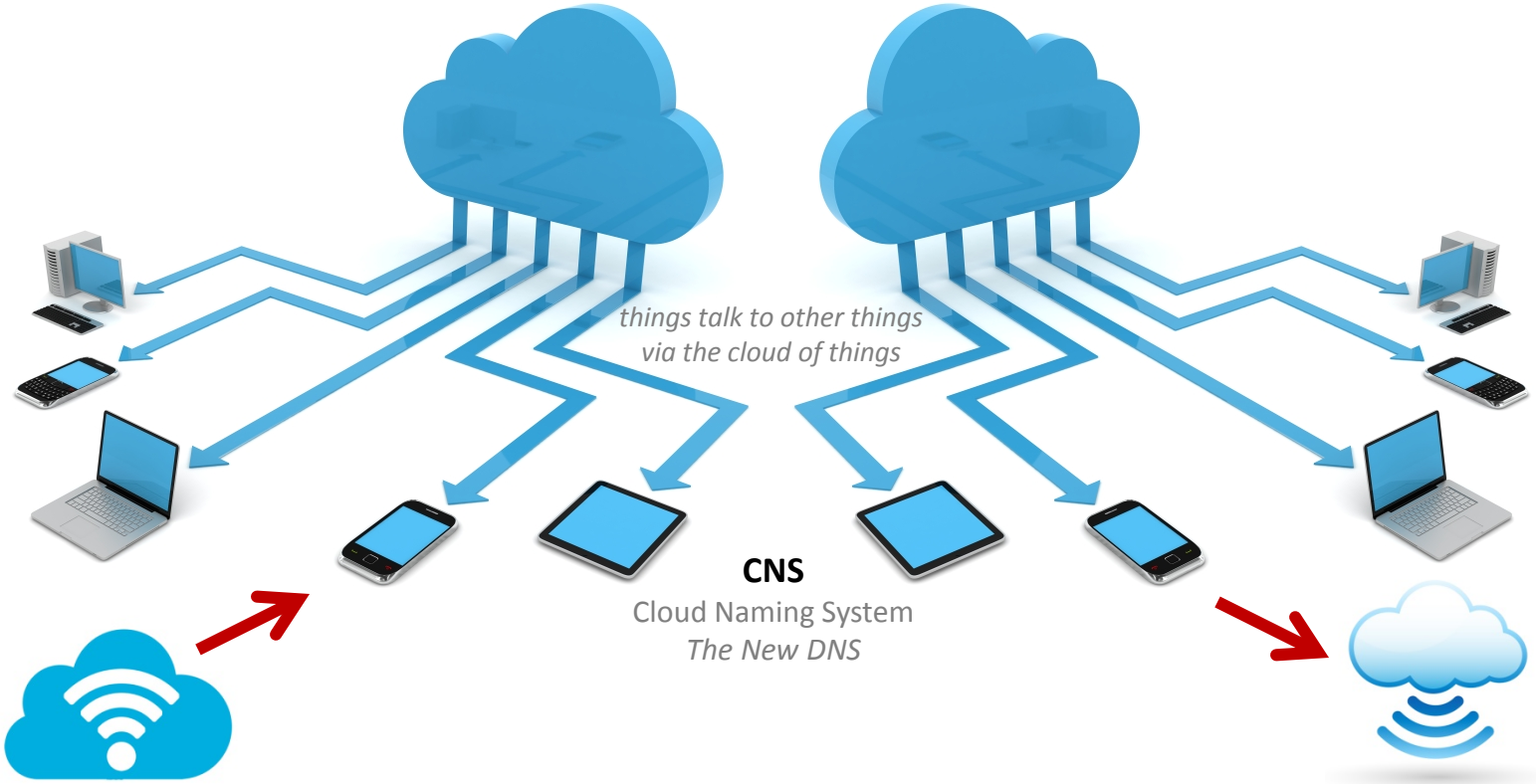
- Optimize MRO to improve asset uptime
- Mobile data collection and dissemination
  - soil sample / nutrient analysis (GCMS)
  - moisture monitors / field connect data
  - temperature / dielectric constant
  - color and chemistry of crops
  - growth rate / fertilizer distribution
  - weather micro-impact / acidity-alkalinity

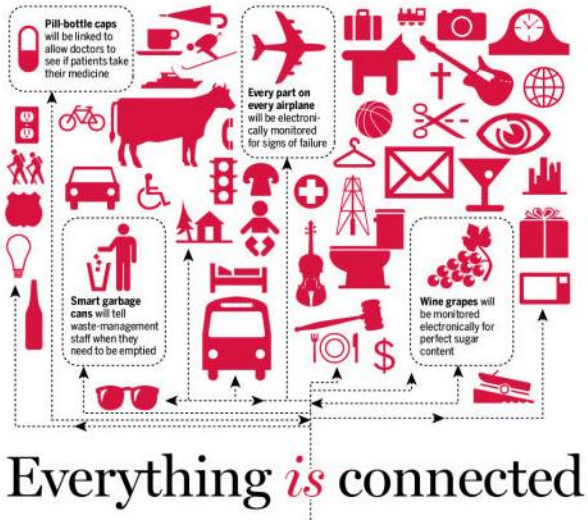
Farming in California alone is a $50 billion industry

IoT Connectivity Architectures

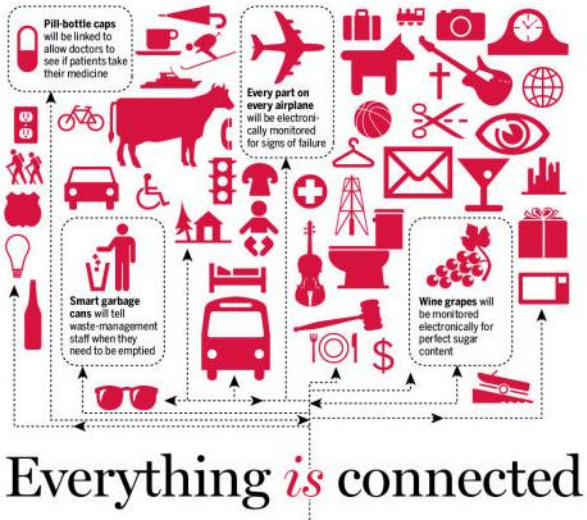
IoT functions will be influenced by architecture and data (stack)

The Industrial Internet – Internet of Things (IoT) – Internet of Everything (IoE) – Cloud of Things

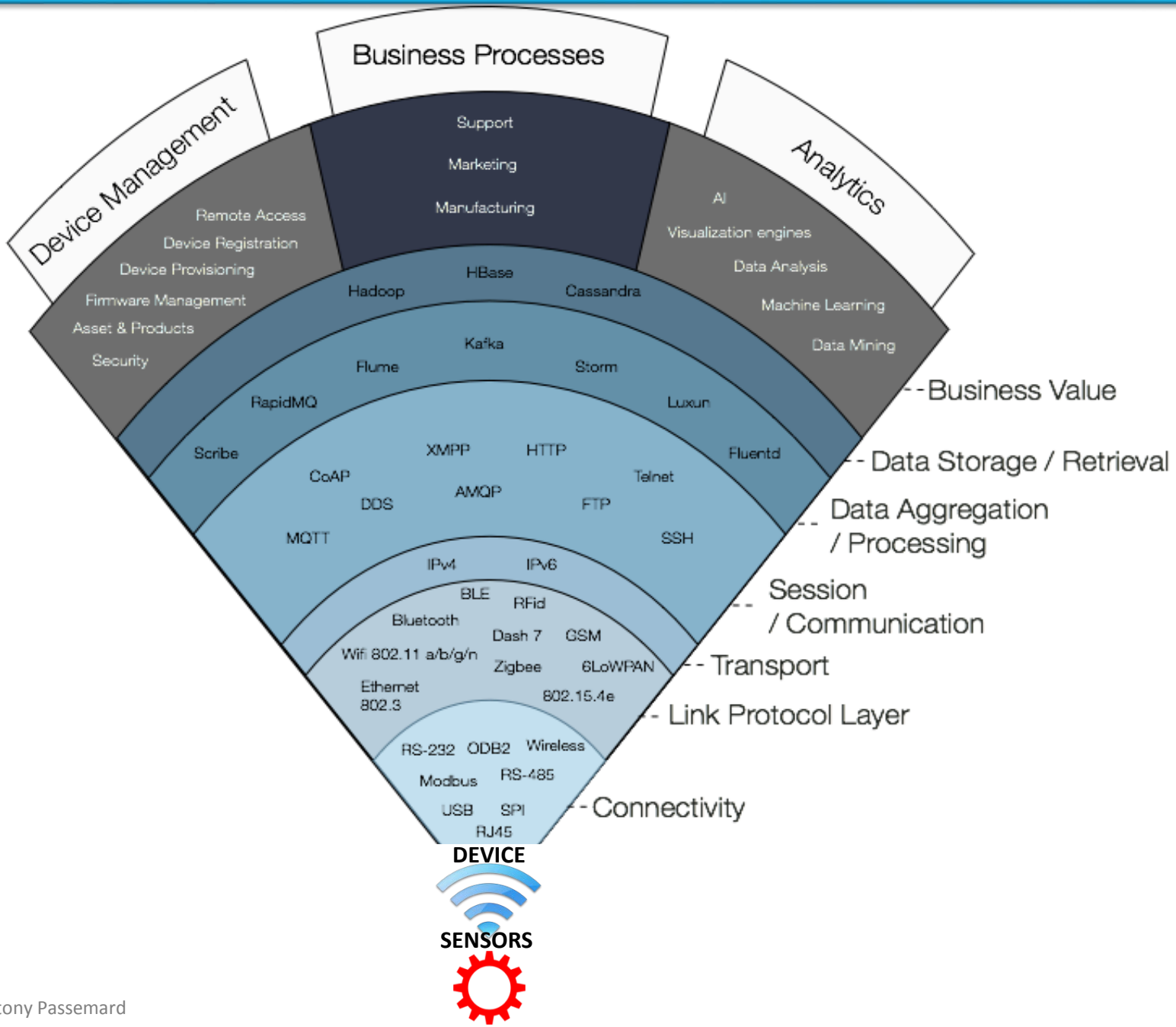




Exception – Instances of cyber-physical systems (CPS) where time guarantee vs latency must be evaluated.

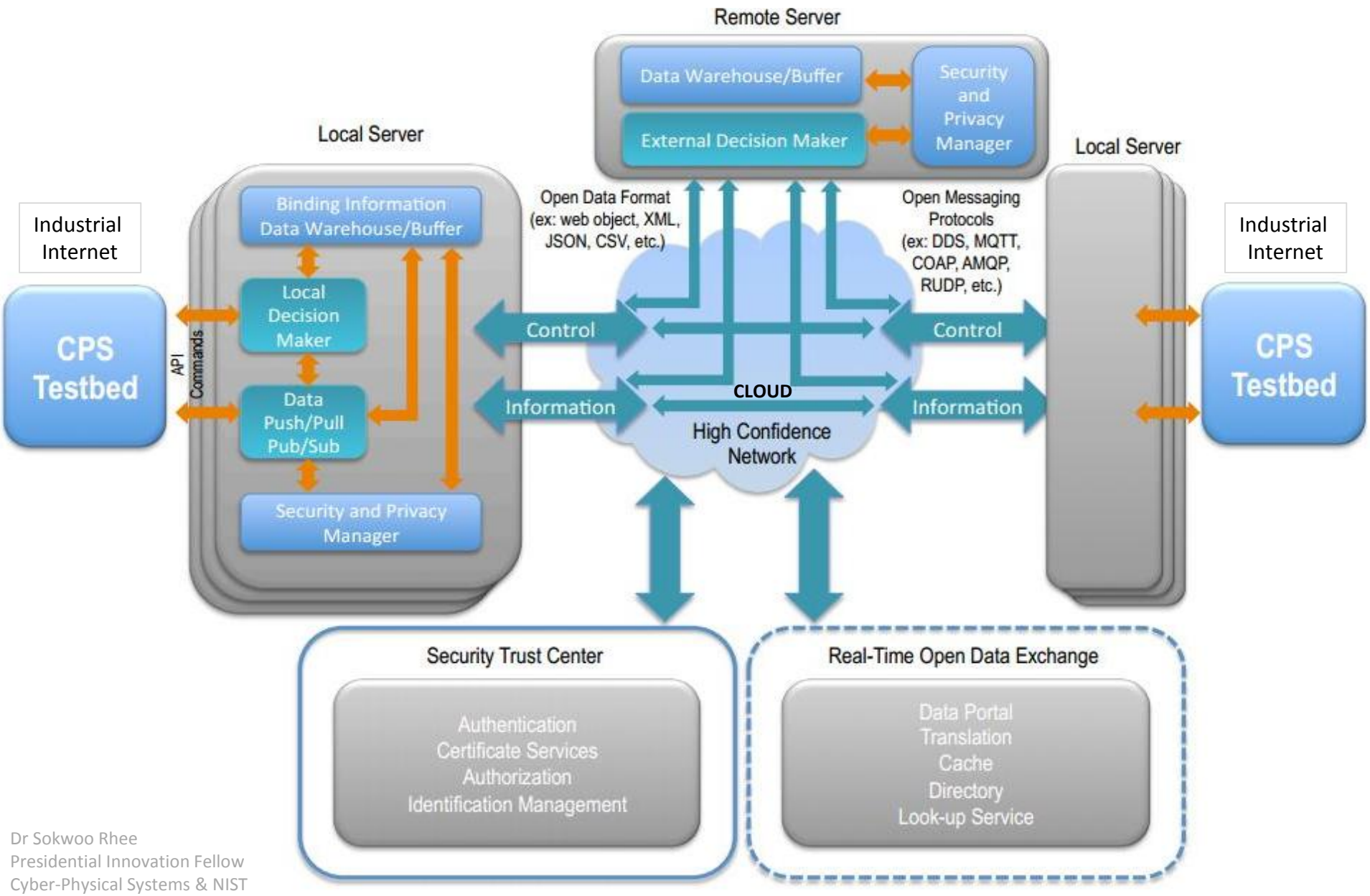


A Version of Potential Protocol Landscape for The Industrial Internet – Internet of Things (IoT)



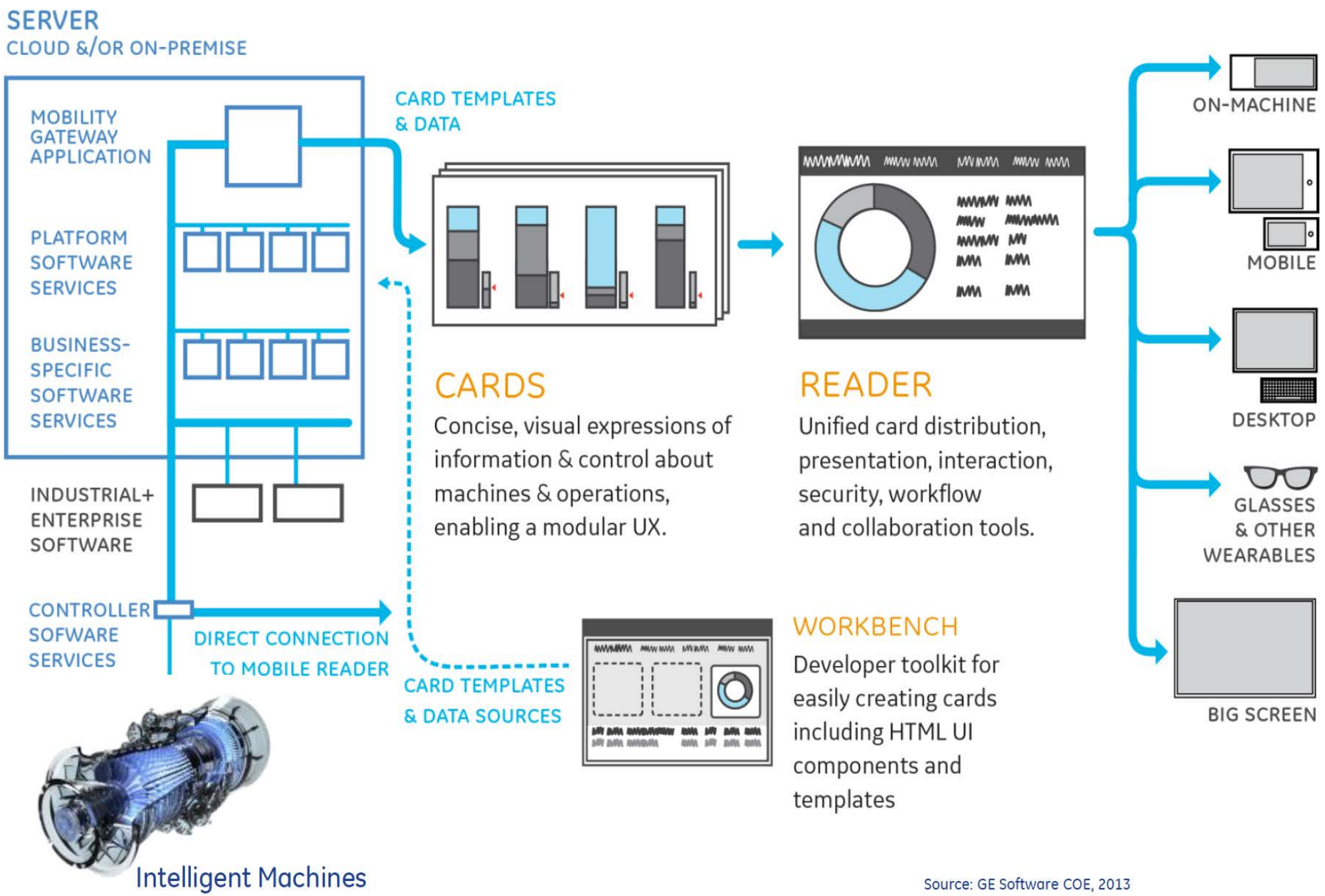
Adapted from Antony Passemard

The Industrial Internet Architecture – CyberPhysical Systems Perspective



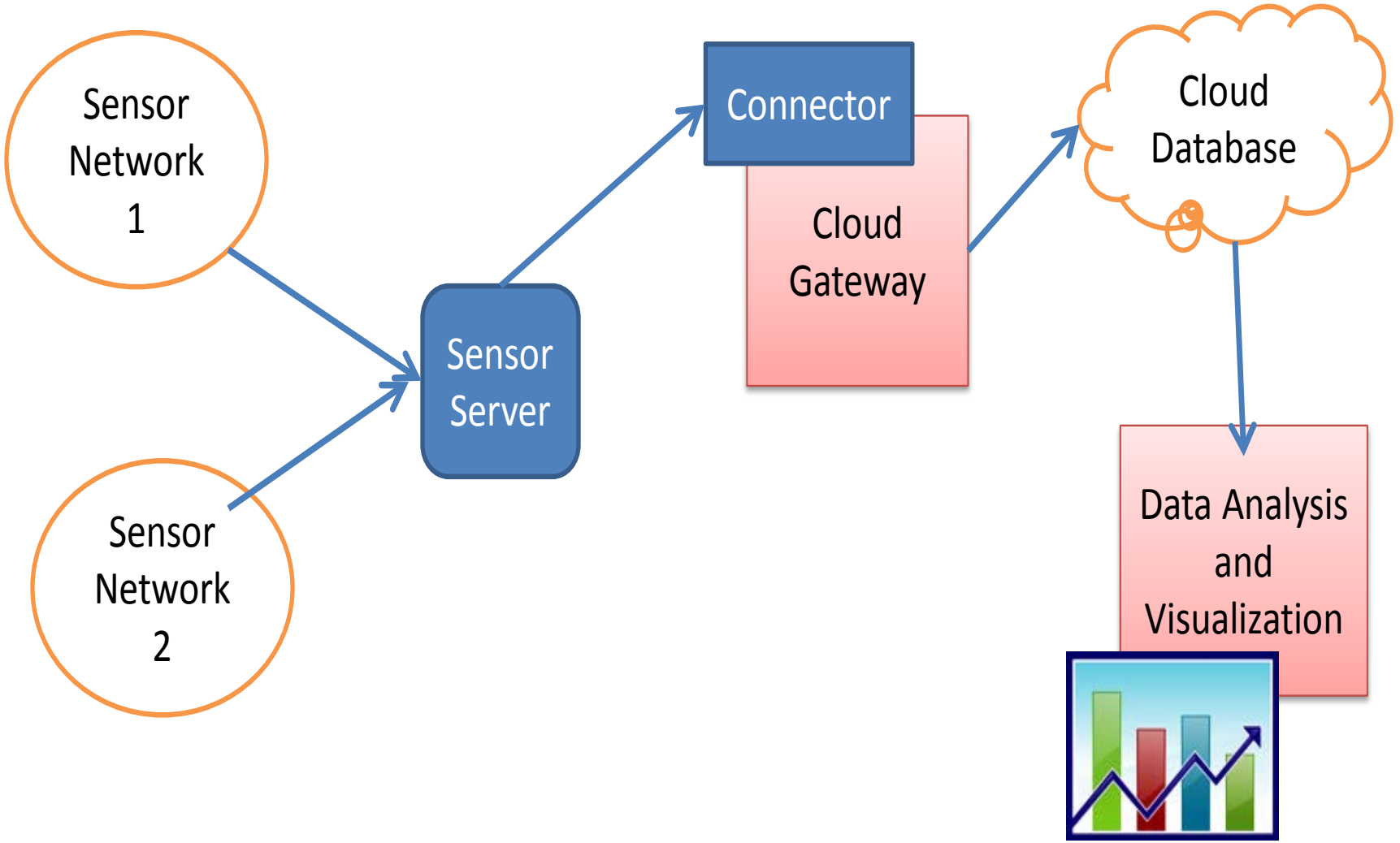
Dr Sokwoo Rhee
Presidential Innovation Fellow
Cyber-Physical Systems & NIST

Industrial IoT – The Man-Machine Integration and Connection

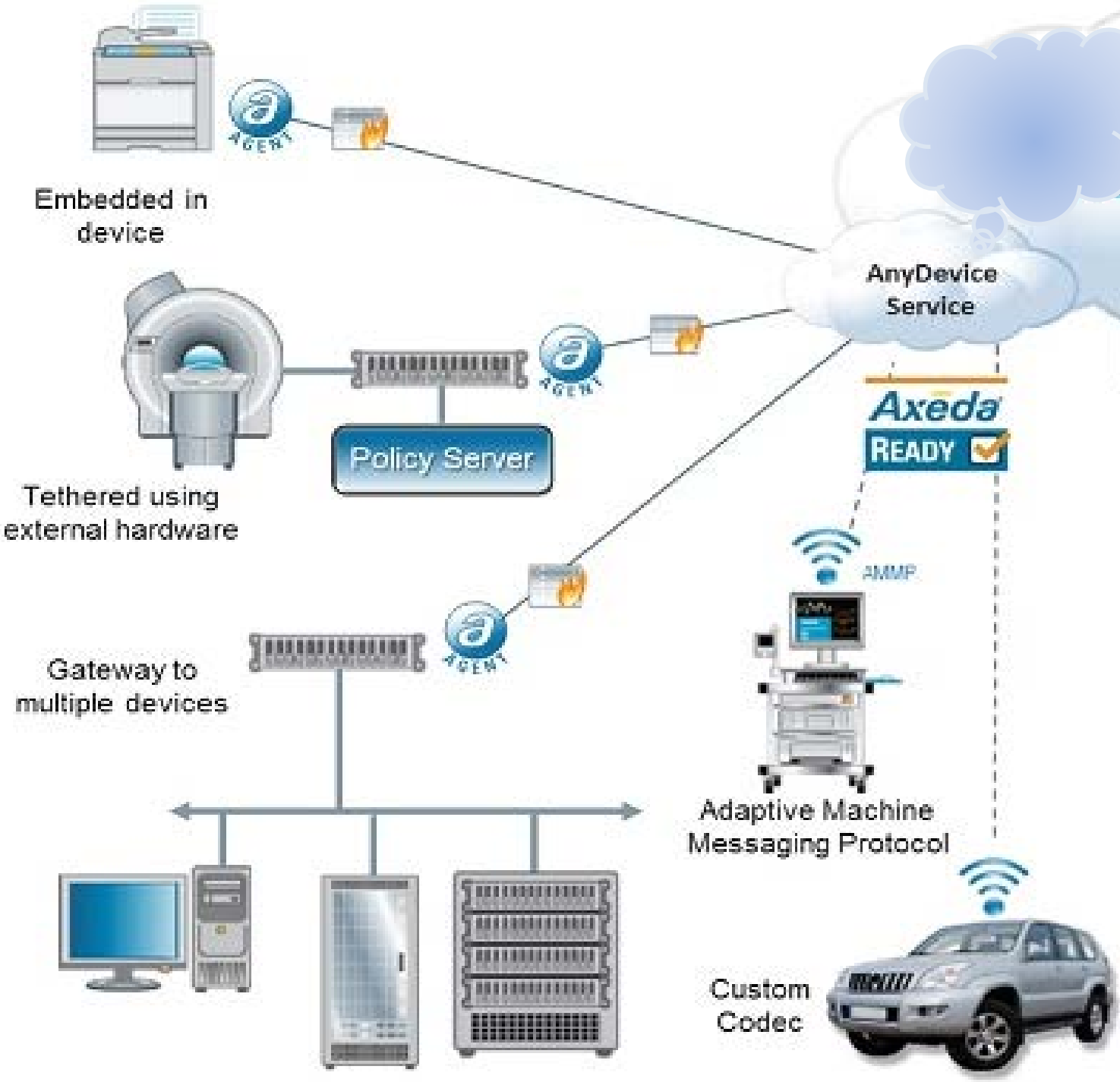


Source: GE Software COE, 2013

Cloud of Sensors



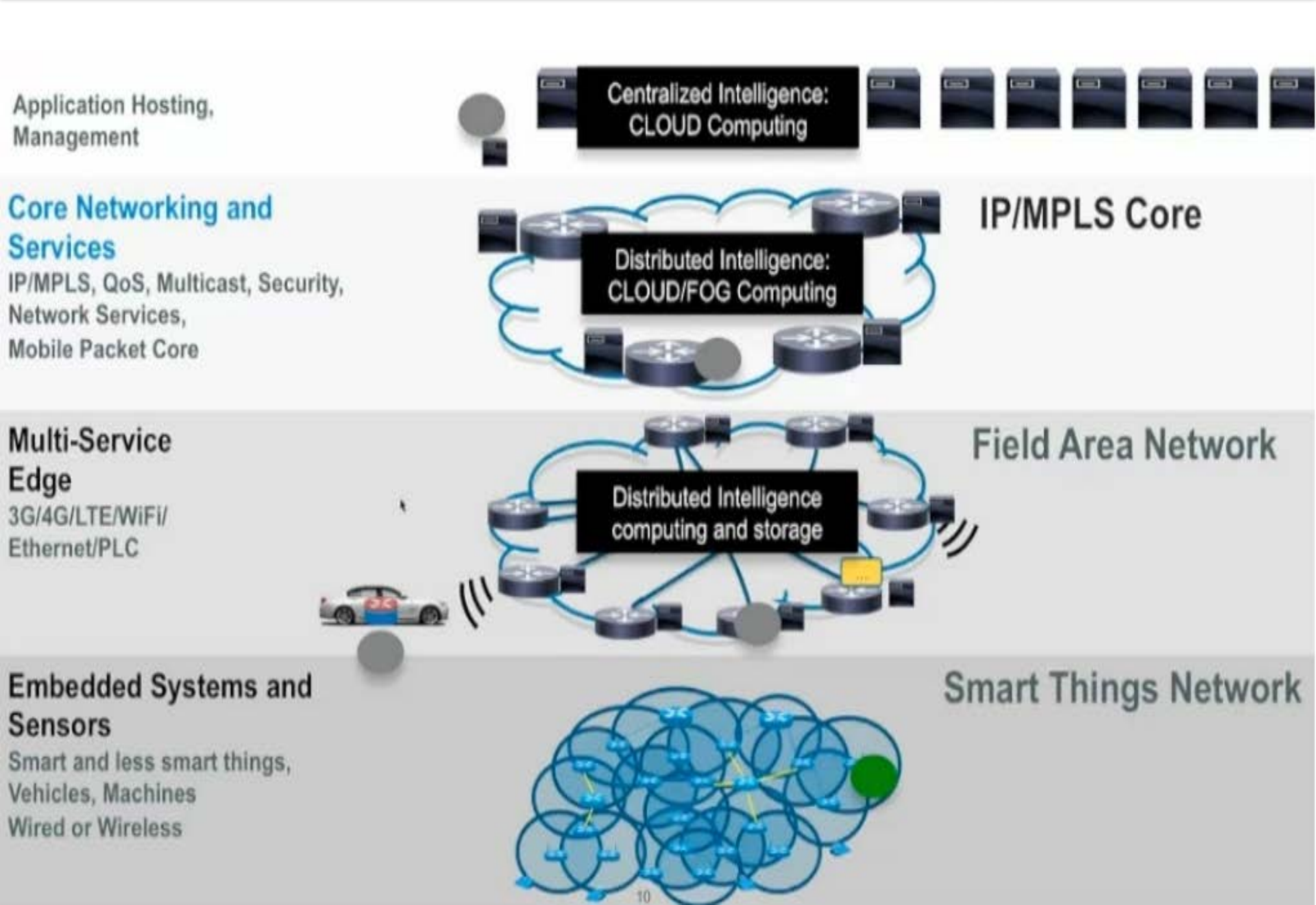
More Clouds


Embedded in device
AGENT
AnyDevice Service
Tethered using external hardware
Policy Server
Axeda
READY
AMMP
Gateway to multiple devices
Adaptive Machine Messaging Protocol
Custom Codec

Choice of IoT Platforms – How will it support end-2-end interoperability ?

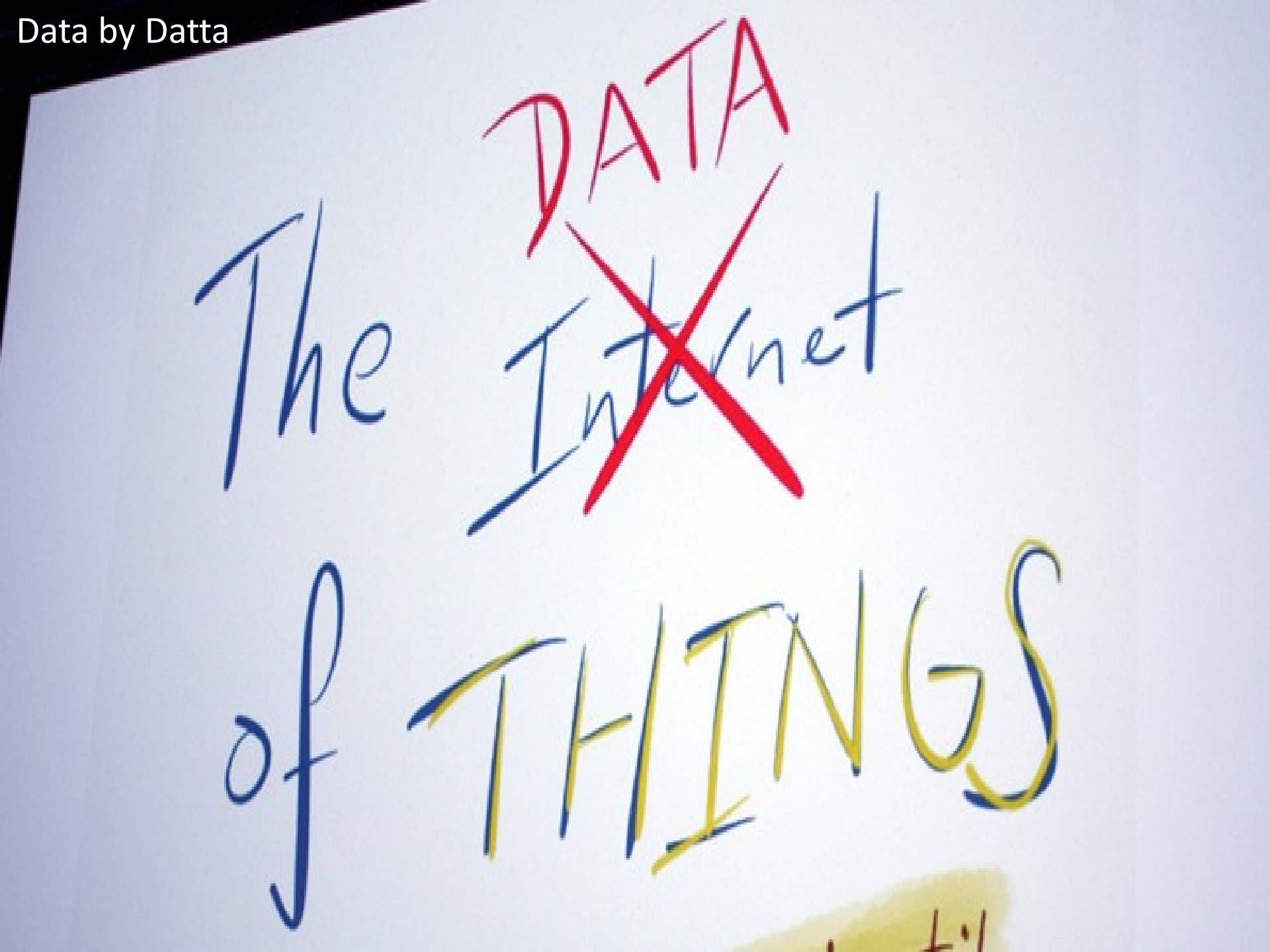
- What is the definition of an IoT platform?
- What is driving the business need for IoT platform?
- What security and privacy features are essential?
- What connectivity and device management features are critical?
- How will the platform process, store and integrate data from machines and sensors?
- How will the IoT platform manage software and variant configurations on devices?
- What development and integration tools will be necessary?

Elements of IoT Architecture – JP Vasseur, Cisco Systems



IoT will be generating hellabytes of

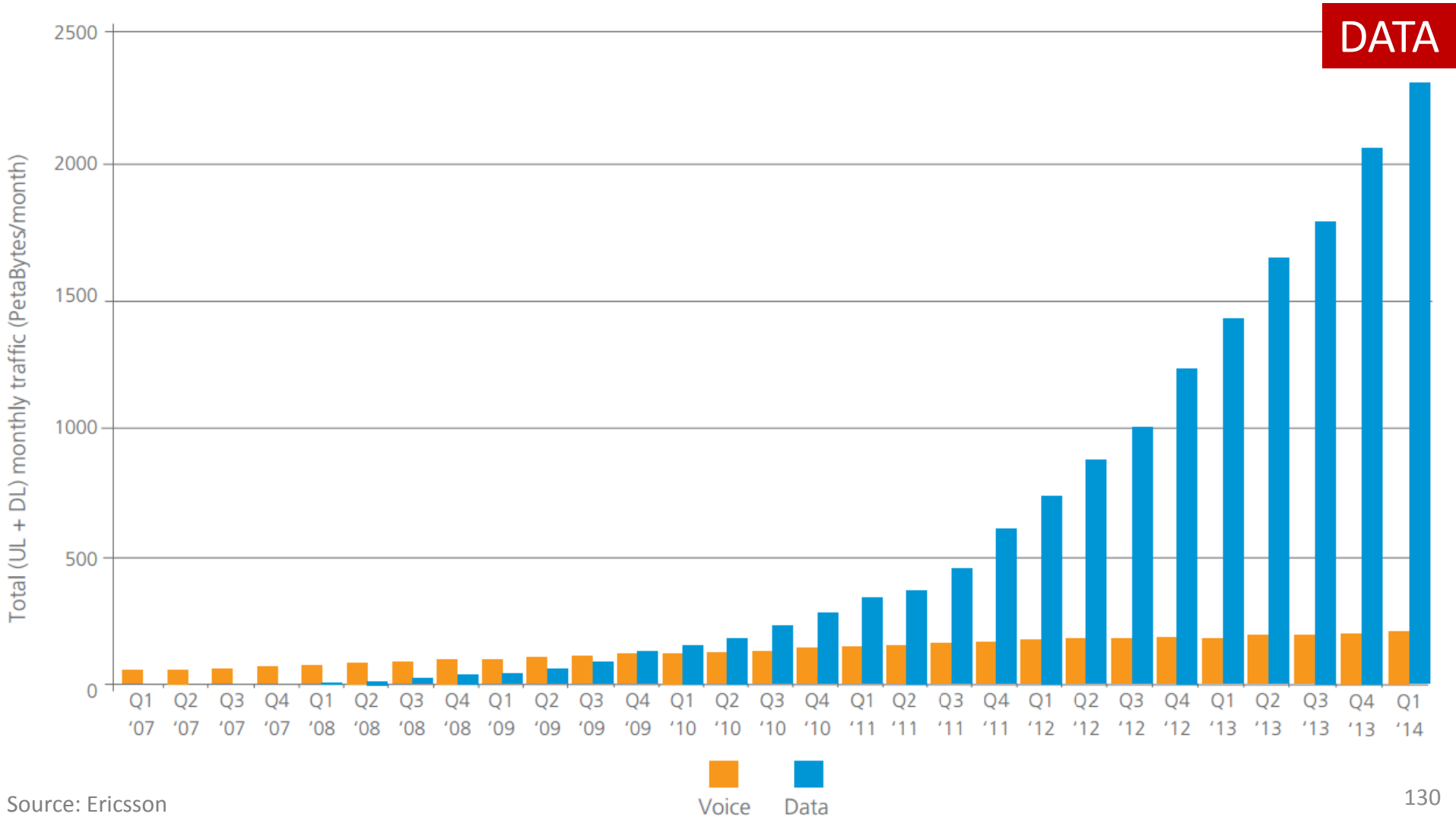
DATA


DATA
The Internet
of THINGS

Identifying new lines of business due to emerging global demand pattern

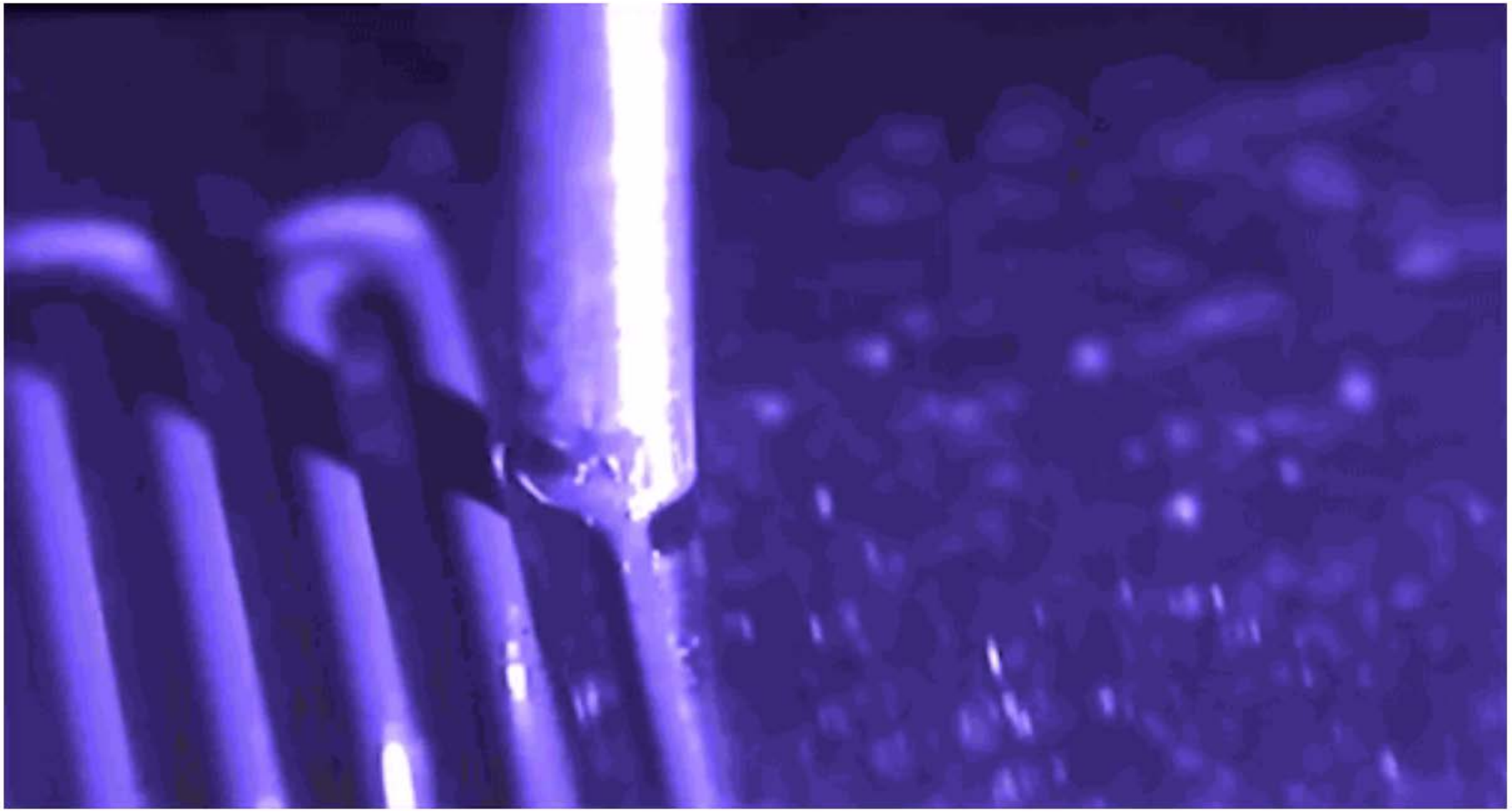
Data is gaining momentum as a "new" dimension for new economic growth

Data – new disruptive dimension for economic growth

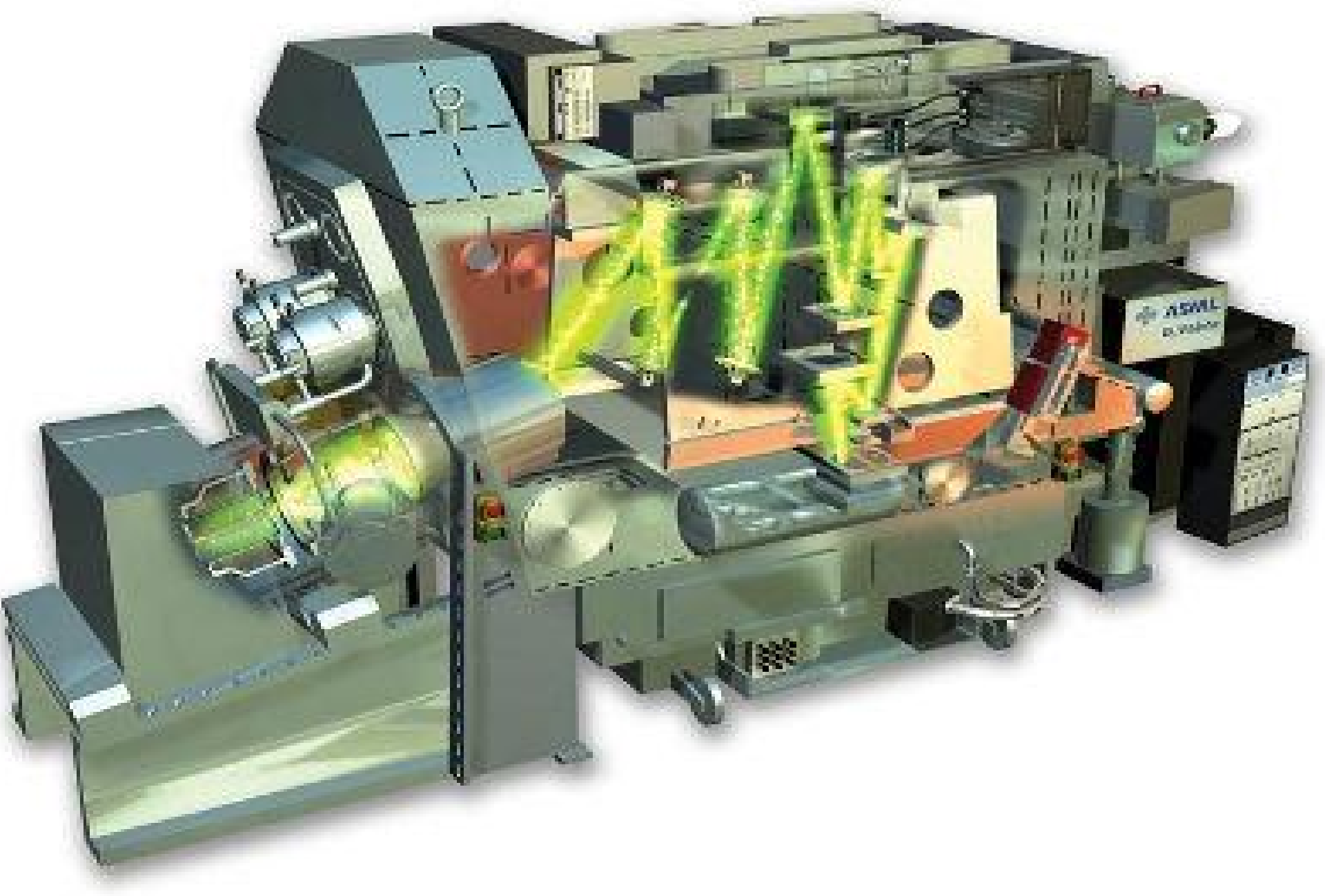


Source: Ericsson

Data from inside machines – GE prints sensors deep inside equipment

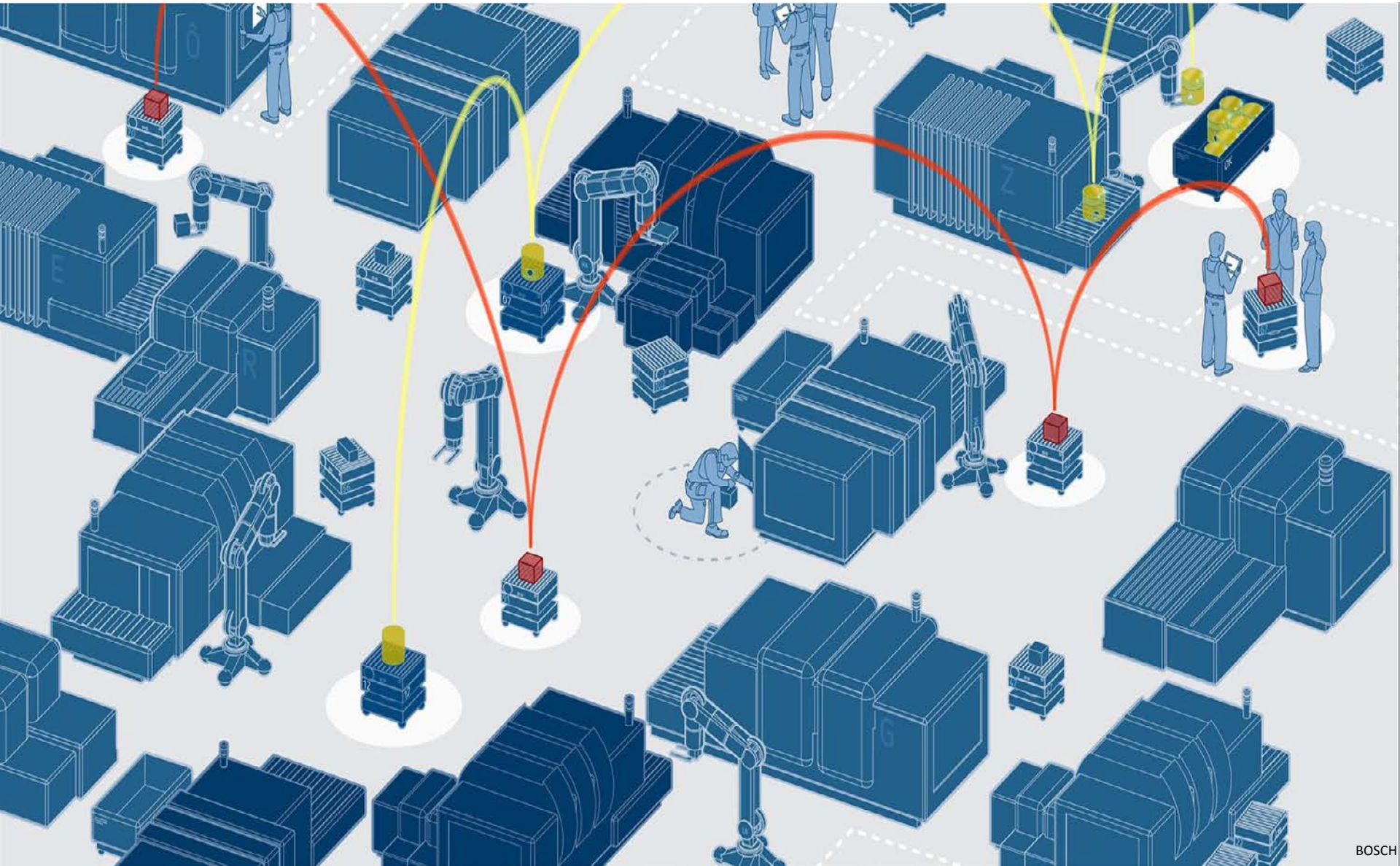


Data from inside machines – sensor networks inside “intelligent” machines



Robotics in manufacturing is nothing new but shop floor data networks?

Data networks improve variant configuration and connects to supply chains



BOSCH

Big Data

IoT

- Volume
- Variety
- Velocity
- Volatility
- Veracity

- Components
- Connectivity
- Convergence
- Collaboration
- Community

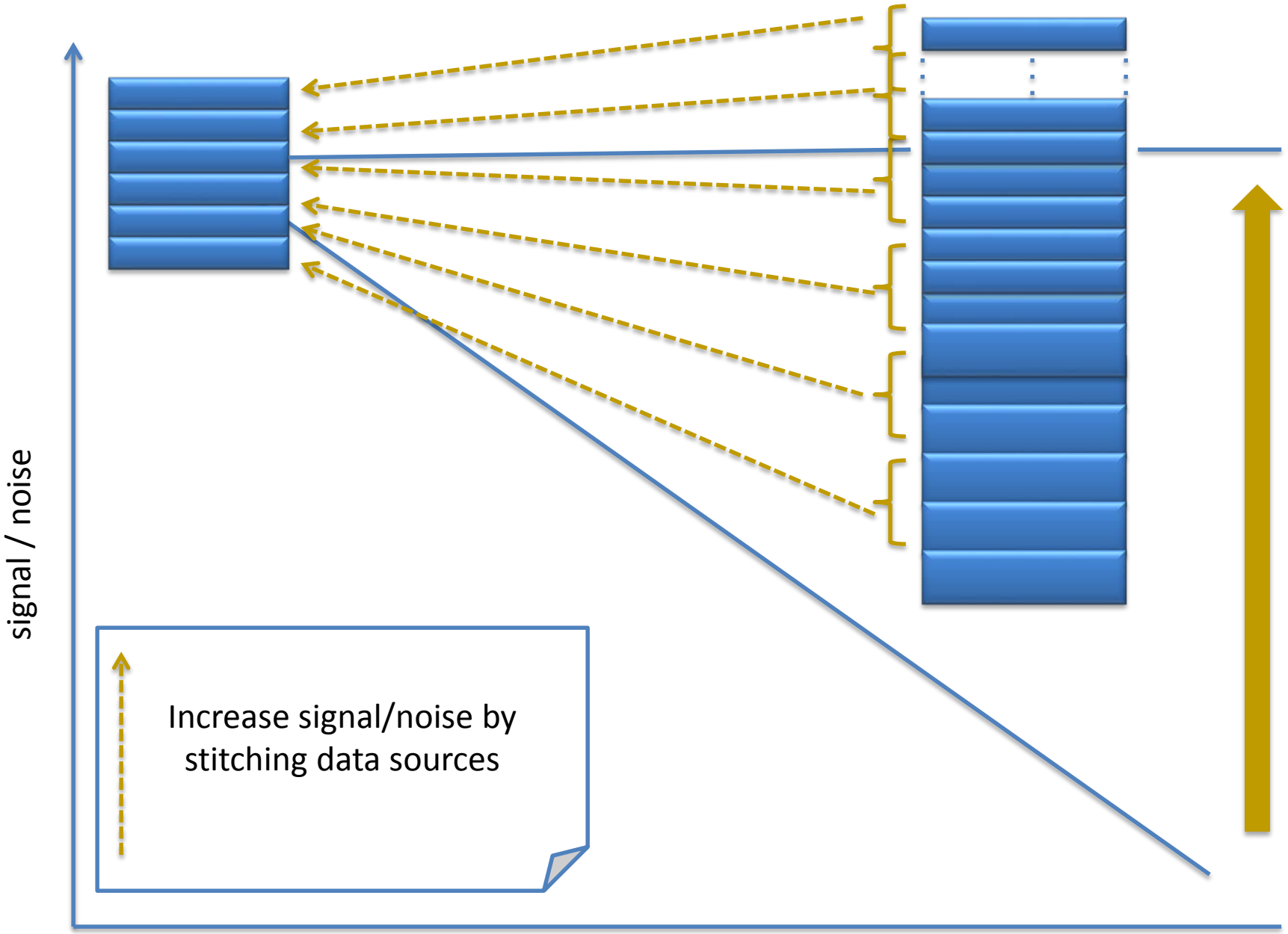
5 V

5 C

It is crucial to make sense of

DATA

Monetization of Perishable Broad Data → extract signal, sanitize, stitch, sell



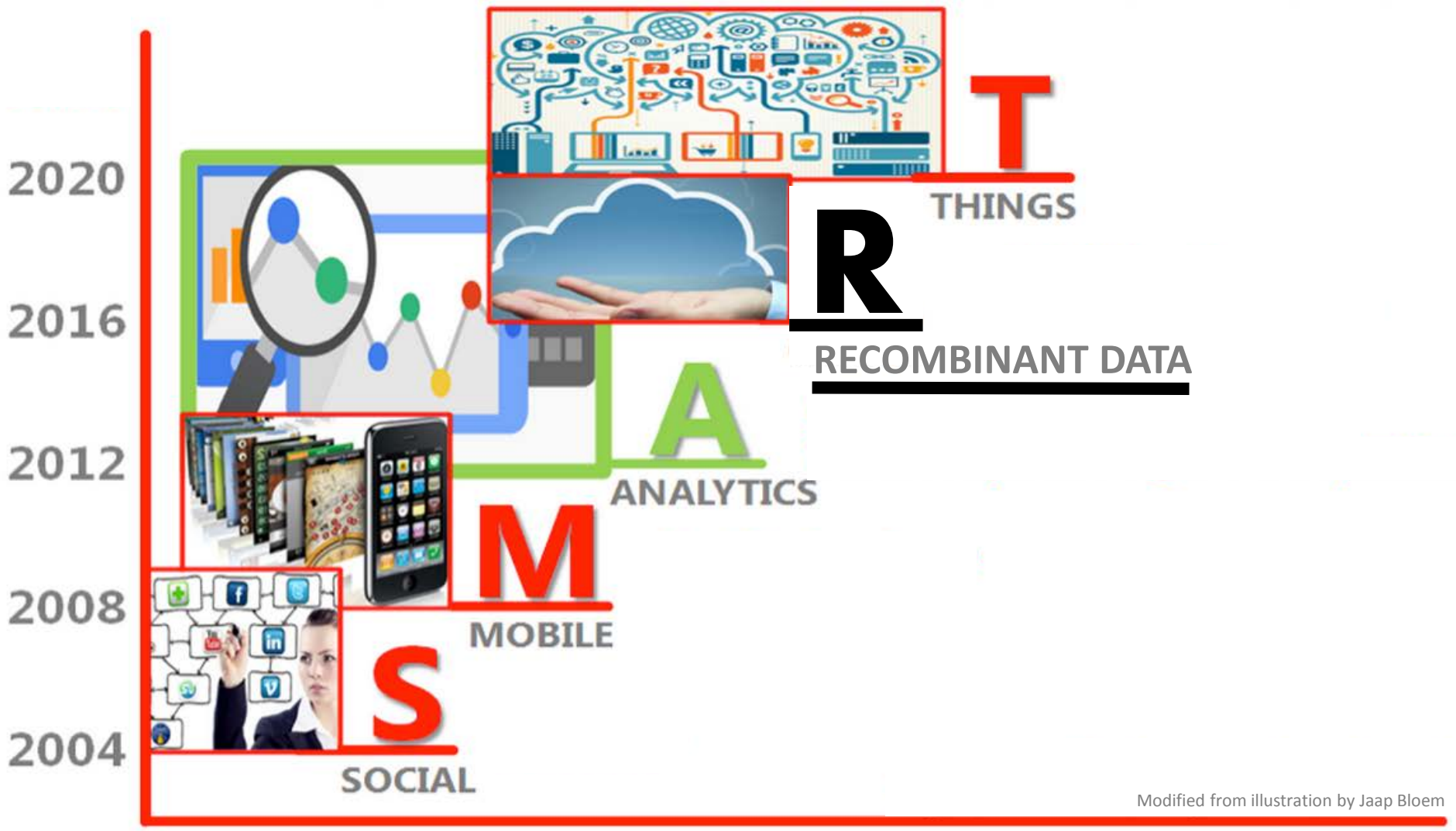
Broad spectrum of data

The range of data related applications will stretch our imagination

Recombinant Data

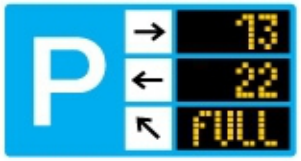
Data (by itself – in one silo) is of limited value unless analyzed in conjunction with other data in context of the application or problem-question

How smart can you make SMART ?? Depends on Recombinant Data

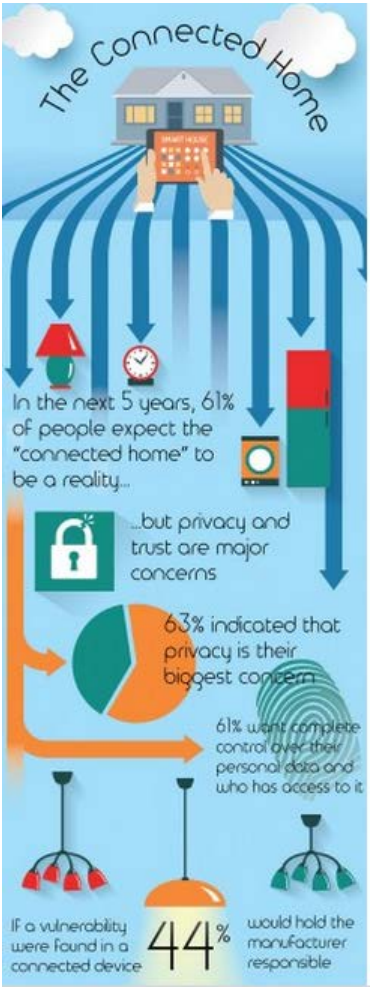


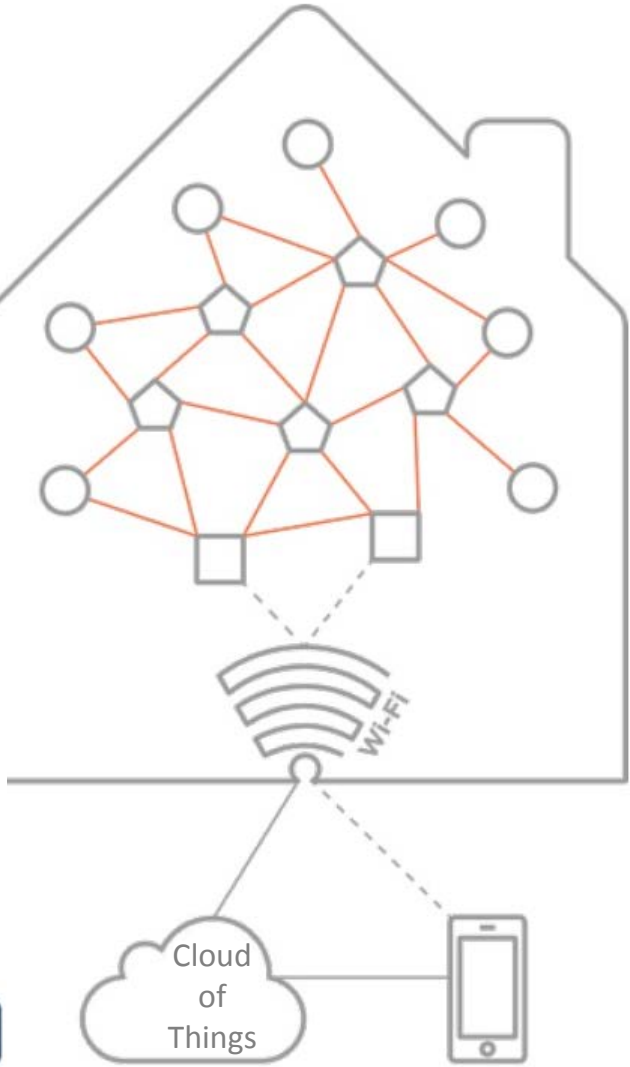
Making Sense of Recombinant Data – unleashing the value cryptic in data

VALUE IS CREATED BY MAKING SENSE OF DATA

	Smart city	Smart home	Smart car
Connected devices	 Sensors embedded in road surface	 Connected lock	 Bluetooth dongle reading vehicle data
Data			
Knowledge	Find an empty parking spot 	Detect when I come home 	Detect collisions 
Action	Park quickly without frustration	Disarm the alarm when I unlock the door	Automatically call emergency services

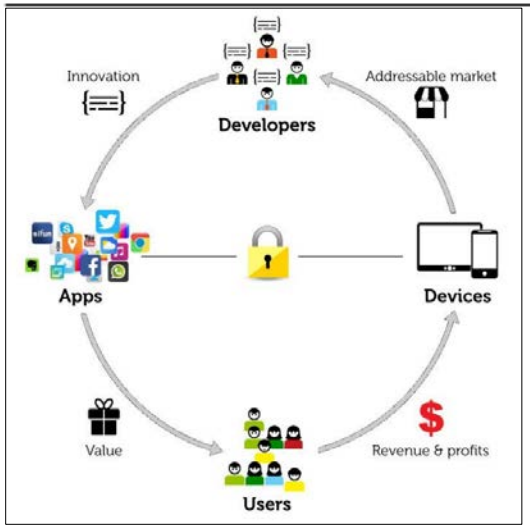
Threading a Home Mesh Network to make every home a smart home?





Job creation catalyzed by the industrial internet and internet of things

THE NUMBER OF IOT DEVELOPERS 2014-2020

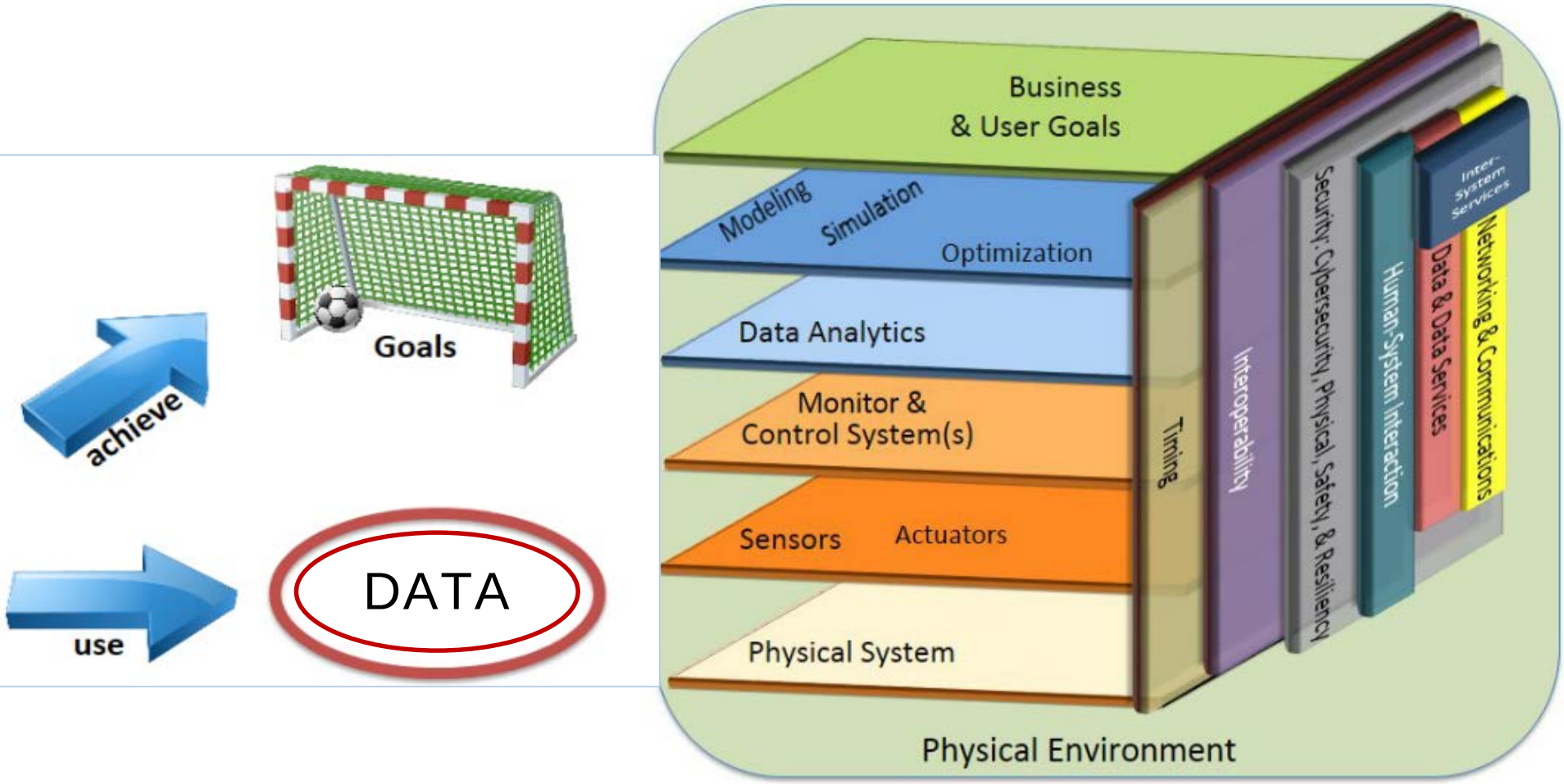


Demand for 4.5 million developers by 2020 – new jobs for software industry

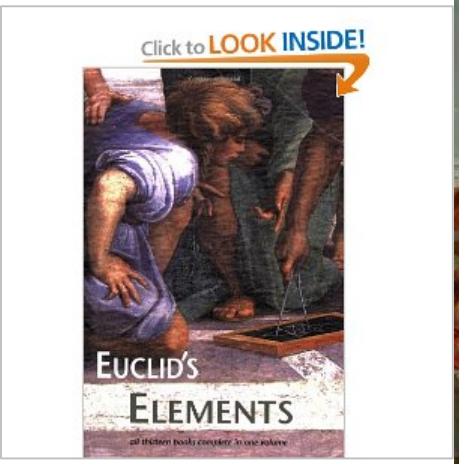
Intelligent Recombinant Data Analytics

Predictions are very difficult, especially if it is about the future – Niels Bohr (1885-1962)

Staple horizontal for Internet of Things – IRDA and Data Driven Decision-making



Did we arrive at a conclusion we knew almost since the beginning of time?



Born Raffaello Sanzio da Urbino in 1483 (Urbino, IT). Died April 6, 1520 (Rome, IT) Raphael - The School of Athens

Mathematics

The quintessential denominator

IoT enabled examples

How the medium of the internet is generating value in other verticals

Examples of IoT enabled value

Boehringer Ingelheim sponsored a competition on Kaggle (platform for data-analysis) to predict if a new drug molecule may cause genetic mutations. The winning team, from among nearly 9,000 competitors, combined experience in insurance, physics and neuroscience. Its analysis beat existing predictive methods by >25%.

FedEx's SenseAware: Customers place a small device the size of a mobile phone inside packages. Device includes GPS, sensors to monitor temperature, light, humidity, barometric pressure and special criteria which may be critical to biomedical products and/or sensitive electronics. Real-time info about product location and if ambient conditions have changed. The data-rich variation of RFID tags helps companies manage complex and perishable supply chains.

Acxiom offers clients, from banks to auto companies, profiles of 500 million customers. Each profile enriched by more than 1,500 data points gleaned from the analysis of up to 50 trillion transactions.

Data from real-time monitoring of blogs, news and Tweets may detect subtle shifts in sentiment that can affect product and pricing strategy. Advanced analytic software allows machines to identify hidden patterns in massive data flow or documents. This machine "intelligence" means that a wider range of knowledge tasks may be automated at lower cost. As companies collect more data from operations, they may gain new revenue streams by selling sanitized information on spending patterns or physical activities to third parties ranging from economic forecasters to health-care companies.

Examples of IoT enabled value

Clearwell Systems (Silicon Valley) analyzes legal documents for pretrial discovery. Machines scanned >0.5 million documents and pinpointed the 0.5% which were relevant. What would have taken a legal team several weeks took 3 days. Machines are becoming adept at structuring basic content for reports, auto-generating marketing and financial materials by scanning documents and data.

Signaling a new quest for AI based decision support system (DSS), IBM's Watson is tackling cancer research by reading >600,000 medical-evidence reports, 1.5 million patient records and 2 million pages of clinical-trial reports and medical-journal articles. Aids decision-support for oncologists at Memorial Sloan-Kettering Cancer Center, NY.

Food retailers Tesco and Delhaize deployed life-size store displays at S. Korean & Belgian subway stations. It allows commuters waiting for trains to use smartphones to order groceries, which are shipped to their homes or available for pickup at a physical store location. Other retailers are using similar displays in physical stores so consumers can also order out-of-stock (OOS) products.

Connectivity and IoT enabled value will influence government, healthcare, education

India has enrolled 380 million citizens in the largest biometric-identity program (Aadhaar). It plans to use the system to make >$50billion in cash transfers to the poor (saves $6billion fraud)

Smartphones and tablets are entering classrooms to deliver personalized MOOC. India is running trials of the sub-$50 Aakash tablet to link more than 25,000 colleges in an e-learning program.

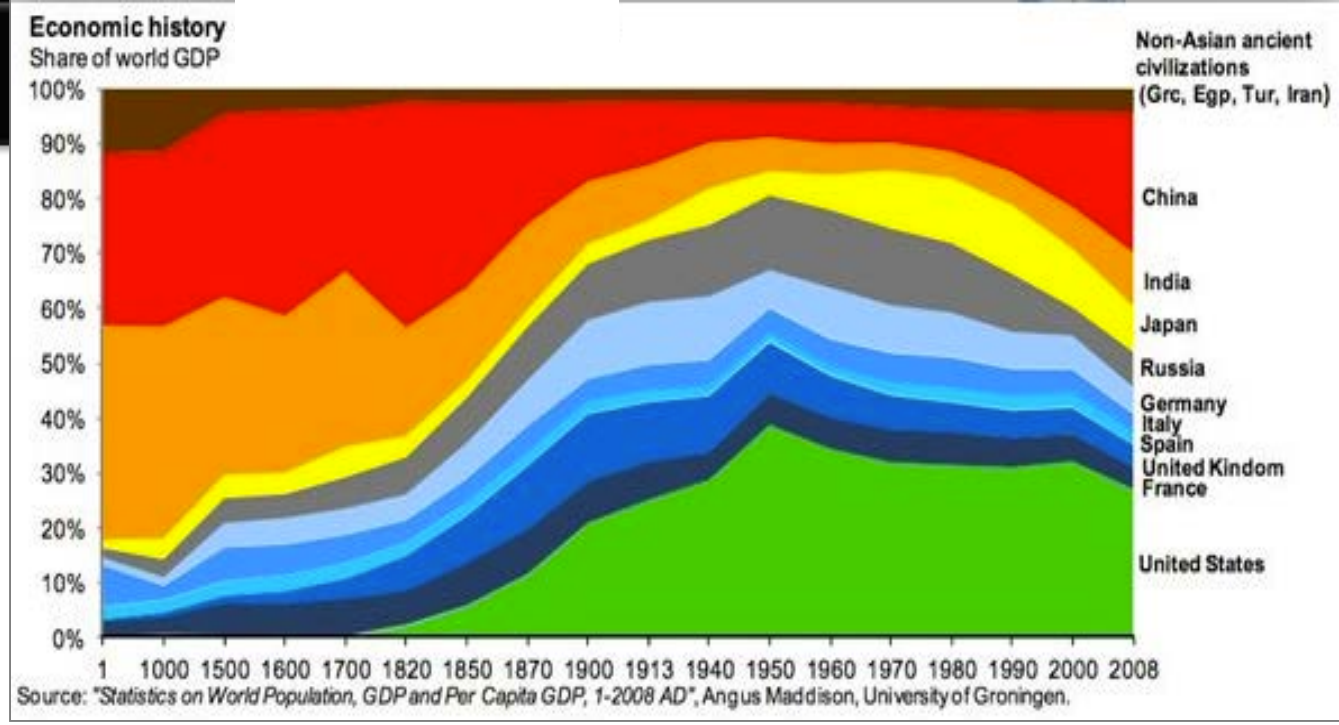
In rural Bangladesh, 90% of births occur outside hospitals. A mobile-notification system alerts clinics to dispatch nurse–midwife teams.

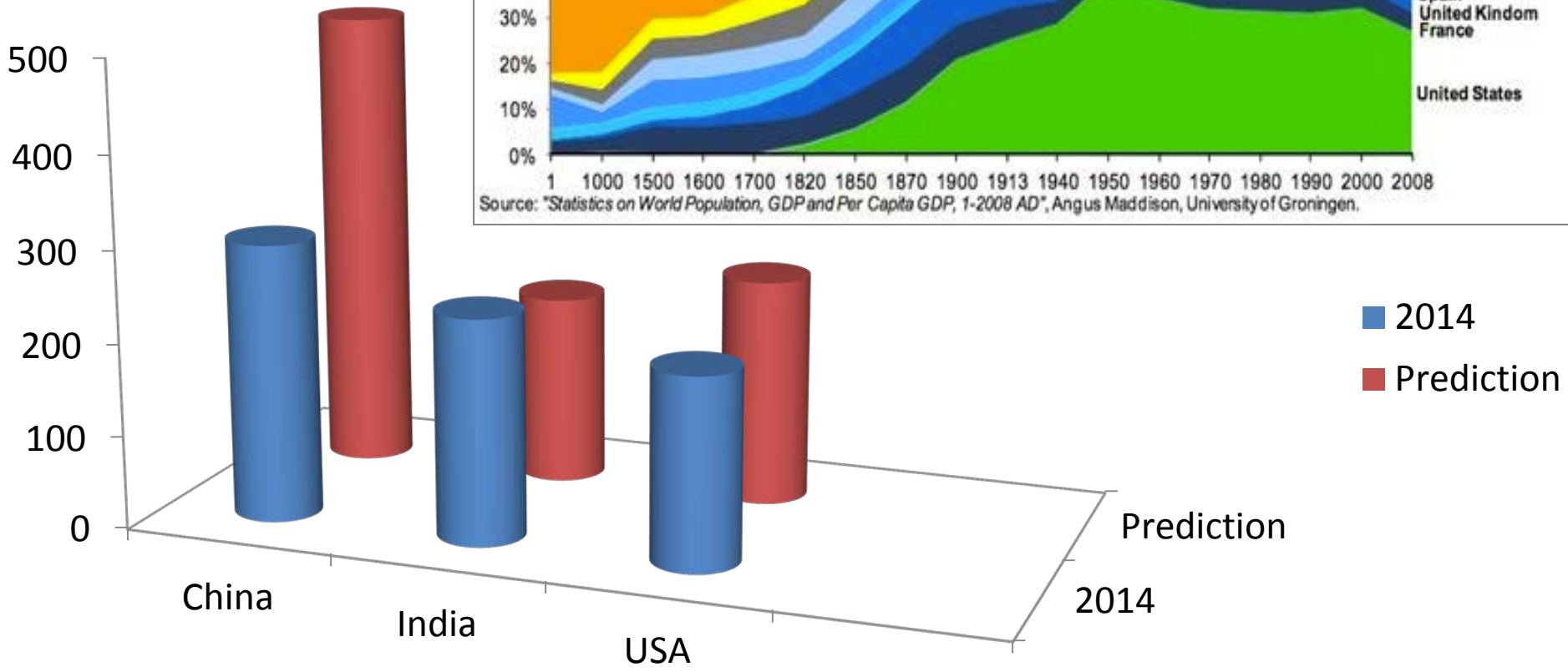
In China, a public–private partnership created a cardiovascular-monitoring system that allows patients to self-administer electrocardiograms and transmit data to specialists in Beijing, who may suggest treatments by phone.

In 2011, US government introduced a Cloud First policy, which laid out a vision to shift a quarter of the $80 billion in annual federal spending to the cloud from in-house data centers. It may save 20-30% on the cost of the shifted work.

Mt Sinai Hospital (NYC) collaborates with GE to use smart tags to track the flow of hundreds of patients, treatments and medical assets in real time. The hospital estimates may treat 10,000 more patients / year and generate $120 million in savings and revenues over several years.

Return of the Halcyon Days?

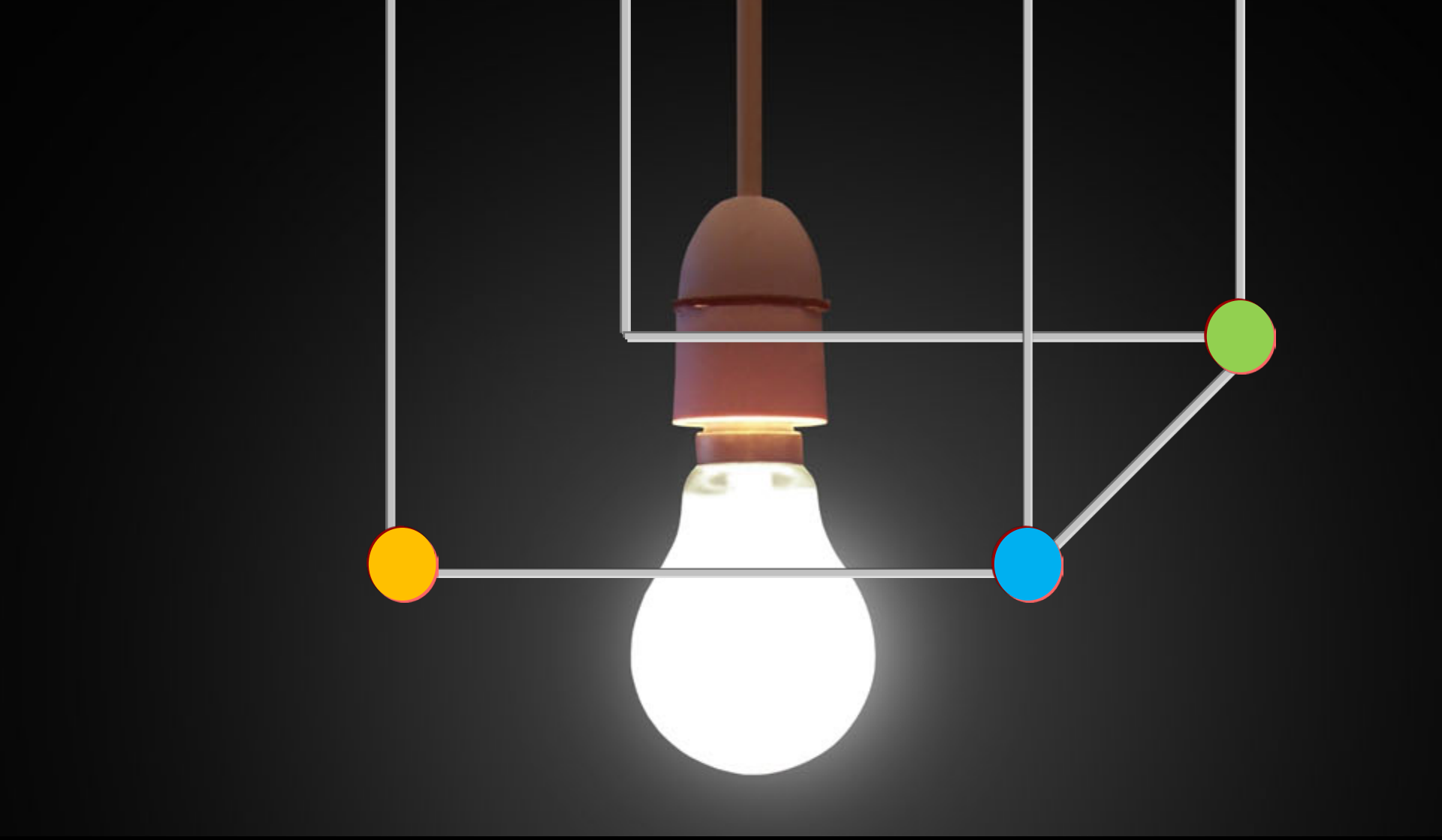




Can IoT Spur Economic Growth for the Dragon and the Elephant to Dominate the Share of Global GDP? With 243 million users by 2014, India exceeds US in internet reach. But, India's digital penetration is only 10% and China 40%. Rising levels of connectivity presents potentially enormous opportunities for business.

Return of the Halcyon Days?

Market Cap as of Sep 19, 2014



Internet of Things

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