Pervasive Systems
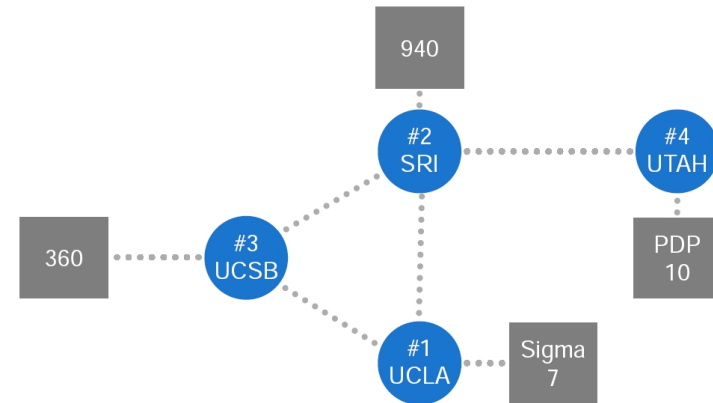
Ioannis Chatzigiannakis

Sapienza University of Rome
Department of Computer, Control, and Management Engineering (DIAG)
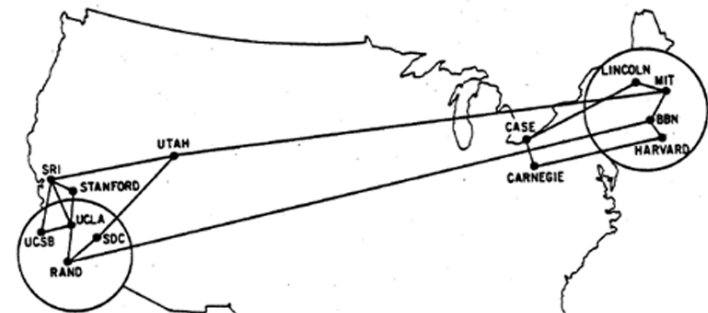
Lecture 1:
Introduction

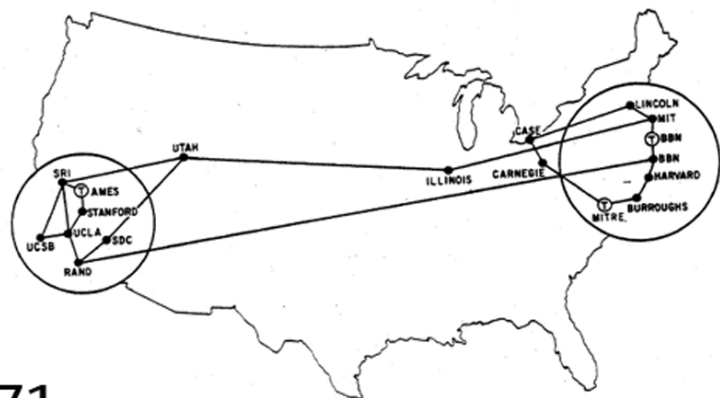---

The beginning of Internet (ArpaNet)

- ▶ The initial topology of the network on December, 1969
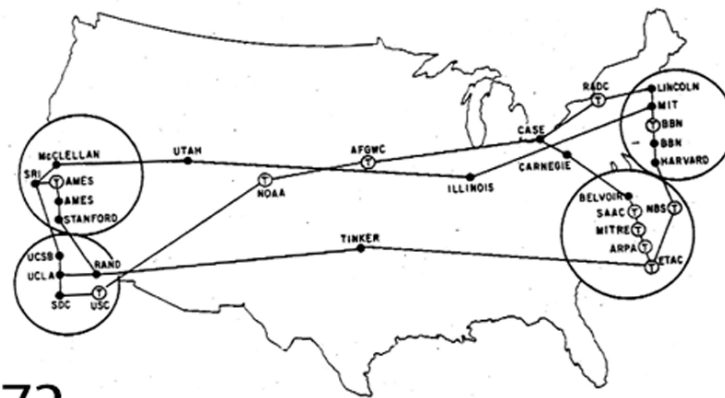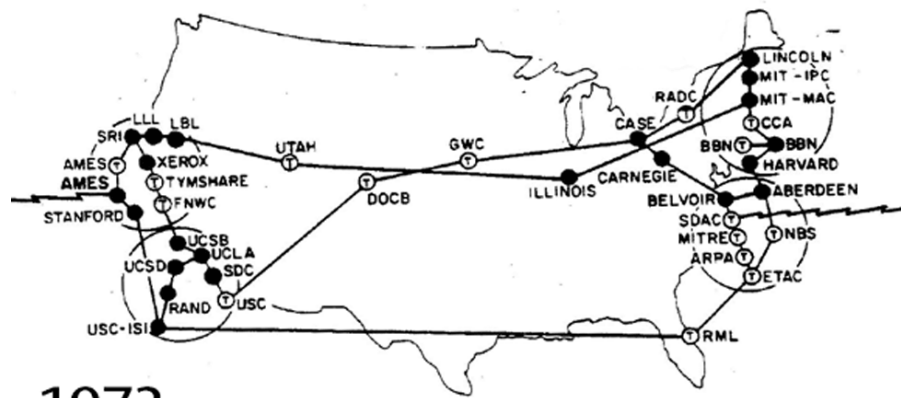- ▶ 4 computers connected via a simple packet switching network

---

1969

1970

1971

1972

1973
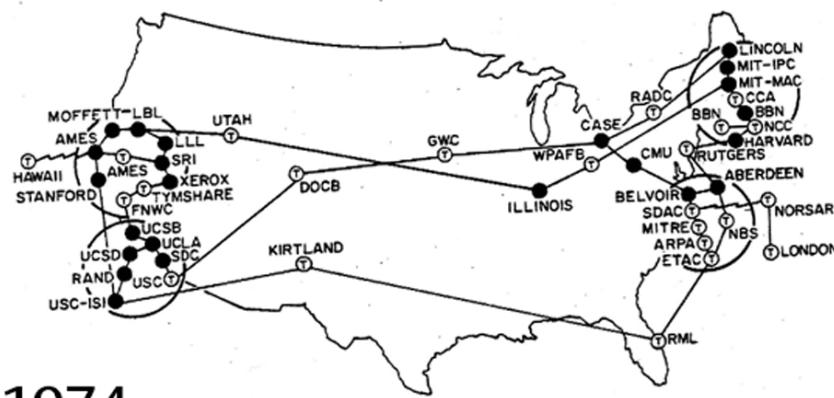
1974

1975

1976

1977

1978

1979

1980

1981

1982
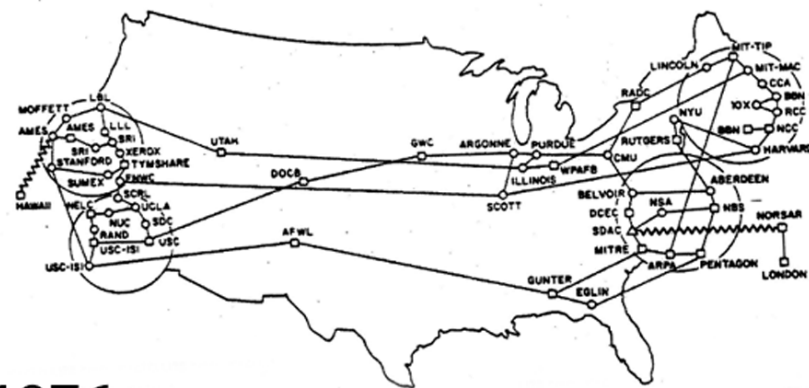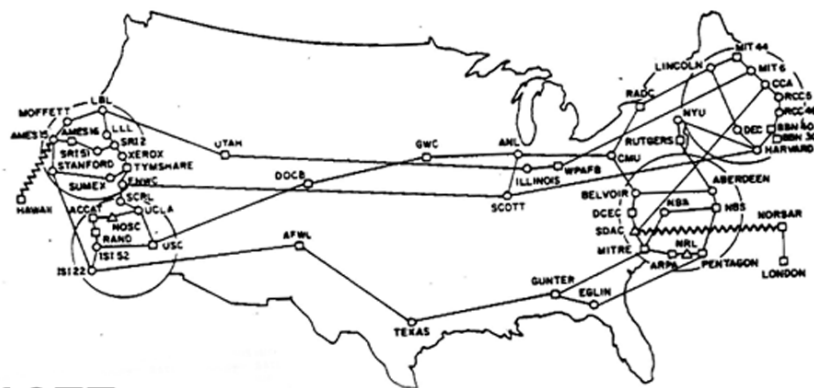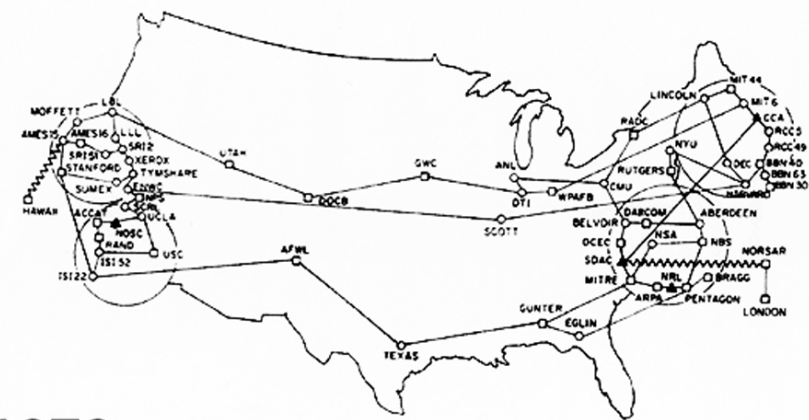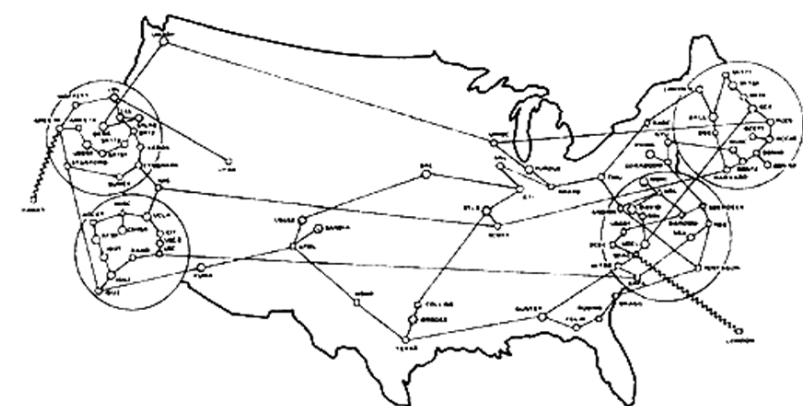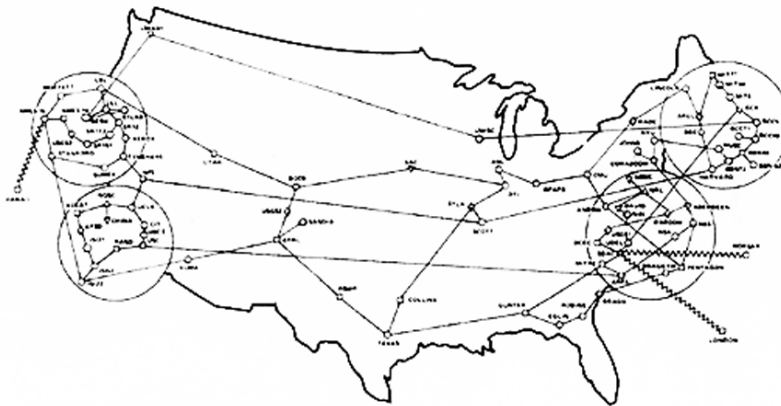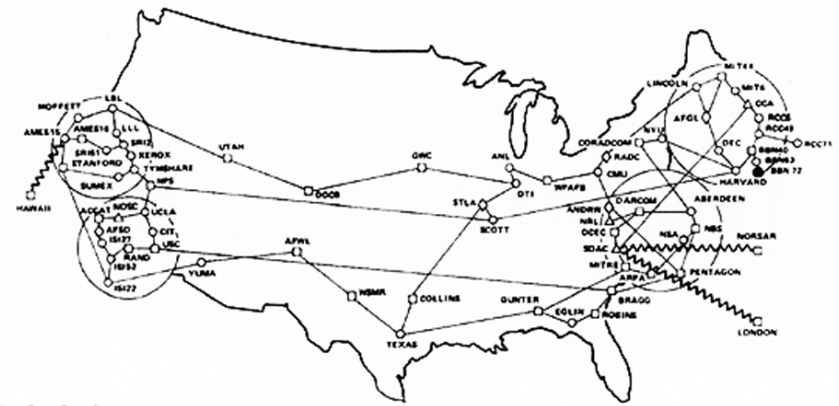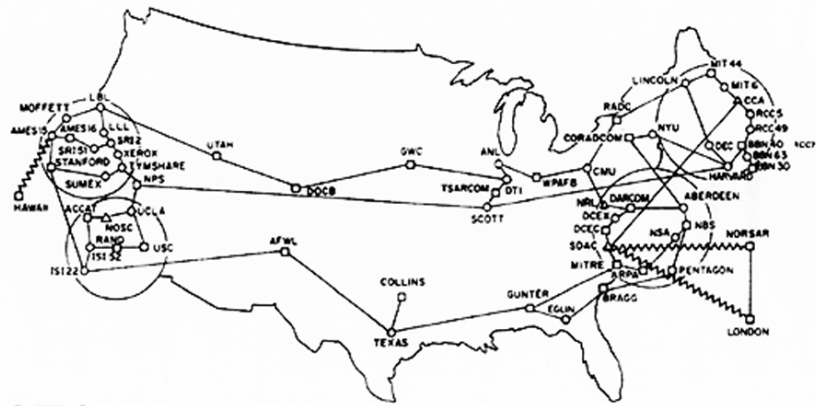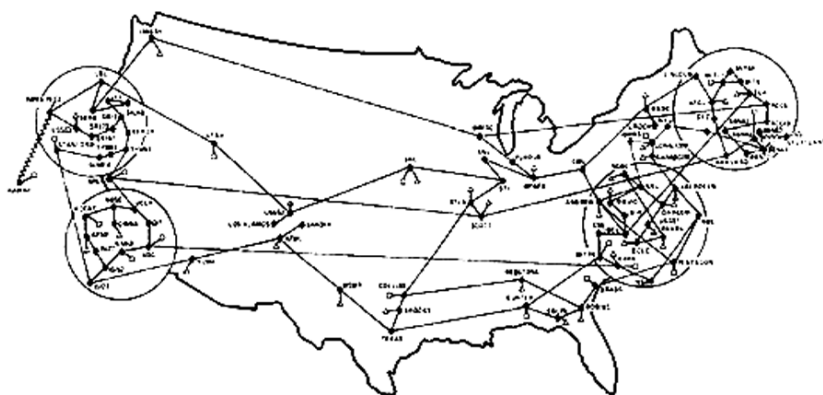
1983

1984

1986

1987

1988

1988

1989

1989

Internet 1999

telstra.net
cw.net
sprintlink.net
(not an ISP)
att.net
globalcenter.net
verio.net
psi.net
ft.net
other ISPs
bbnplanet.net
ans.net
alter.net
eu.net

Burch/Cheswick map of the Internet
showing the major ISPs. Data collected 28 June 1999

http://www.cheswick.com/map/index.html
Copyright (C) 1999, Lucent Technologies
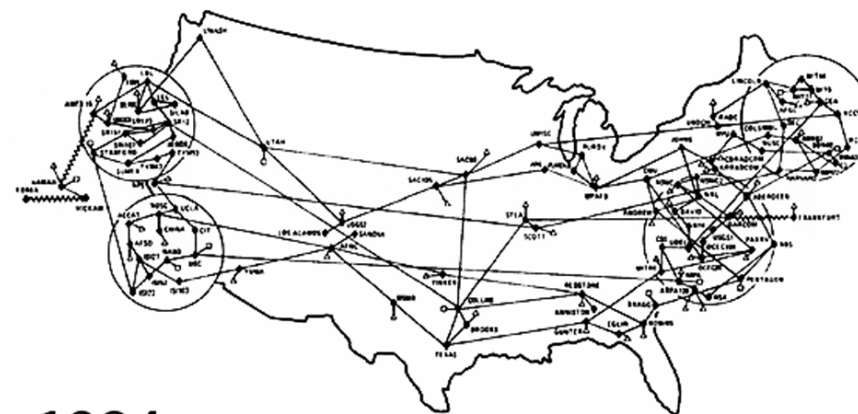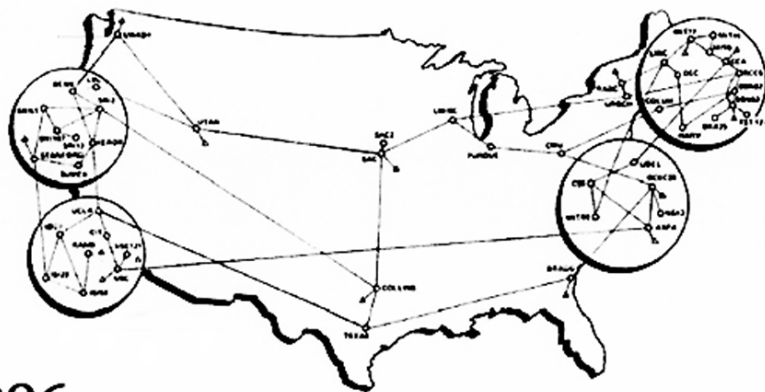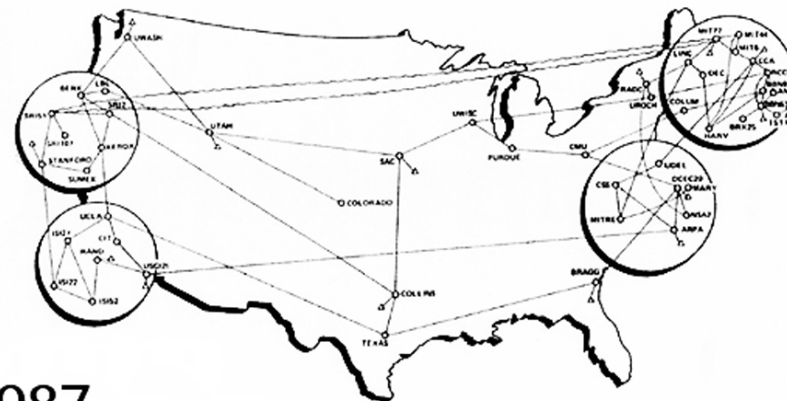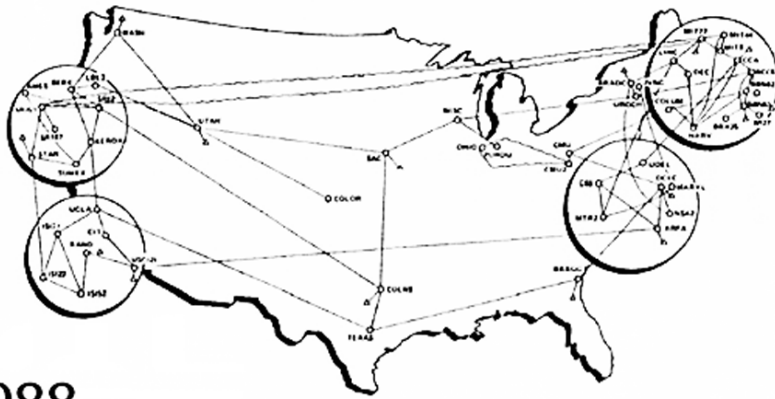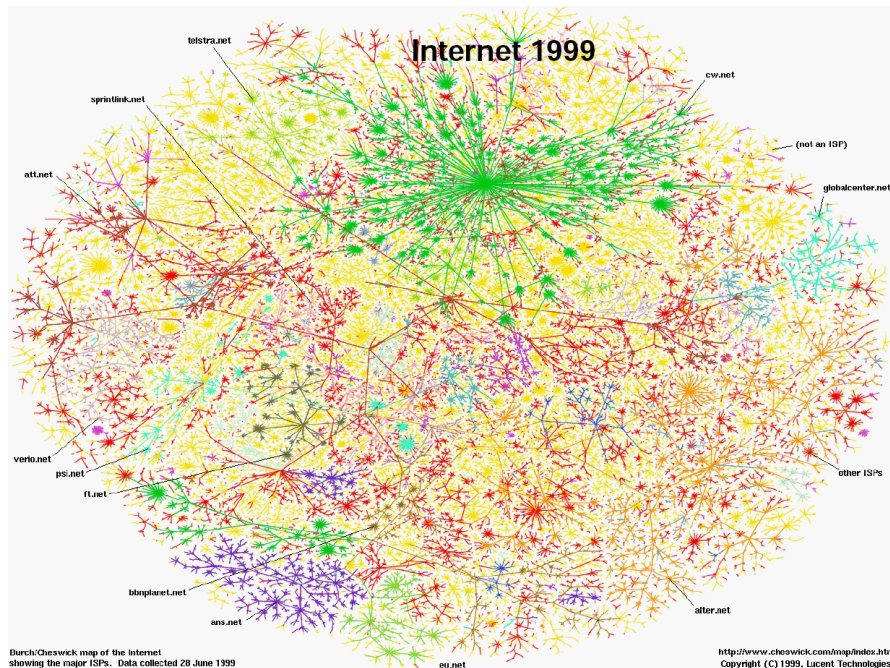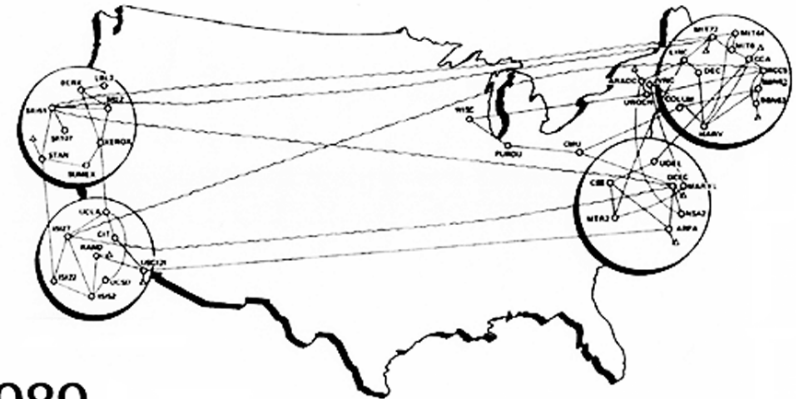
Growth of web sites connected to the Internet
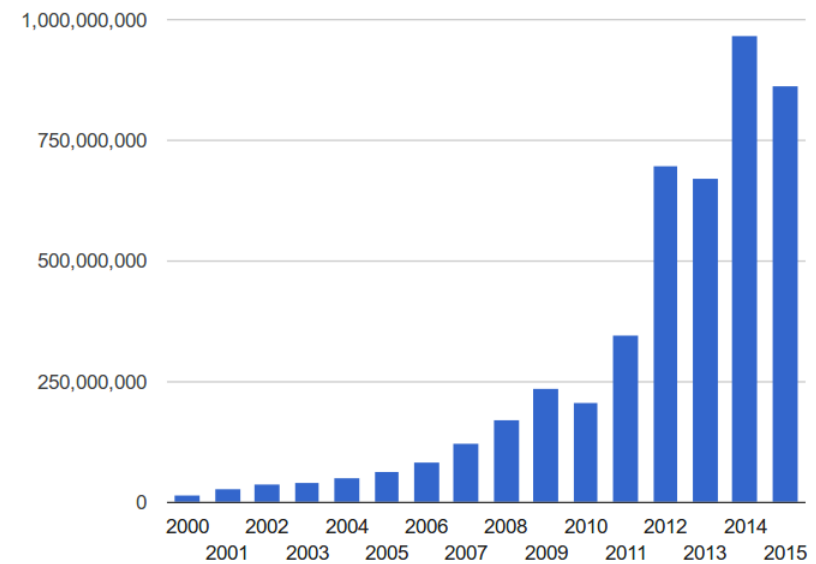
Worldwide Internet Users

	2005	2010	2013	2016
World population	6.5 b	6.9 b	7.1 b	7.5 b
Not using the Internet	84%	70%	61%	54%
Using the Internet	16%	30%	39%	46%
Users in the developing world	8%	21%	31%	34%
Users in the developed world	51%	67%	77%	79%

Source: International Telecommunication Union official website

Mobile vs Static Internet Usage

StatCounter GlobalStats

Internet Usage Worldwide
October 2009 – October 2016

■ Desktop ■ Mobile & Tablet

Desktop **48.7%**

Mobile & Tablet **51.3%**

Oct 2009 Oct 2010 Oct 2011 Oct 2012 Oct 2013 Oct 2014 Oct 2015 Oct 2016
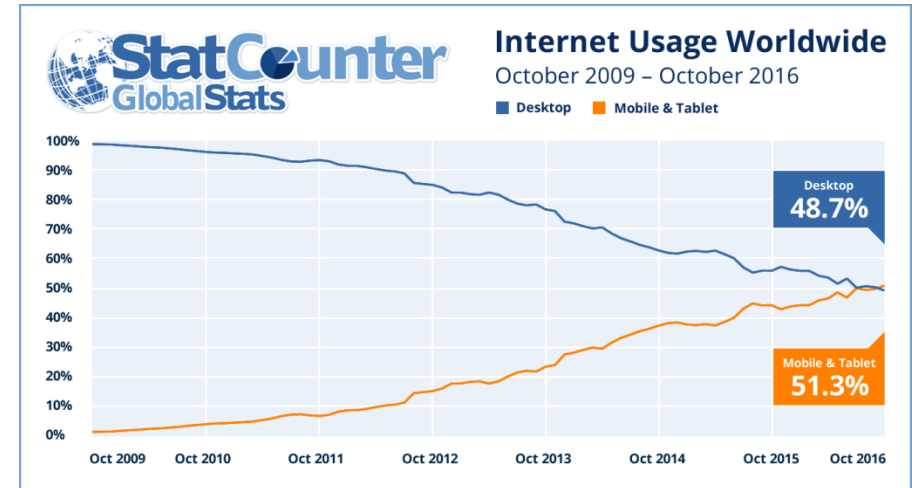
Sensors & Actuators: a digital nervous system

Machine Vision / Optical Ambient Light
Position / Presence / Proximity
Acceleration / Tilt
Motion / Velocity / Displacement
Electric / Magnetic
Temperature
Leaks / Levels
Humidity / Moisture
Acoustic / Sound / Vibration
Force / Load / Torque Strain / Pressure
Flow
Chemical / Gas
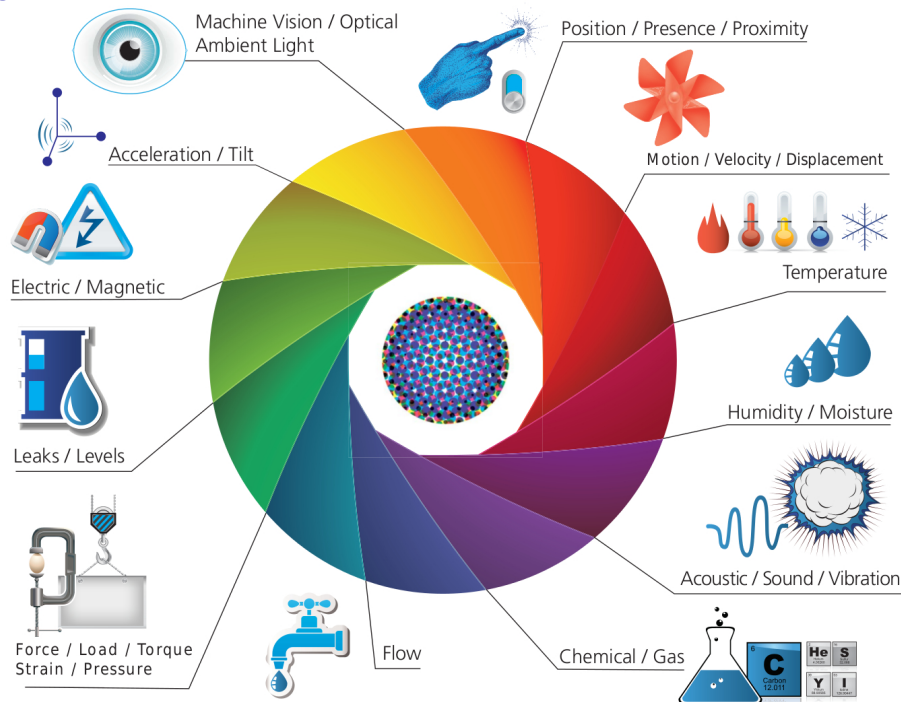
Connectivity: inputs are digitized and placed onto networks

InterPlanetary Network

LTE Advanced
Cellular 4G / LTE
3G - GPS / GPRS
2G / GSM / EDGE, CDMA, EVDO
WEIGHTLESS
WIMAX
LICENSE-FREE SPECTRUM
DASH 7

WiFi

BLUETOOTH
UWB
Z-WAVE
ZIGBEE
6LoWPAN
NFC
ANT
RFID

POWERLINE
ETHERNET
PRINTED

IPv4 IPv6 UDP DTLS RPL Telnet MQTT DDS CoAP XMPP HTTP SOCKETS REST API

WAN
Wide Area Network - 80

MAN
Metropolitan Area Network -80

LAN
Local Area Network - 802.11

PAN
Personal Area Network - 802.15

An explosion of connected possibility
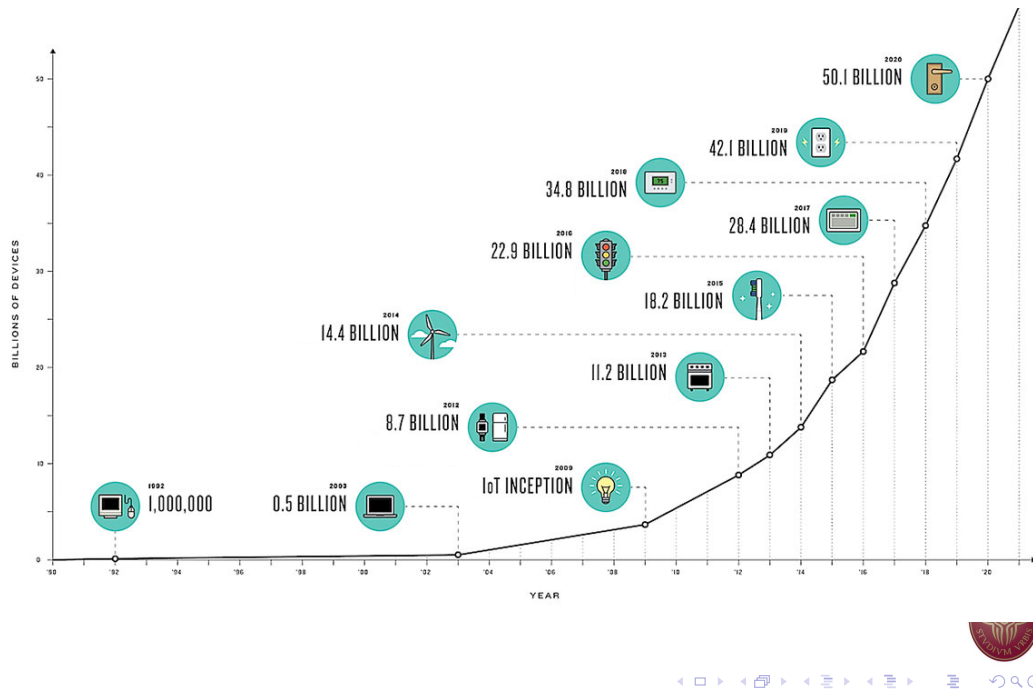
Things, People & Processes are becoming connected

The Internet of Things
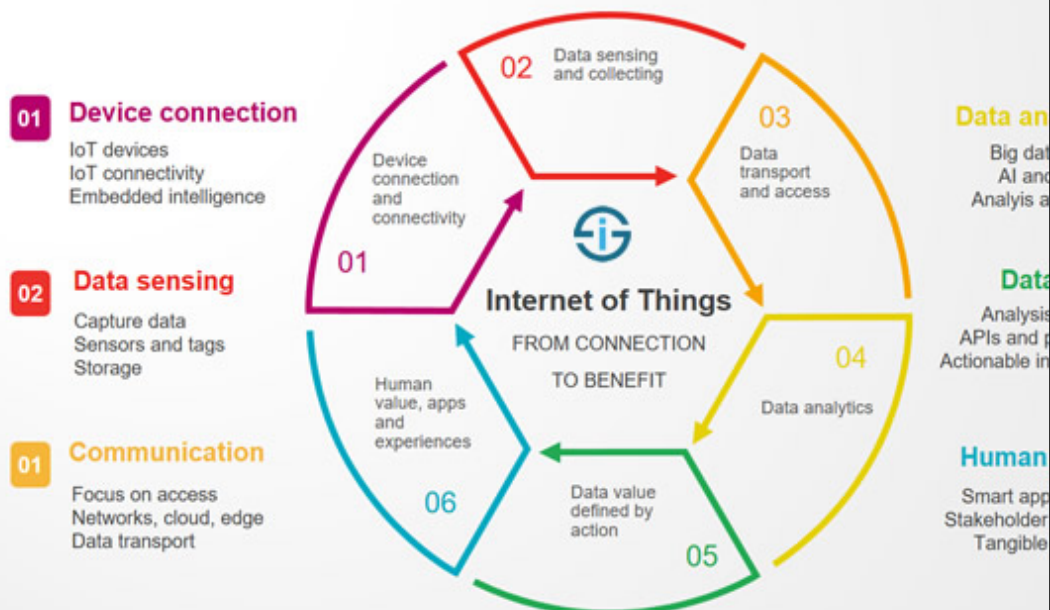
People & Processes: bi-directional systems
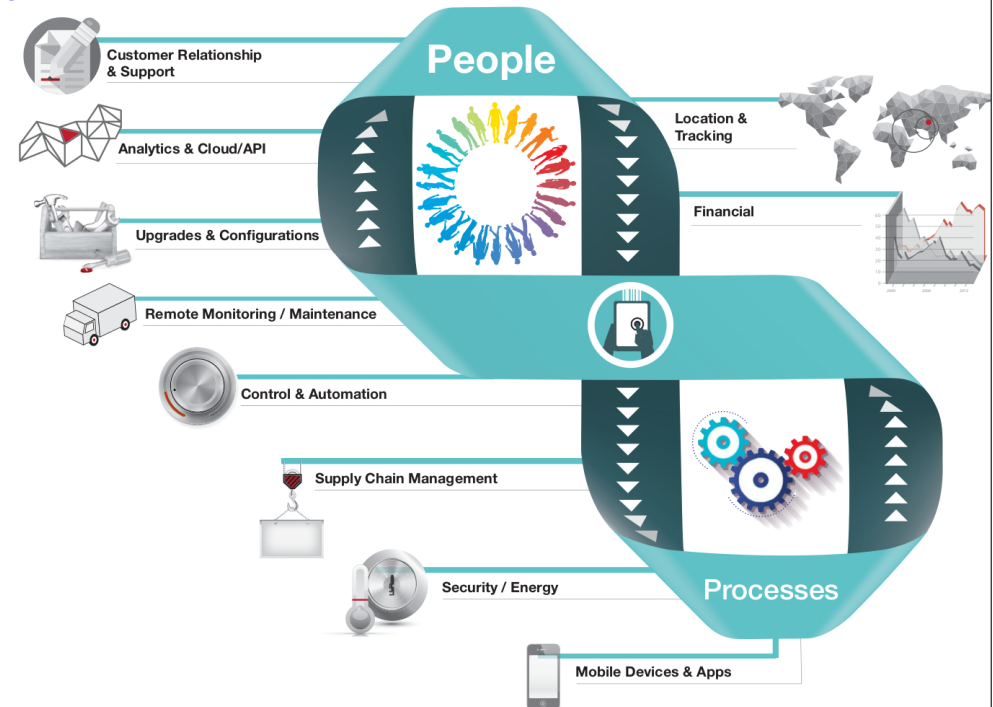
The interactions between these entities are creating new types of smart applications and services.

SENSORS + CONNECTIVITY + PEOPLE + PROCESSES

HOME
CONSUMER

TRANSPORT
MOBILITY

HEALTH
BODY

BUILDINGS
INFRASTRUCTURE

CITIE...
INDUSTR...

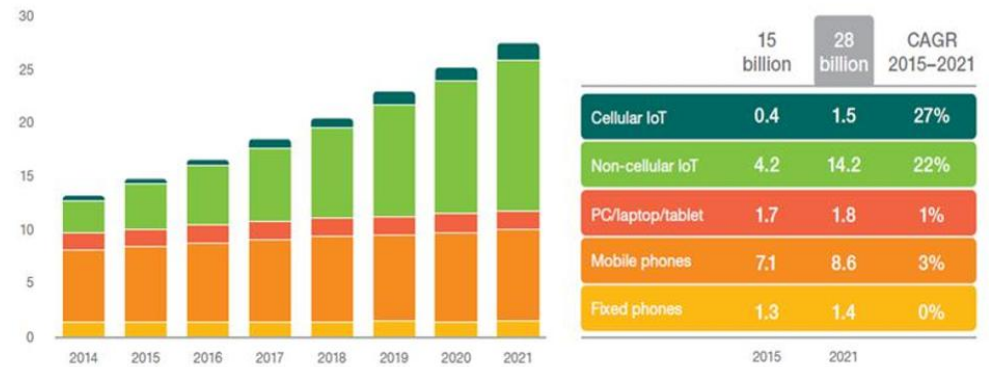| HOME CONSUMER	TRANSPORT MOBILITY	HEALTH BODY	BUILDINGS INFRASTRUCTURE	CITIES INDUSTR...
Light bulbs	Traffic routing	Patient Care	HVAC	Electrical Distrib...
Security	Telematics	Elderly Monitoring	Security	Maintenance
Pet Feeding	Package Monitoring	Remote Diagnostic	Lighting	Surveillance
Irrigation Controller	Smart Parking	Equipment Monitoring	Electrical	Signage
Smoke Alarm	Insurance Adjustments	Hospital Hygiene	Transit	Utilities / Smar...
Refrigerator	Supply Chain	Bio Wearables	Emergency Alerts	Emergency Ser...
Infotainment	Shipping	Food sensors	Structural Integrity	Waste Manage...
Washer / Dryer	Public Transport		Occupancy	
Stove	Airlines		Energy Credits	
Energy Monitoring	Trains			

© Machina Research, 2015

Transportation & Smart Cities

Sofia and her son Luis are on their way Downtown for an appointment.

Using the cars's parking details the vehicle schedules a mobile mechanic to change the oil while the two are away for the afternoon.

Wireless sensors embedded in the parking lot help direct the car to an open spot in the city while also initiating the parking fee.
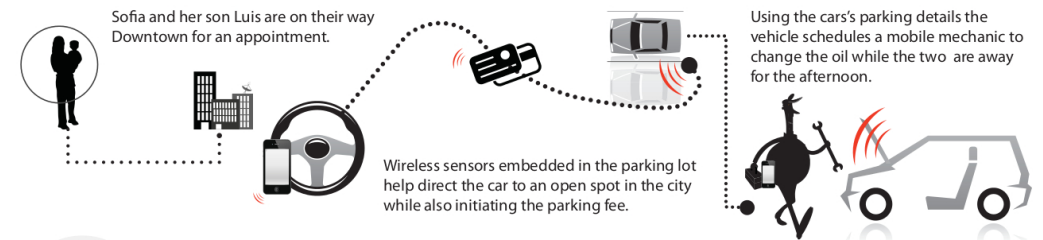
In Downtown San Francisco 20-30% of all traffic congestion is caused by people hunting for a parking spot.

- San Francisco Municipal Transportation Agency (SFMTA)

Aging uncle Earl is still living isolated at his home and you are concerned about his safety.

Wireless sensors throughout his house help measure healthy activity levels, sleeping patterns and medication schedules.

Alerts are automatically sent to health care services and authorized family members if any abnormal activity is detected.

40 million adults age 65 and over will be living alone in the U.S, Canada and Europe.
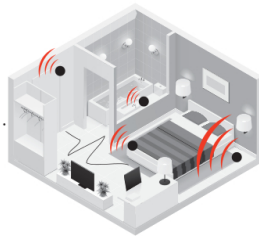- U.S. Department of Health and Human Services: Administration for Community Living (ACL)

Anna is being pressured to reduce her company's expenses for their new corporate office.

After speaking with experts she decides to install sensors to automate energy usage according to building occupancy, people flow, temperature, and other ambient conditions -- improving the building's overall efficiency.

Energy used by commercial and industrial buildings in the US creates nearly 50% of our national emissions of greenhouse gases.
- United States Environmental Protection Agency

REAL-TIME SERVICE NETWORKS

- Appliance Monitoring
- Predictive Maintenance
- Service Technician / CRM
- Waste Management / Recycling

R Hotel Denver, Industrial Washer #GHS40-2608

Location: ID: FC-RM #00243
Manufacturer: Appliance Park
Louisville, KY ID: #45205343
Materials: FC / SUS
Sensor: Vibration
Connectivity: Wireless

Connor, the Lead Maintenance Manager at the R Hot receives a sensor notification that the pump body O- washing machine #230243 is starting to fail in the ho laundry room.

On his mobile, Connor prompts the machine to orde This action triggers a bidding opportunity for local s technicians within the product's authorized mainten

The request lays out:
- Pricing parameters
- Timing requirements
- Machine history
- Part specs
- Predictive se
  measuremen

Tom from IA Appliances bids on the service request a notification a few moments later that his bid was acc

Within 1.5 hours, a service technician from IA Applia (Using a temporary facility access code for the wireless door l the water pump. Connor sends a brief note on the se quality and IA Appliances releases a bid request for t materials to local recycling centers.

DIGITAL FARM TO TABLE

- Farm & Livestock ID & Sensors
- Food packaging sensors
- Retail Supply Chain Monitoring
- Health Services
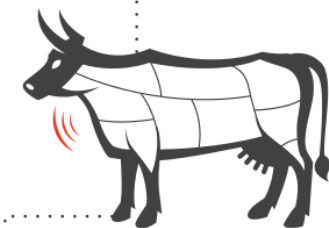
Cattle AIN: 840 003 123

Location: ID: Braymea #00285453543
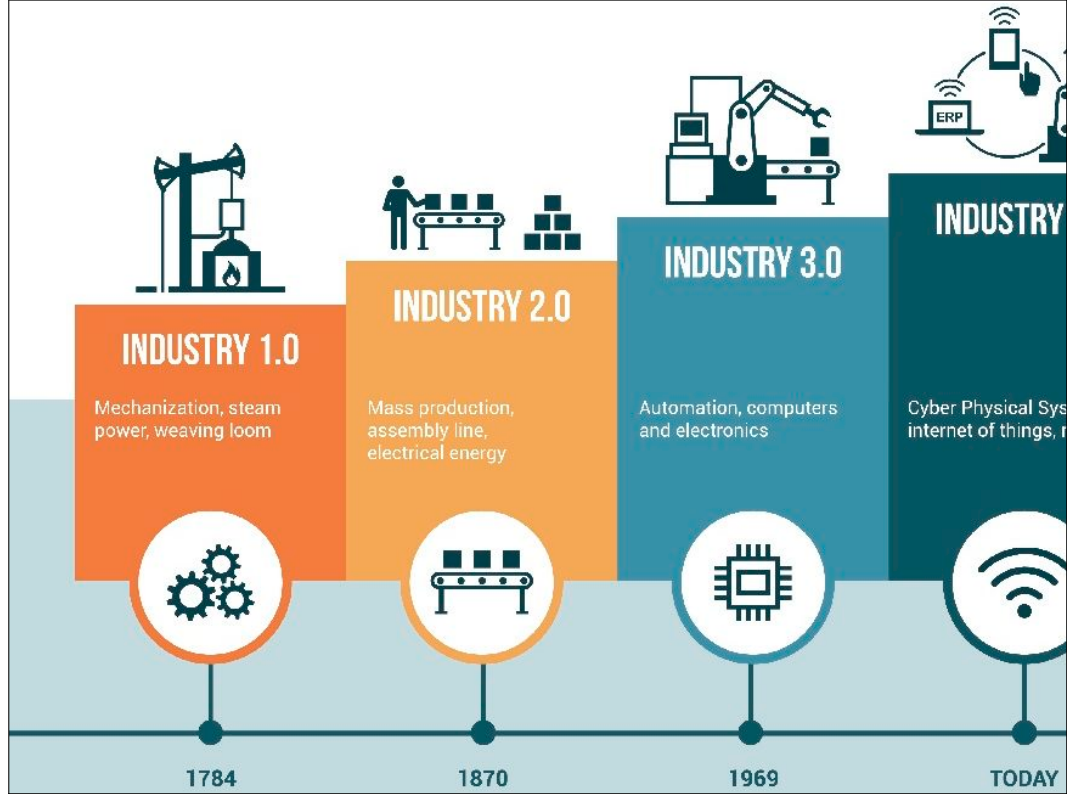**Slaughterhouse ID**:
Sensor: Temperature, A
Connectivity: RFID, N

Maria and her daughter are picking up groceries for the packaging with printed sensors, the two can make sure beef they are purchasing has never reached unsafe tem while on the shelf or being transported.

The packaging also contains a QR code which they can the cow's RFID tag and bring up its history:

- Where it was raised
- What it was fed
- Where it was slaughtered
- How it was transported
- Where it was
- The last time i
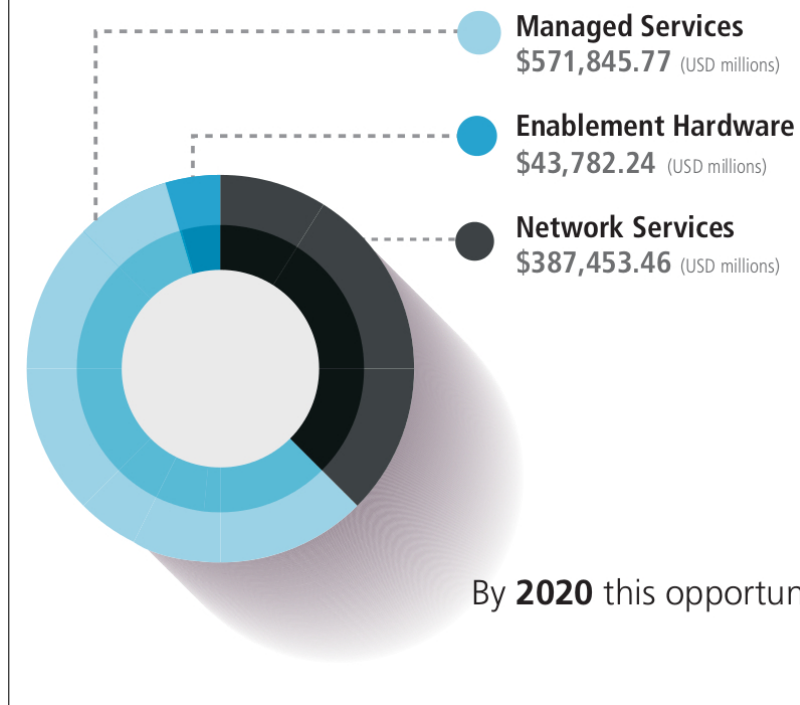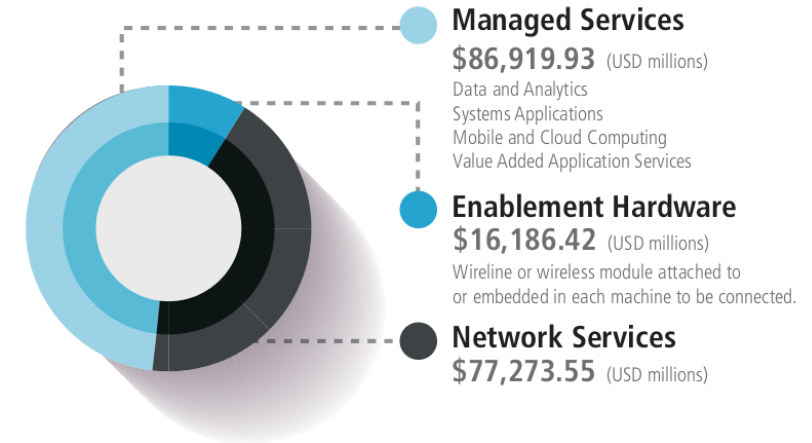
A week later the U.S. Department of Agriculture's Food S determines ground beef from originating from a region company and sold at a neighboring store is contaminat O157:H7. All packages from this distributer change their color and notification messages are sent to those shopp have been impacted.

INDUSTRY 1.0
Mechanization, steam power, weaving loom

INDUSTRY 2.0
Mass production, assembly line, electrical energy

INDUSTRY 3.0
Automation, computers and electronics

INDUSTRY
Cyber Physical Sys internet of things,

1784   1870   1969   TODAY

Business Impact & Revenue Opportunities

180+ Billion in Revenue
in 2014

Managed Services
$86,919.93 (USD millions)
Data and Analytics
Systems Applications
Mobile and Cloud Computing
Value Added Application Services

Enablement Hardware
$16,186.42 (USD millions)
Wireline or wireless module attached to
or embedded in each machine to be connected.

Network Services
$77,273.55 (USD millions)

Managed Services
$571,845.77 (USD millions)

Enablement Hardware
$43,782.24 (USD millions)

Network Services
$387,453.46 (USD millions)

By **2020** this opportunity will grow to m

>$1 Tril

A interesting era

- ▶ The Internet gave us the opportunity to connect in ways we could never have dreamed possible.
- ▶ The Internet of Things will take us beyond connection to become part of a living, moving, global nerbous system.
- ▶ Whether you are an individual, technology developer, or adopter of these technologies, the Internet of Things will strech the boundaries of today's systems.
- ▶ Are you prepared for the changes in the way we learn, work and innovate?

New Era, Great Opportunities. Join in + be a part of it!