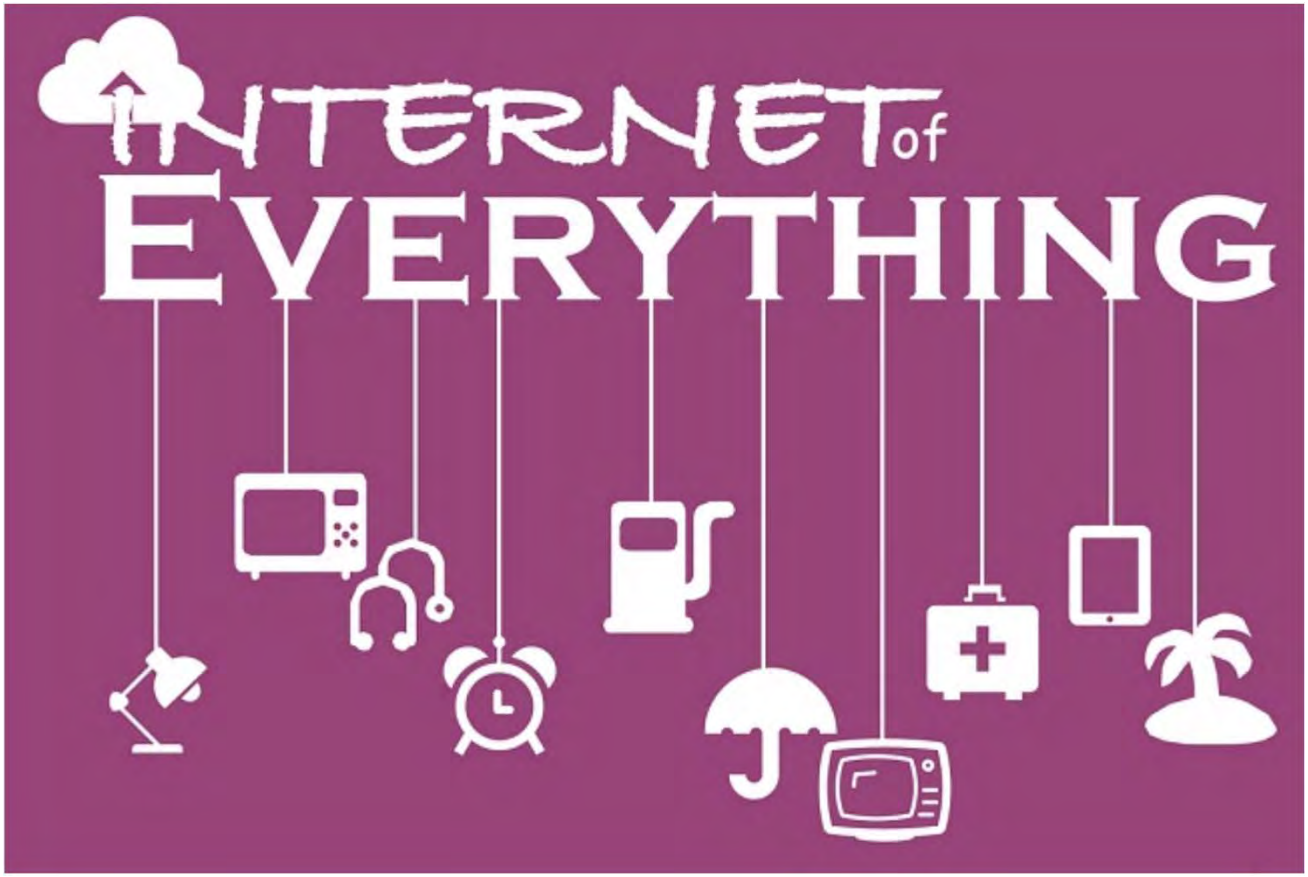


Michael I. Shamos, Ph.D., J.D.
School of Computer Science
Carnegie Mellon University

The University of Hong Kong

institute for SOFTWARE RESEARCH

Background

- Ph.D., Yale University (computer science, 1978)
- J.D., Duquesne University (law, 1981)
- Carnegie Mellon computer science faculty (1975 -)
  - Institute for Software Research
  - Language Technologies Institute
- Director, Universal Library
- Director, Master's Program in eBusiness Technology
- Visiting Professor, University of Hong Kong (2001-)

The Internet of Things



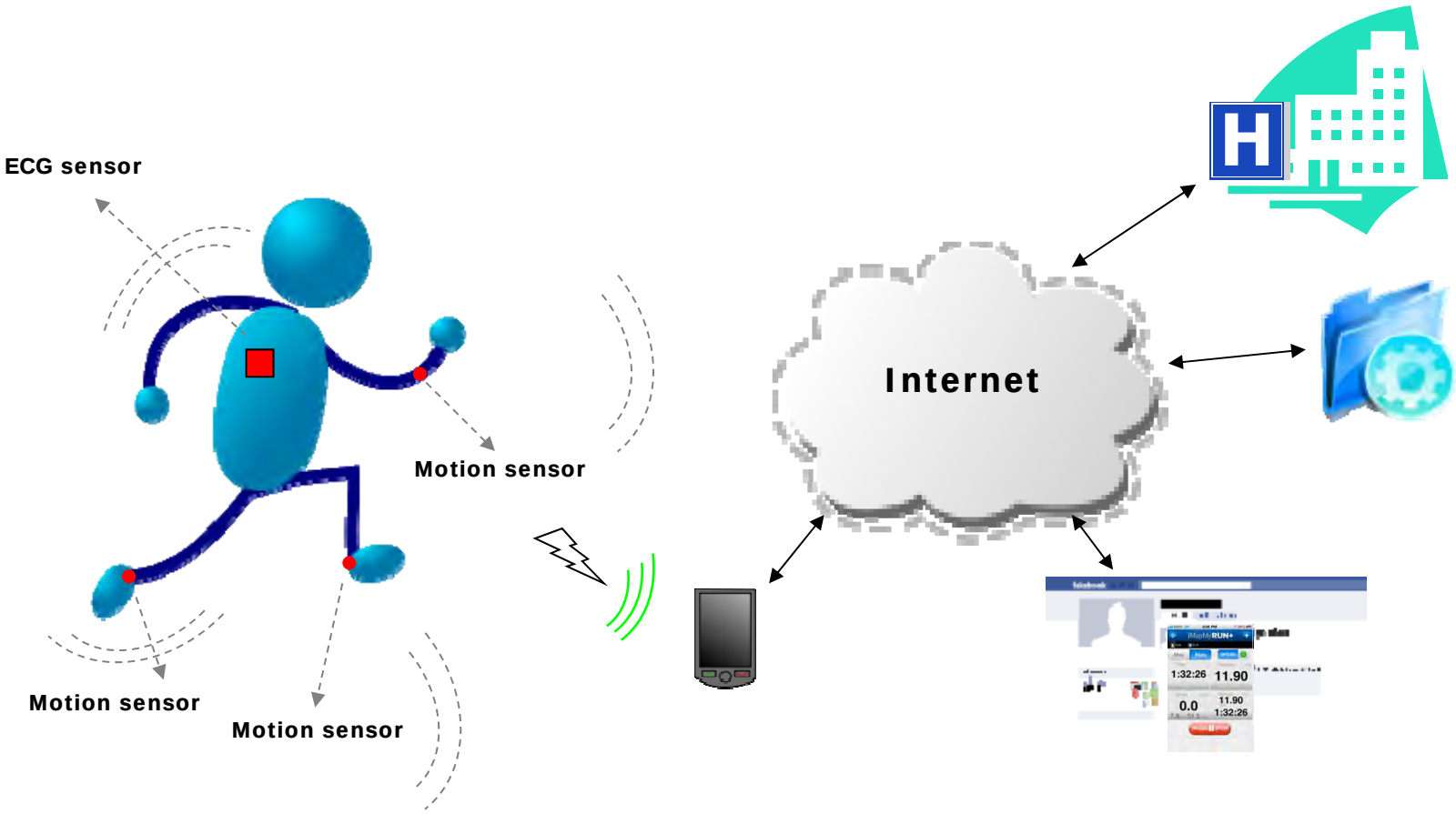






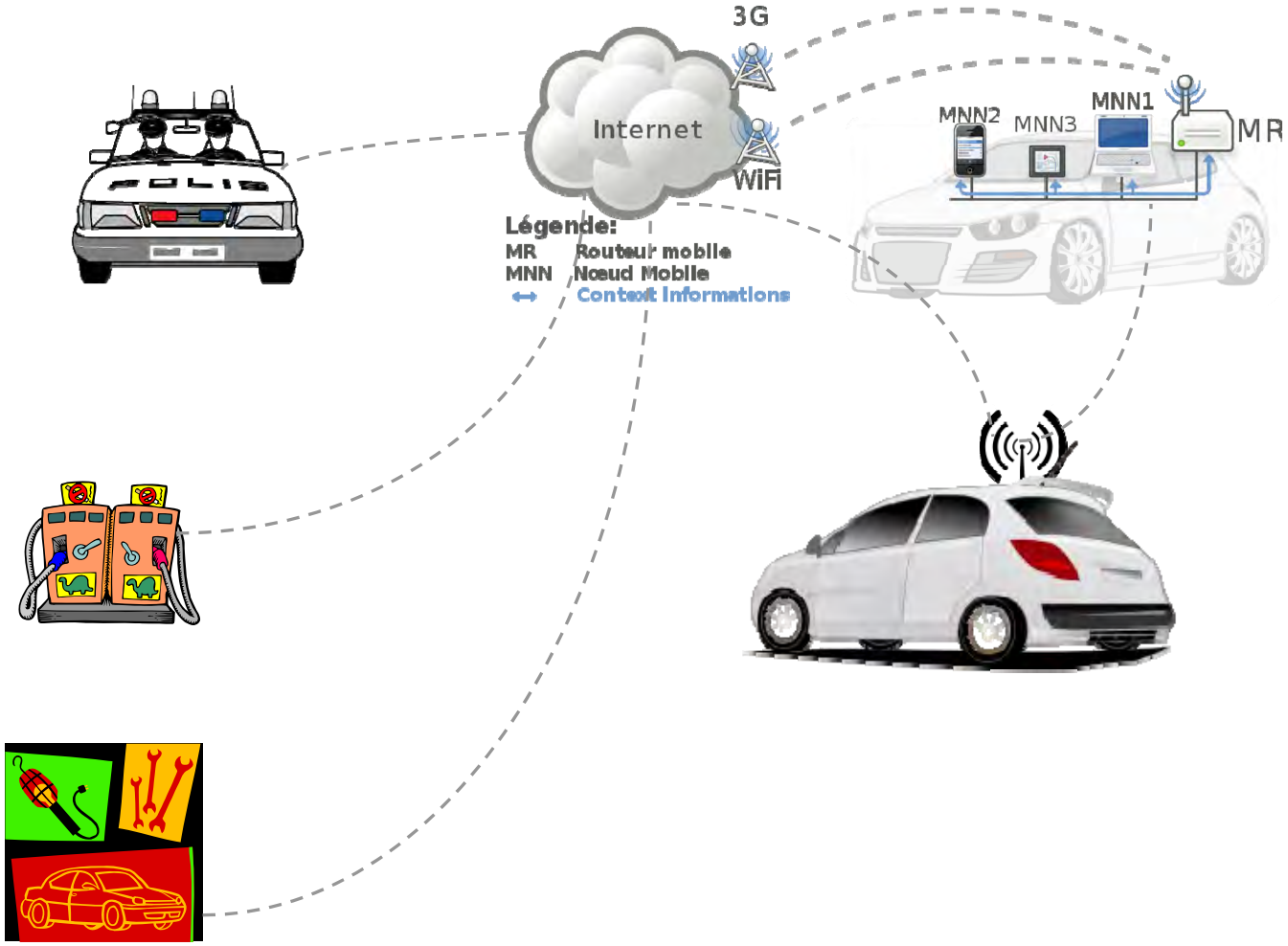


People Connected to Things



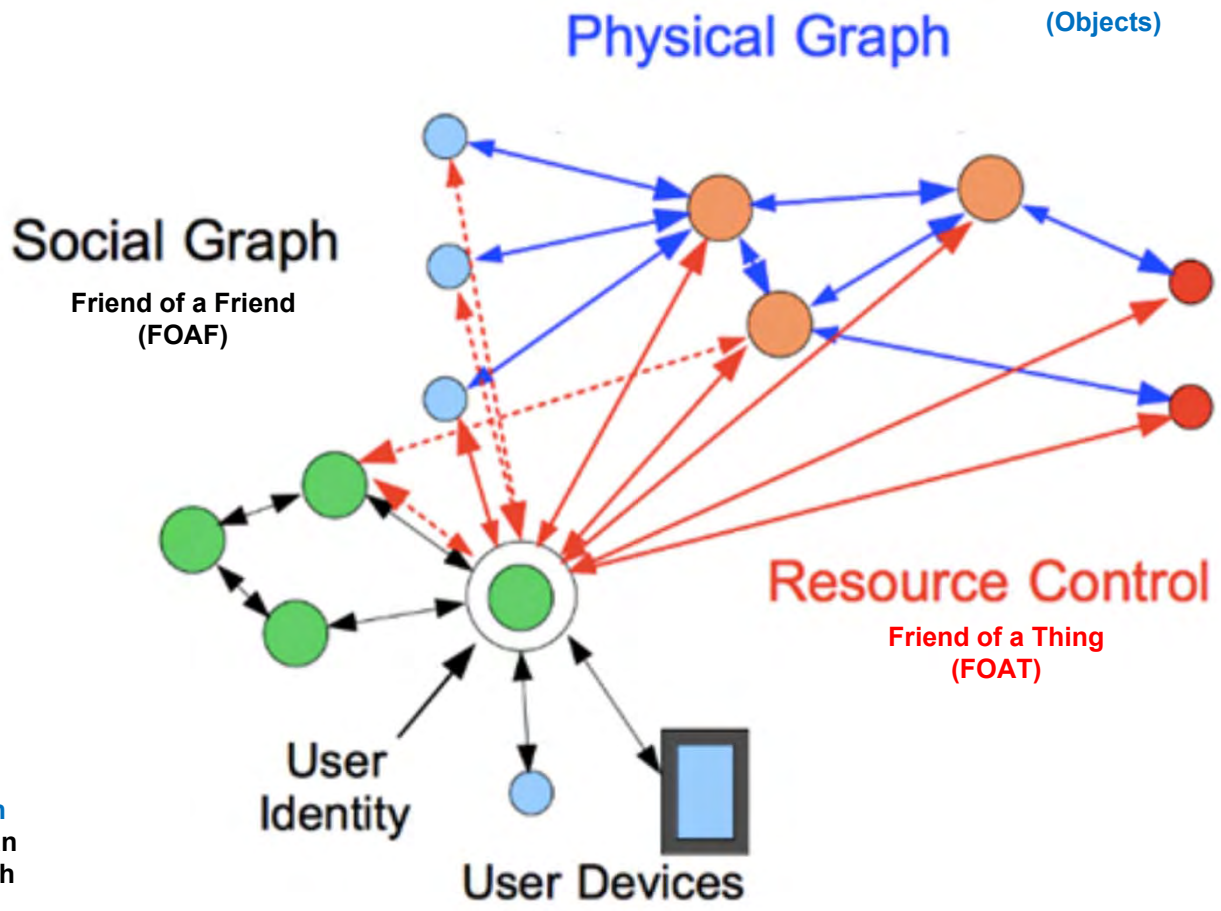
SOURCE: PAYAM BARNAGHI, UNIV. OF SURREY

Things Connected to Things



SOURCE: PAYAM BARNAGHI, UNIV. OF SURREY

IOT + Internet of People

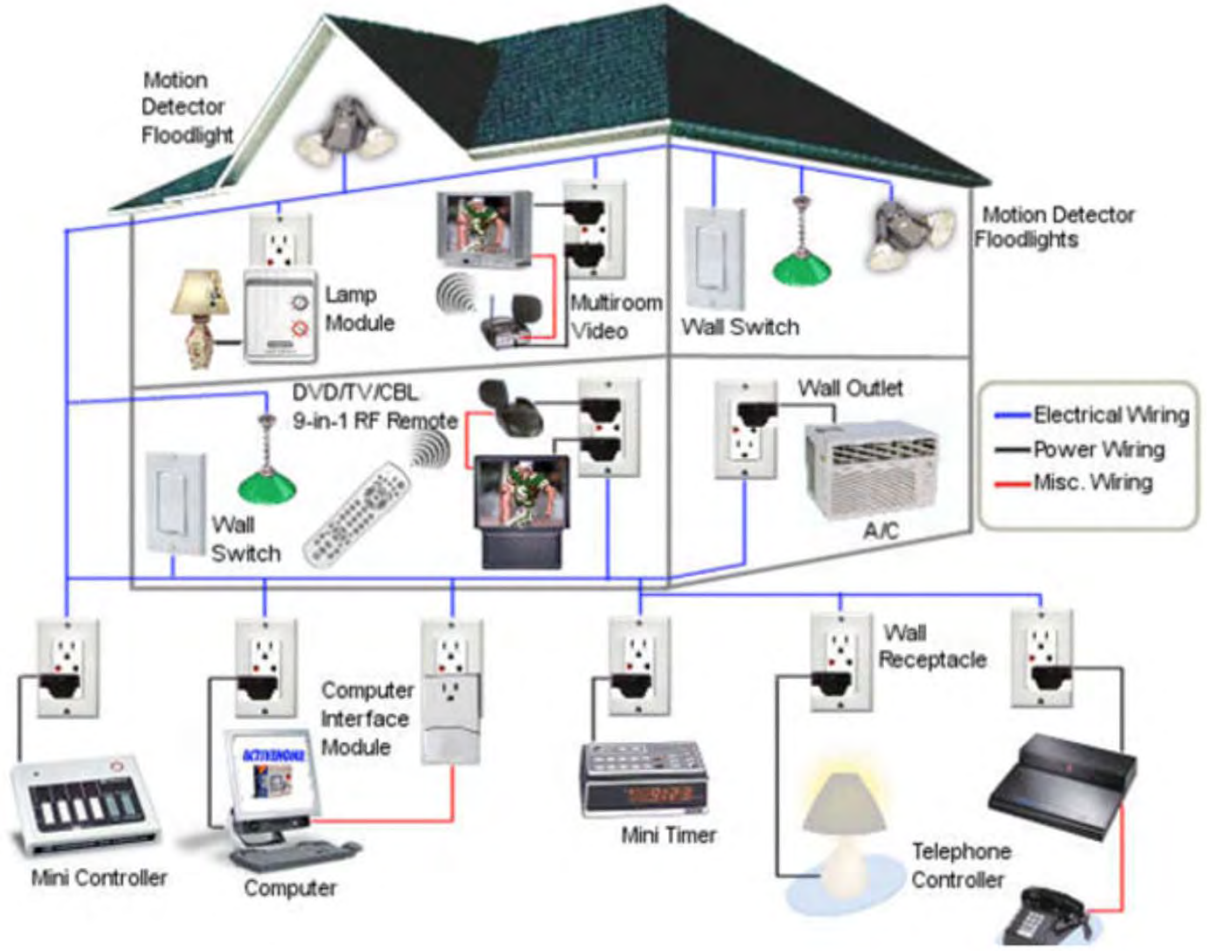


Physical Graph much larger than the Social Graph

SOURCE: THEODOROS MICHALAREAS

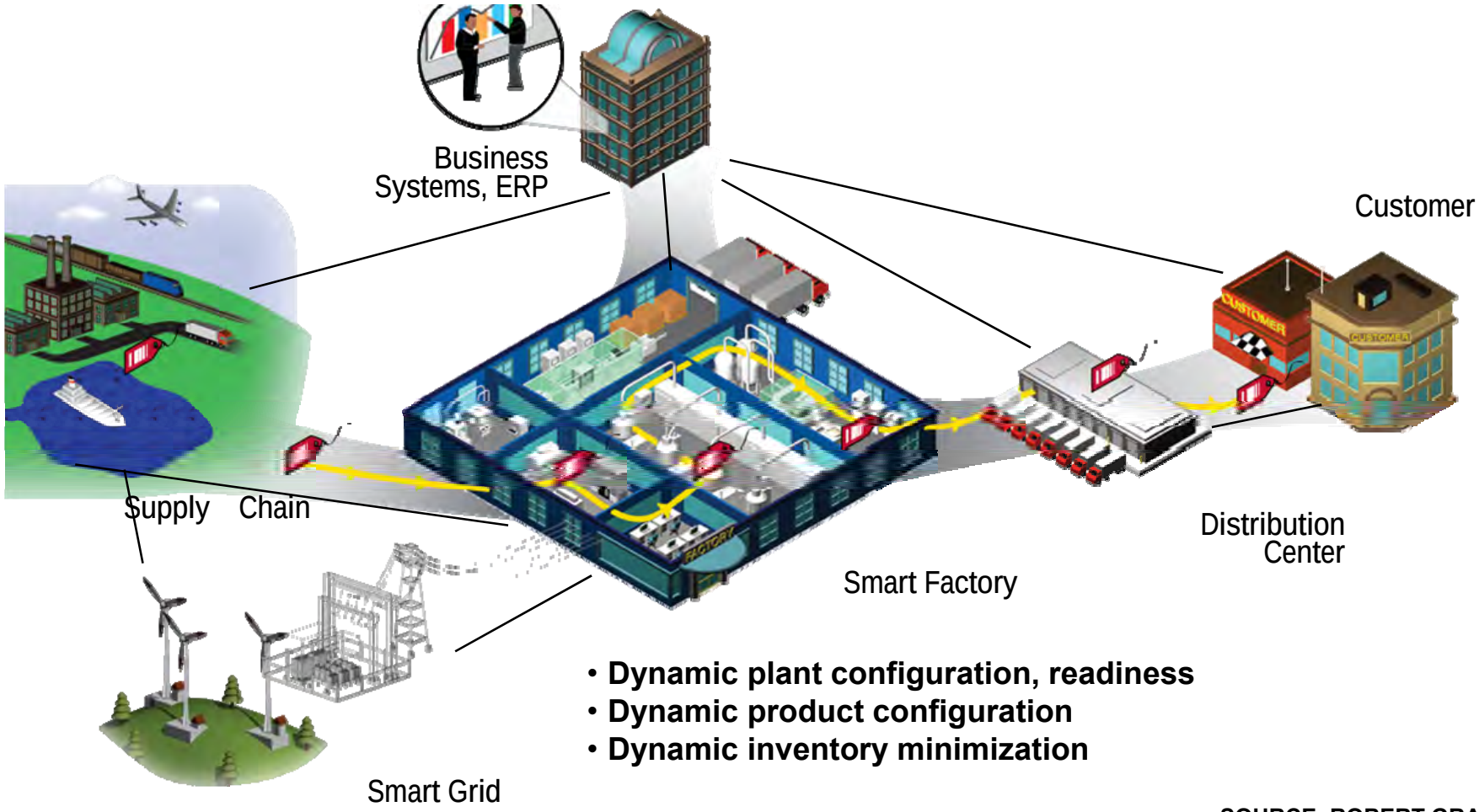
"Bad news - the scale is threatening to cut off our access to the fridge..."

Smart Home



- Home automation expected to grow to US$50B by 2018

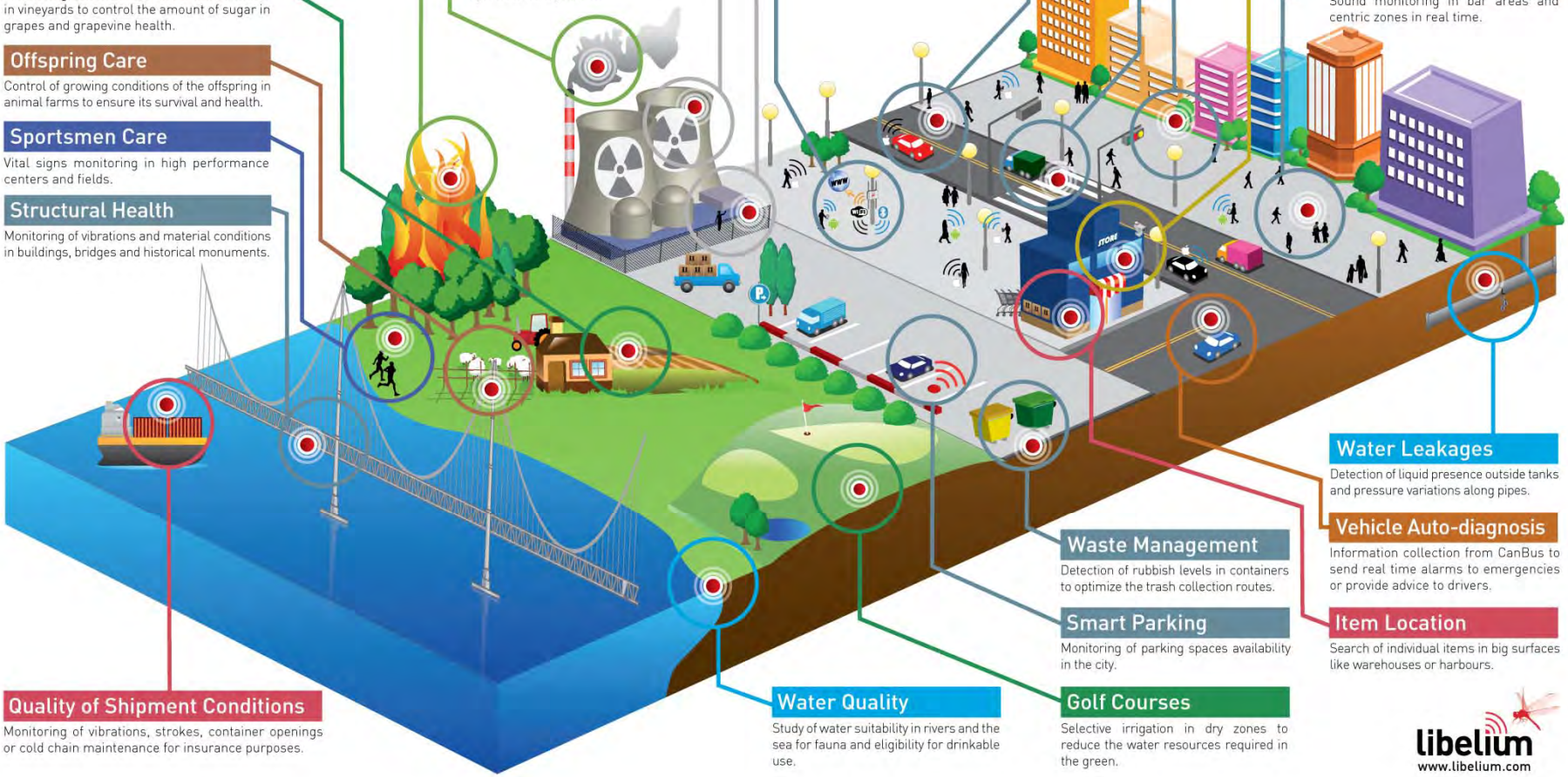
Smart Manufacturing



- **Dynamic plant configuration, readiness**
- **Dynamic product configuration**
- **Dynamic inventory minimization**

SOURCE: ROBERT GRAYBILL

Libelium Smart World



Air Pollution
Control of CO_2 emissions of factories, pollution emitted by cars and toxic gases generated in farms.

Forest Fire Detection
Monitoring of combustion gases and preemptive fire conditions to define alert zones.

Wine Quality Enhancing
Monitoring soil moisture and trunk diameter in vineyards to control the amount of sugar in grapes and grapevine health.

Offspring Care
Control of growing conditions of the offspring in animal farms to ensure its survival and health.

Sportsmen Care
Vital signs monitoring in high performance centers and fields.

Structural Health
Monitoring of vibrations and material conditions in buildings, bridges and historical monuments.

Quality of Shipment Conditions
Monitoring of vibrations, strokes, container openings or cold chain maintenance for insurance purposes.

Smartphones Detection
Detect iPhone and Android devices and in general any device which works with Wifi or Bluetooth interfaces.

Perimeter Access Control
Access control to restricted areas and detection of people in non-authorized areas.

Radiation Levels
Distributed measurement of radiation levels in nuclear power stations surroundings to generate leakage alerts.

Electromagnetic Levels
Measurement of the energy radiated by cell stations and and WiFi routers.

Traffic Congestion
Monitoring of vehicles and pedestrian affluence to optimize driving and walking routes.

Water Quality
Study of water suitability in rivers and the sea for fauna and eligibility for drinkable use.

Waste Management
Detection of rubbish levels in containers to optimize the trash collection routes.

Smart Parking
Monitoring of parking spaces availability in the city.

Golf Courses
Selective irrigation in dry zones to reduce the water resources required in the green.

Smart Roads
Warning messages and diversions according to climate conditions and unexpected events like accidents or traffic jams.

Smart Lighting
Intelligent and weather adaptive lighting in street lights.

Intelligent Shopping
Getting advices in the point of sale according to customer habits, preferences, presence of allergic components for them or expiring dates.

Noise Urban Maps
Sound monitoring in bar areas and centric zones in real time.

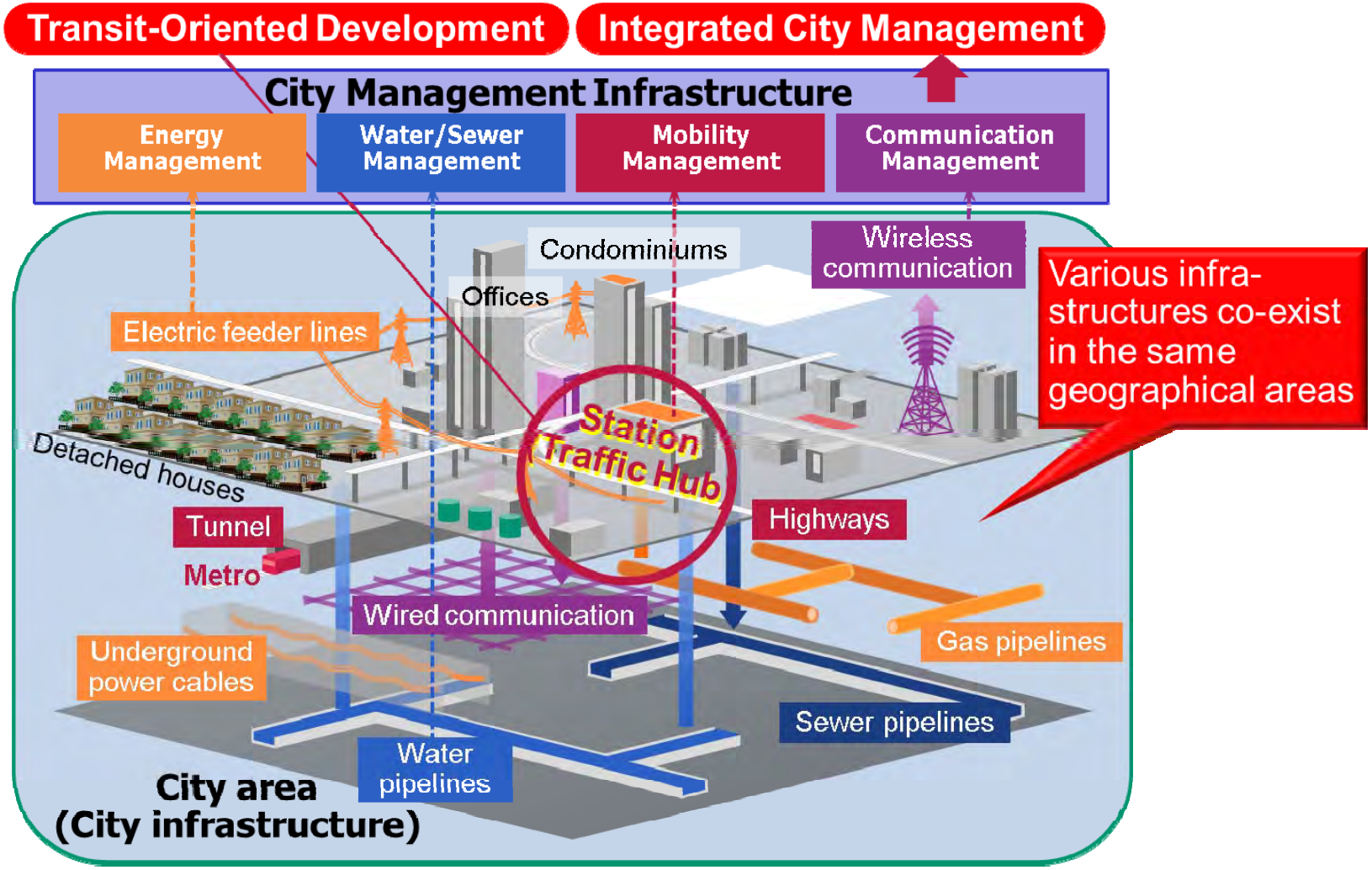
Water Leakages
Detection of liquid presence outside tanks and pressure variations along pipes.

Vehicle Auto-diagnosis
Information collection from CanBus to send real time alarms to emergencies or provide advice to drivers.

Item Location
Search of individual items in big surfaces like warehouses or harbours.

libelium
www.libelium.com

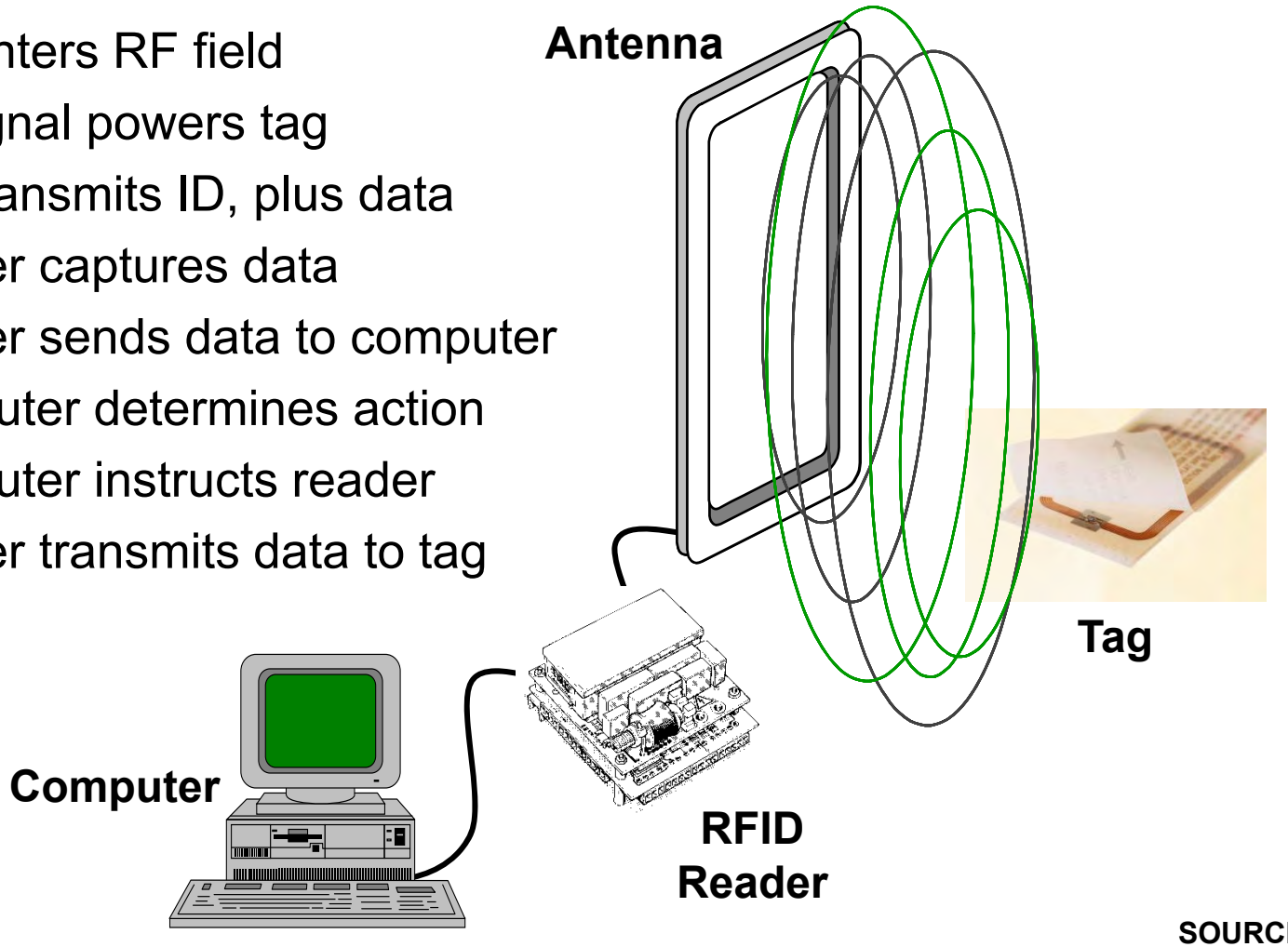
Smart City Infrastructure



SOURCE: HITACHI CONSULTING

How RFID Works

- Tag enters RF field
- RF signal powers tag
- Tag transmits ID, plus data
- Reader captures data
- Reader sends data to computer
- Computer determines action
- Computer instructs reader
- Reader transmits data to tag

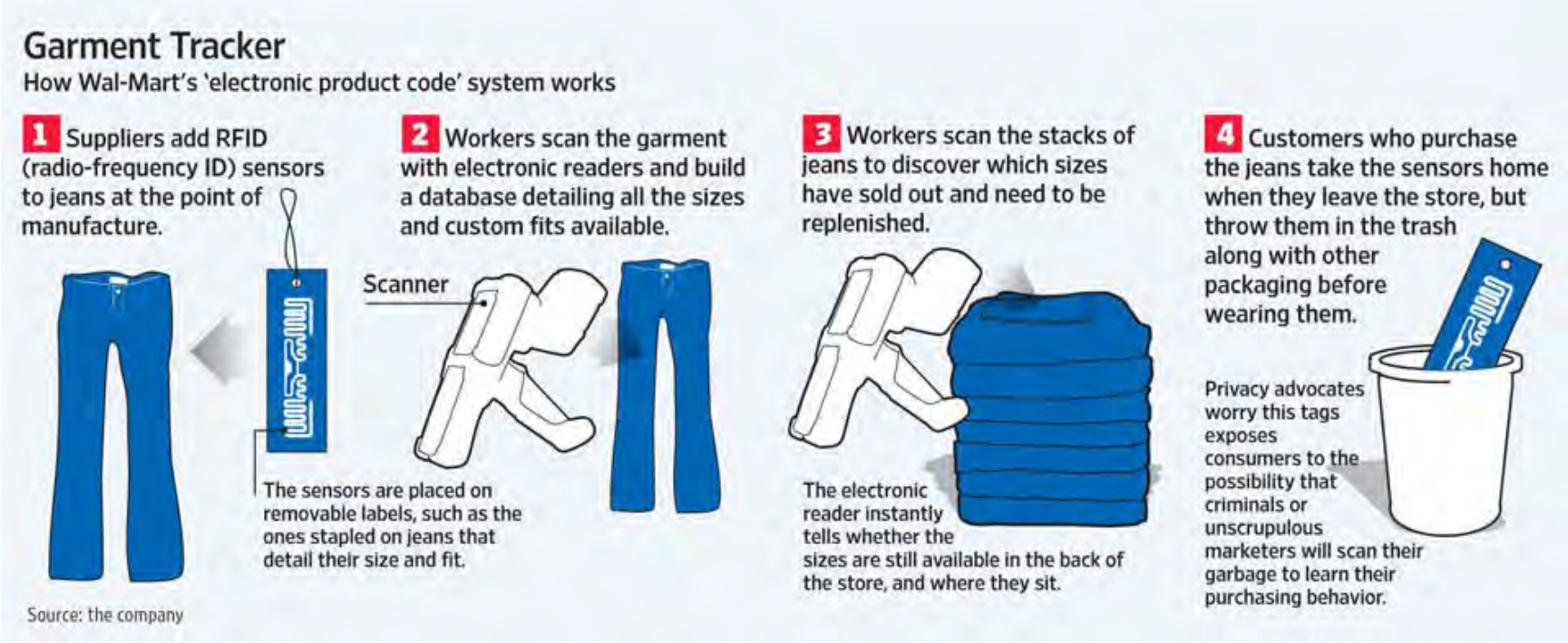


SOURCE: PHILIPS

Radio Frequency ID (RFID)

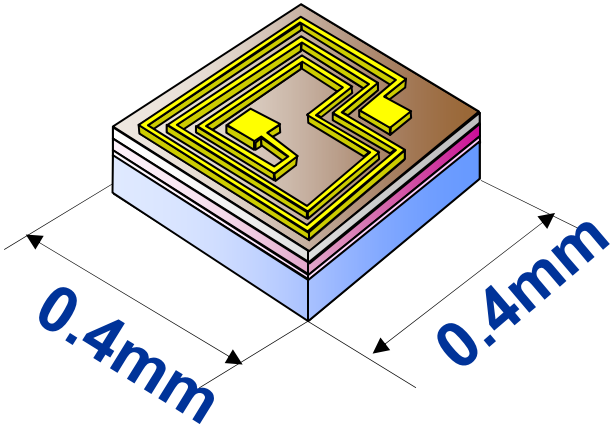
RFID Diagnostic
Skin Patch

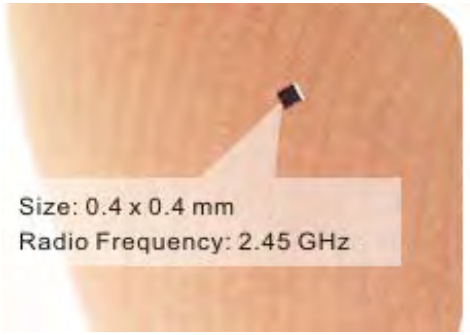
Retail Applications



Hitachi μ-chip

- 0.4 mm square
- 128-bit storage
- Range: 1 foot
- Embedded antenna
- Small enough to put in currency





SOURCE: HITACHI

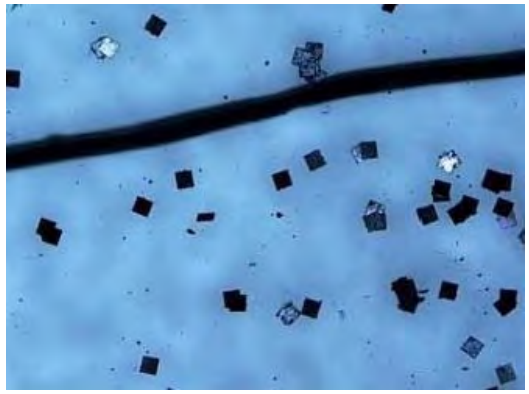
Euro Banknotes

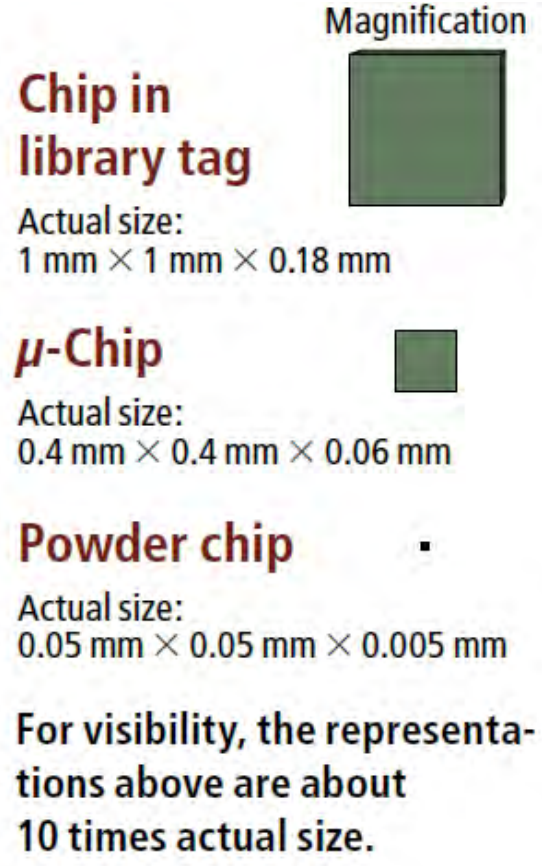
- European Central Bank announced plans to implant RFID tags in banknotes

- Uses
  - Anti-counterfeiting
  - Tracking money flows

Hitachi RFID "Powder"

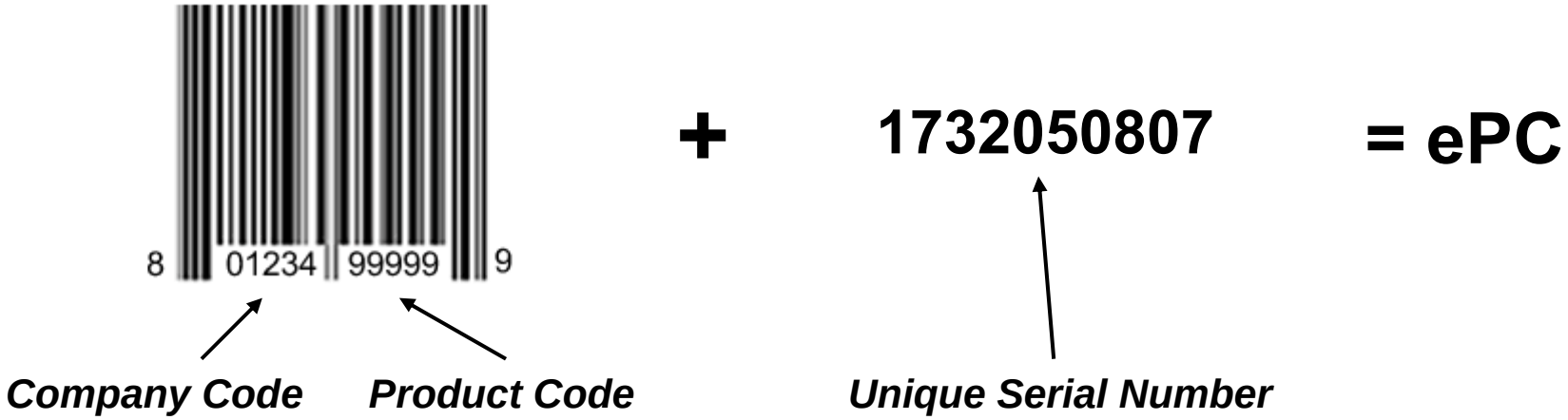
- 1/64 the size of a μ-chip!





SOURCE: SCIENTIFIC AMERICAN

Electronic Product Code (ePC)



- Extension of barcode
- Every item in the world has a distinct serial number
- Capacity for 200 billion serial numbers per item (on a 96-bit tag)

theguardian
Winner of the Pulitzer prize

Sunday 1 March 2015

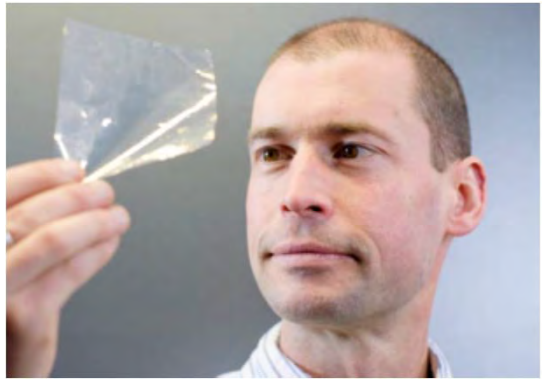
Cheap and ultraslim circuits could make the internet of things a reality

From medicine to legal documents, small integrated circuits promise revolutionise how we interact with everyday objects

In Scott White's vision for the supermarket of the near future, there would be no irritating interruption, no barcodes to scan and no check-outs. Instead shoppers would simply load their trolleys and walk out of a supermarket with wireless technology registering all of the items they have bought from tiny flexible circuits embedded on the food packaging.

"With something which is slimmer than a human hair and very flexible, you can embed that in objects in a way that is not apparent to the user until it is called upon to do something. But also the cost is dramatically lower than with conventional silicon so it allows it to be put in products and packaging that would never justify the cost of a piece of normal electronics," said White.

One of the first possible uses which has emerged is in blister packets for medication. If combined with a printed battery, a light could show the right time to take the next pill in a packet and the packaging could communicate directly with a doctor.



- **Food expiration**
- **Payments**
- **Legal documents**
- **Tax stamps**

UNIVERSITY of WASHINGTON

August 4, 2014

No-power Wi-Fi connectivity could fuel Internet of Things reality

Imagine a world in which your wristwatch or other wearable device communicates directly with your online profiles, storing information about your daily activities where you can best access it – all without requiring batteries. Or, battery-free sensors embedded around your home could track minute-by-minute temperature changes and send that information to your thermostat to help conserve energy.

This not-so-distant "Internet of Things" reality would extend connectivity to perhaps billions of devices. Sensors could be embedded in everyday objects to help monitor and track everything from the structural safety of bridges to the health of your heart. But having a way to cheaply power and connect these devices to the Internet has kept this from taking off.

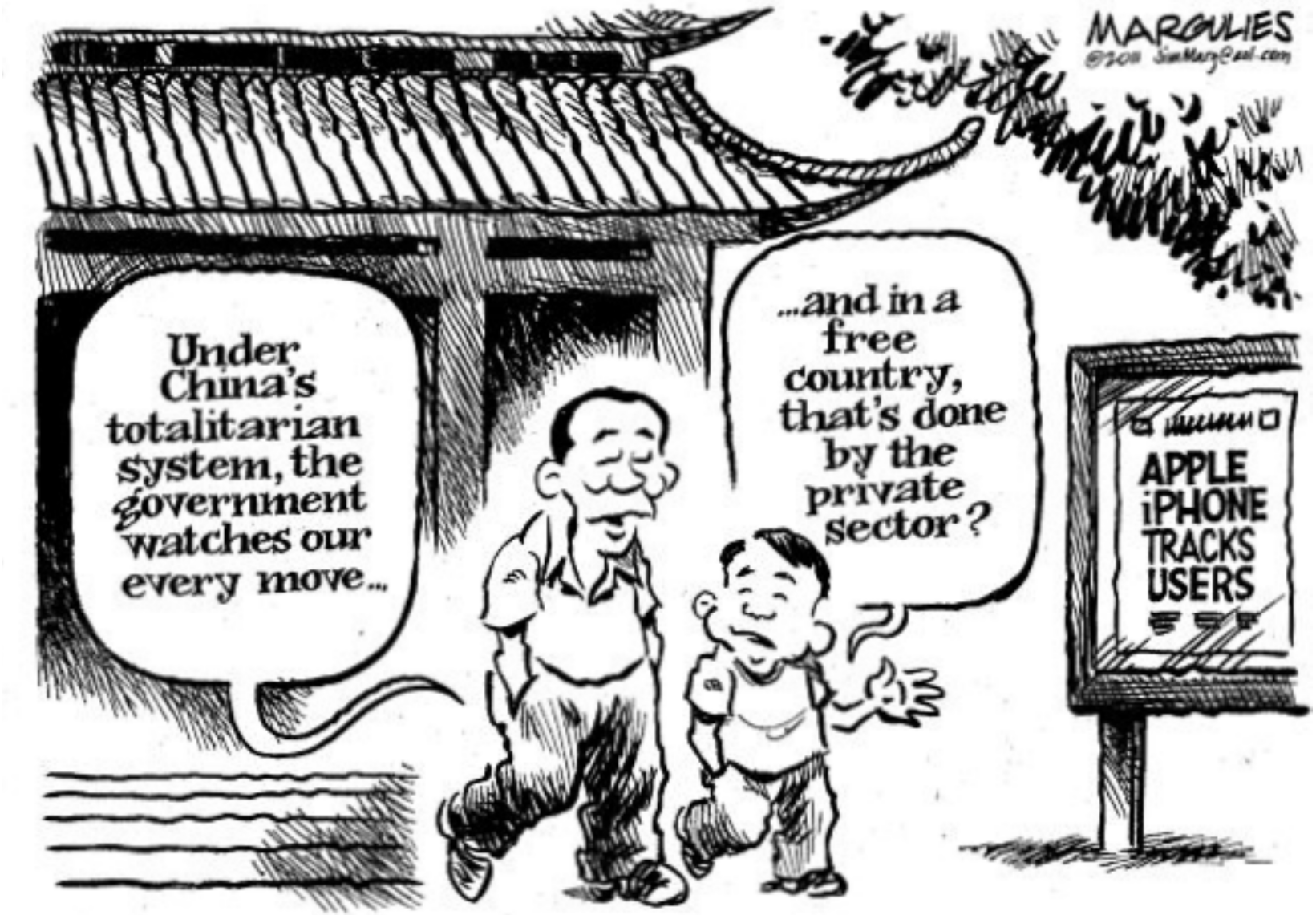
U of Washington

Wi-Fi backscatter uses radio frequency signals as a power source and reuses existing Wi-Fi infrastructure to provide Internet connectivity to battery-free devices.

Now, University of Washington engineers have designed a new communication system that uses radio frequency signals as a power source and reuses existing Wi-Fi infrastructure to provide Internet connectivity to these devices. Called Wi-Fi backscatter, this technology is the first that can connect battery-free devices to Wi-Fi infrastructure.

Smartphone as Sensor

SOURCE: THEODOROS MICHALAREAS

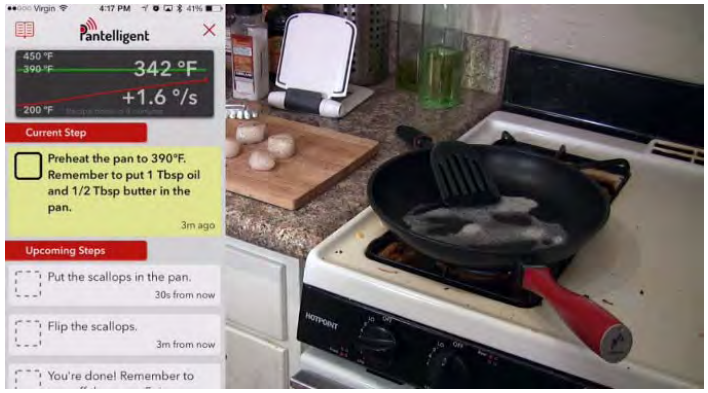


The Internet of Food

- Smart appliances, smart pantry

Smart crockpot

DropKitchen Smart Scale



Pantelligent frying pan

Quirky Egg Minder

Smart Refrigerator Data Model

Sensor 1 - Status

AccumulatedPowerUsed	(kW-h, Cumulative)
FreezerTemp	(degC, Average)
GroceryTemp	(degC, Average)
VegtableTemp	(degC, Average)
DoorOpenAlarm	("Door Id", Timeout)
PowerFaultAlarm	(0|1)
StatusInterval	(s)

Sensor 2 - Control

FreezerTempSetting	(degC - Current, LowLimit, HighLimit)
GroceryTempSetting	(degC - Current, LowLimit, HighLimit)
VegtableTempSetting	(degC - Current, LowLimit, HighLimit)

Parameters	Value
/UPnP/SensorMgt	
SensorCollectionsNumberofEntries	1
SensorCollections/	
1/CollectionID	Collection0001
1/CollectionType	urn:upnp-org:smgt-sct:refrigerator:AcmeSensorsCorp-com:AcmeIntegratedController:FrigidaireCorp:rf217acrs
1/CollectionFriendlyName	"Your Refrigerator"
1/CollectionInformation	"Vendor Refrigerator Model RF217ACRS"
1/CollectionUniqueIdentifier	"123456789"
1/CollectionSpecific	
1/SensorsNumberofEntries	2
1/Sensors/	
1/SensorID	Sensor0001
1/SensorType	urn:upnp-org:smgt-st:refrigerator:AcmeSensorsCorp-com:AcmeIntegratedController:FrigidaireCorp:rf217acrs:monitor
1/SensorUpdateRequest	0
1/SensorPollingInterval	0
1/SensorReportChangeOnly	0
1/SensorsRelatedNumberofEntries	1
1/SensorGroupsNumberofEntries	1

The Internet of Sports

Smart run: personalized, realtime coaching

Smart ball: records speed and rpm

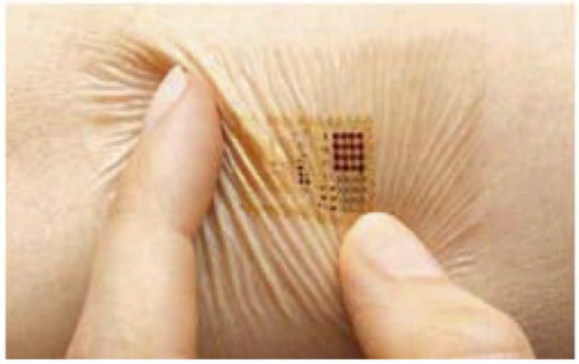
X-Cell: Measures quickness, reaction speed, intensity of play, jump height and heart rate

Speed cell: on-shoe sensor records speed, distance and stride rate

The Internet of Health

Proteus Pill Consumption Tracking

AgaMatrix Glucometer



Continuous blood chemistry patch

Wireless EEG

Sotera Visi-Mobile

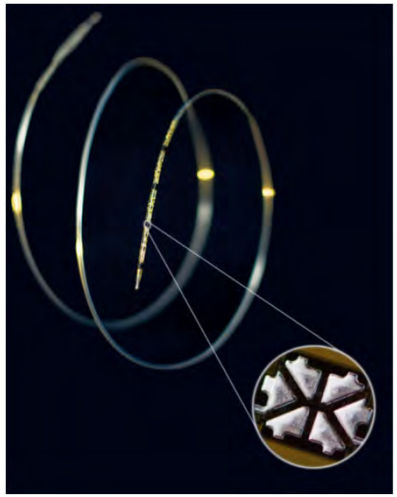
iRhythm cardiac sensor

Intelligent Pharmaceuticals

INGESTIBLE
RFID PILL

EKG ETC. ON
SMARTPHONE

SKIN PATCH
RECEIVER



IMPLANTABLE ELECTRONICS
AT SUB-MILLIMETER SCALE

SOURCE: PROTEUS

Vehicles as Computing Platforms

- Weight, power, memory not limiting
- Vehicles as sensor platforms
  - GPS, video, pollution, radar, road conditions
- Onboard data processing (reduces server and communication load)
- Local vehicular ad hoc cloud

SOURCE: MARIO GERLA

WASHINGTON

NHTSA Proposes Mandating V2V Communications

Move would light fire under need to establish ability to share with cable Wi-Fi

8/18/2014 By: John Eggerton

The FCC has been studying whether cable Wi-Fi using unlicensed spectrum and widespread intelligent vehicle-to-vehicle (V2V) communications, which has a license to use the spectrum, can coexist in the 5.9 GHz band—the FCC thinks they can. The FCC may have to put the pedal to the metal.

The Department of Transportation's National Highway Traffic Safety Administration has put out an Advance Notice of Proposed Rulemaking (ANPRM) proposing to require all new passenger cars and light trucks be capable of talking to each other to help avoid and mitigate crashes. NHTSA concludes that, without a mandate, the market would not develop on its own, or at least not fast enough, because there would not be any benefit to early adopters. "NHTSA believes that no single manufacturer would have the incentive to build vehicles able to 'talk' to other vehicles, if there are no other vehicles to talk to – leading to likely market failure without the creation of a mandate to induce collective action," NHTSA said in the notice.

Sensors for Safe Driving

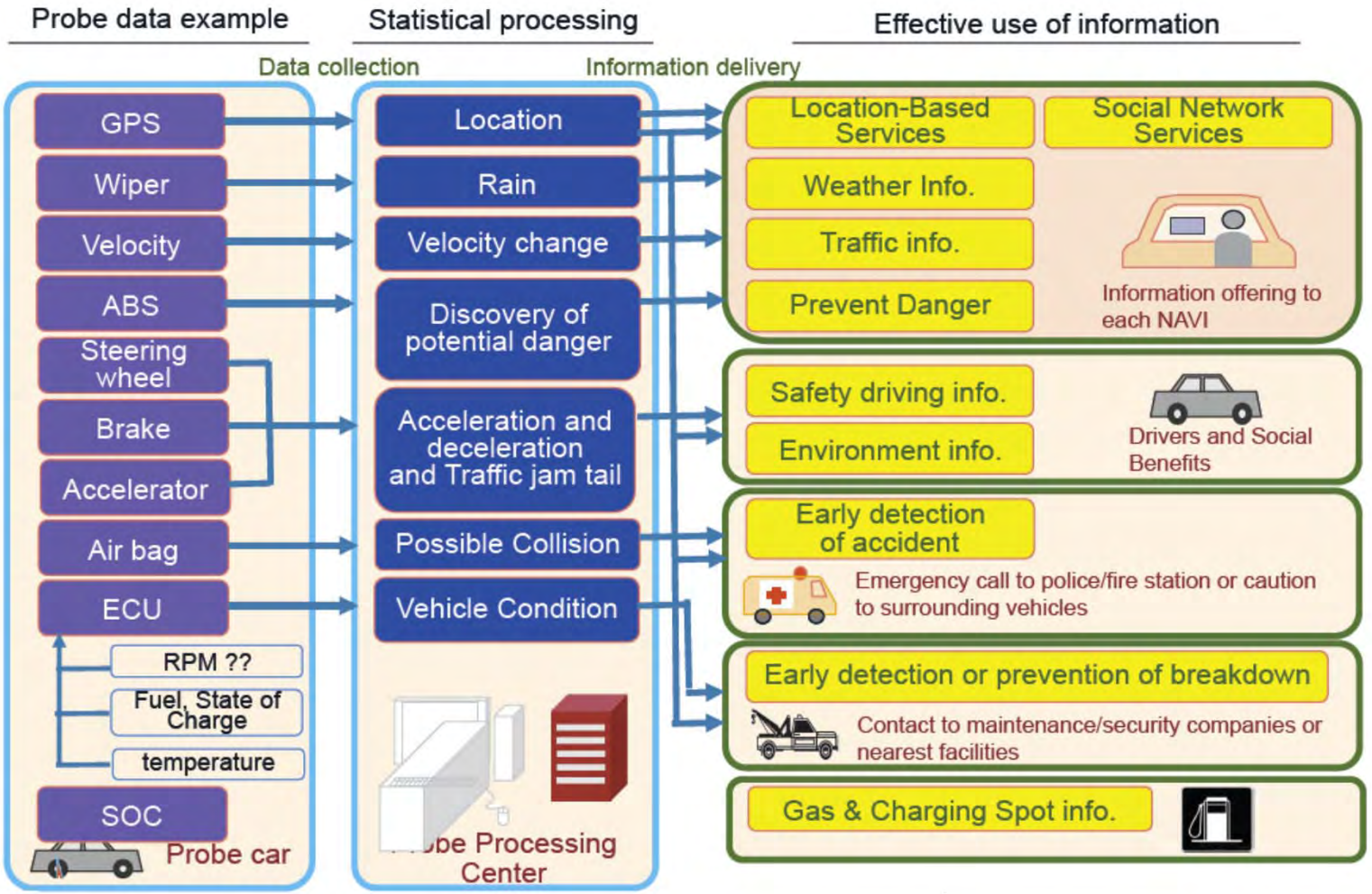
Vehicle type: Cadillac XLR
Curb weight: 3,547 lbs
Speed: 75 mph
Acceleration: **+ 20m/sec^2**
Coefficient of friction: .65
Driver Attention: Yes.

Vehicle type: Cadillac XLR
Curb weight: 3,547 lbs
Speed: 65 mph
Acceleration: **- 5m/sec^2**
Coefficient of friction: .65
Driver Attention: Yes

Vehicle type: Cadillac XLR
Curb weight: 3,547 lbs
Speed: 45 mph
Acceleration: **- 20m/sec^2**
Coefficient of friction: .65
Driver Attention: **No**

Vehicle type: Cadillac XLR
Curb weight: 3,547 lbs
Speed: 75 mph
Acceleration: **+ 10m/sec^2**
Coefficient of friction: .65
Driver Attention: **Yes**

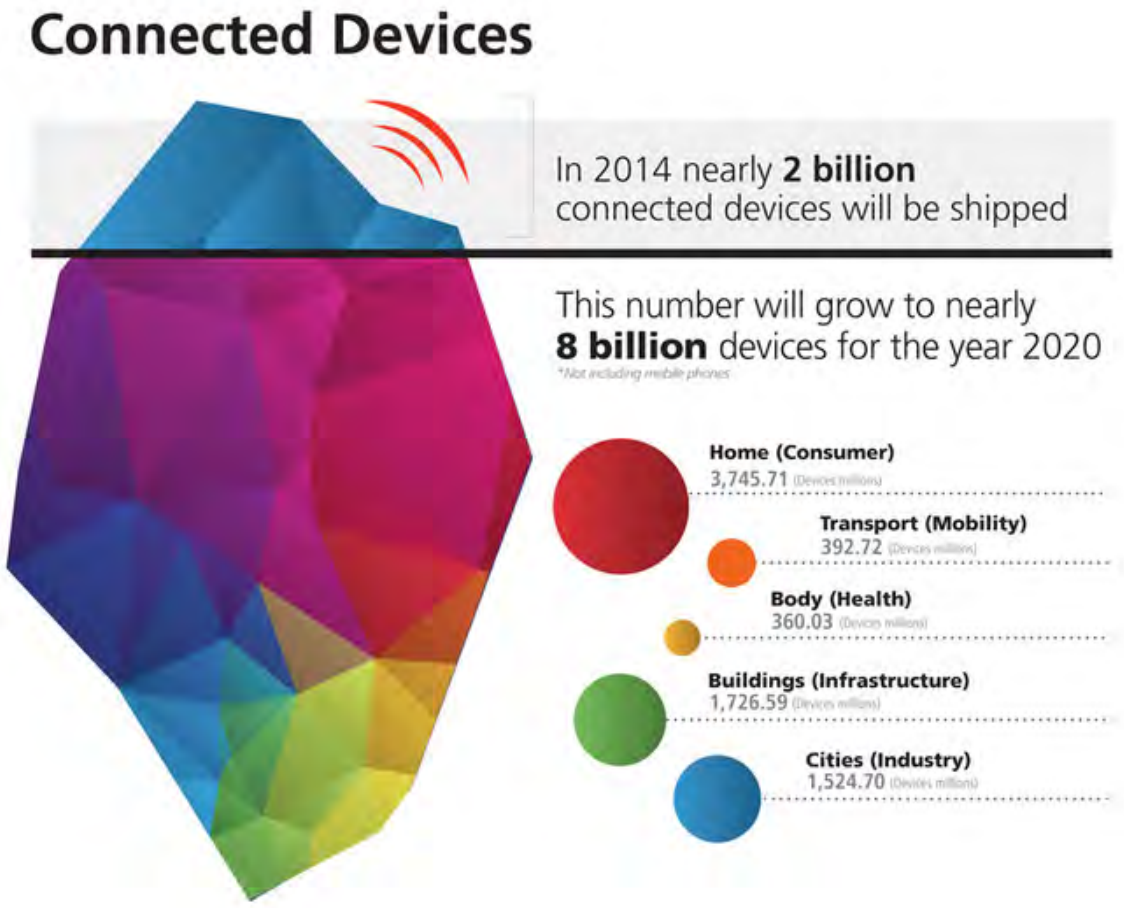
The Connected Car



SOURCE: NATIONAL MUSEUM OF EMERGING SCIENCE AND INNOVATION

Internet of Everything

- Cisco: 99.4% of things that should be connected aren't
- Prediction: 200-800 Billion Devices in 10 years



SOURCE: HARBOR RESEARCH

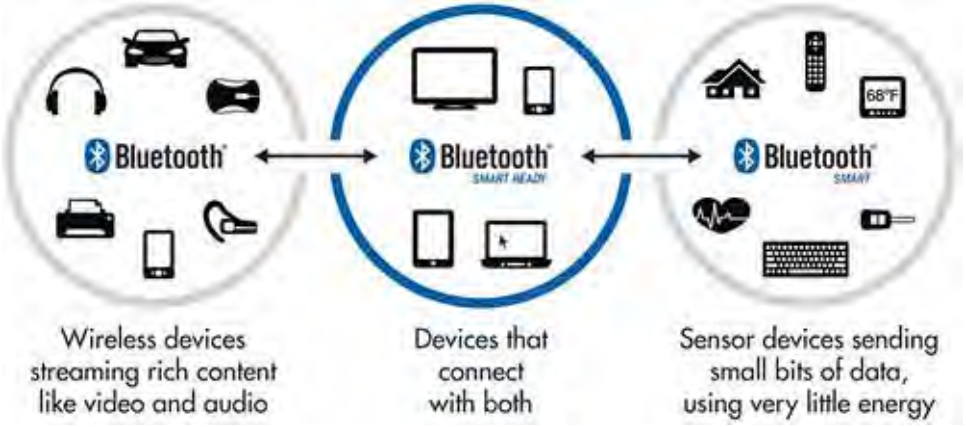
Beacons

- Transmitters that communicate with smart devices
- Connecting store offers with passers-by

DAILY
DEALS

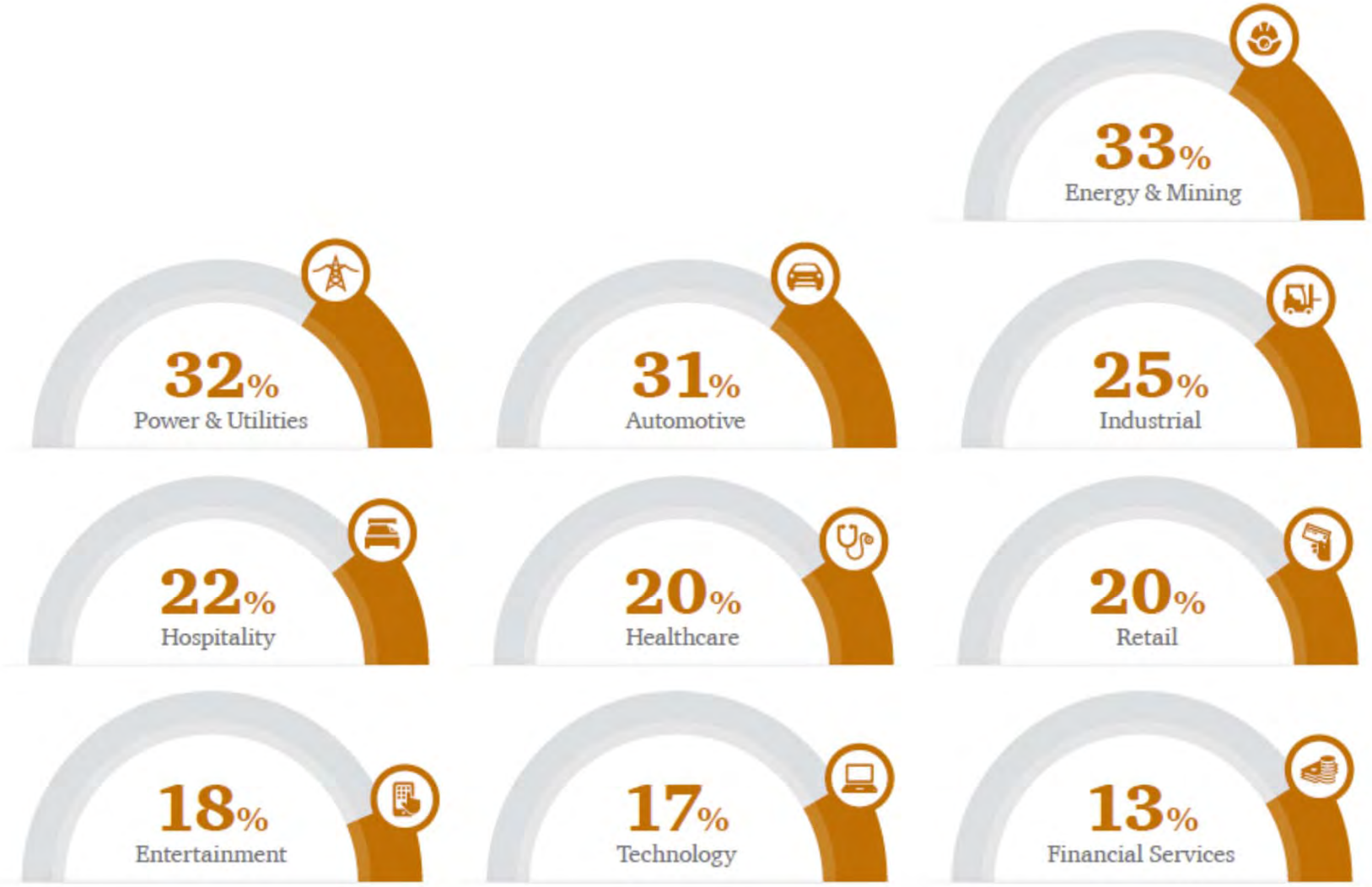
Beacons

- Send out a low energy Bluetooth signal every second
- Signal range varies from 2-500 meters
- Signal contains a unique coded string which is usually the device ID. Billions of beacons have unique codes
- Plug in to wall or USB port of computer or battery-operated device
- (Not technically NFC because of longer range)



IoT "Empowering People in Their Daily Life"

Tope 10 Industries Investing in Sensors



SOURCE: PRICEWATERHOUSECOOPERS