University of Chinese Academy of Sciences

Impact of Big Data on SoC Design
IoT Technology and SoC Design

Chun-Zhang Chen, Ph.D.

June 25-29, 2018

中国科学院大学**2018年夏季**

IoT and SoC Design

IoT and Technology Background ▷

IoT and LPWAN ▷
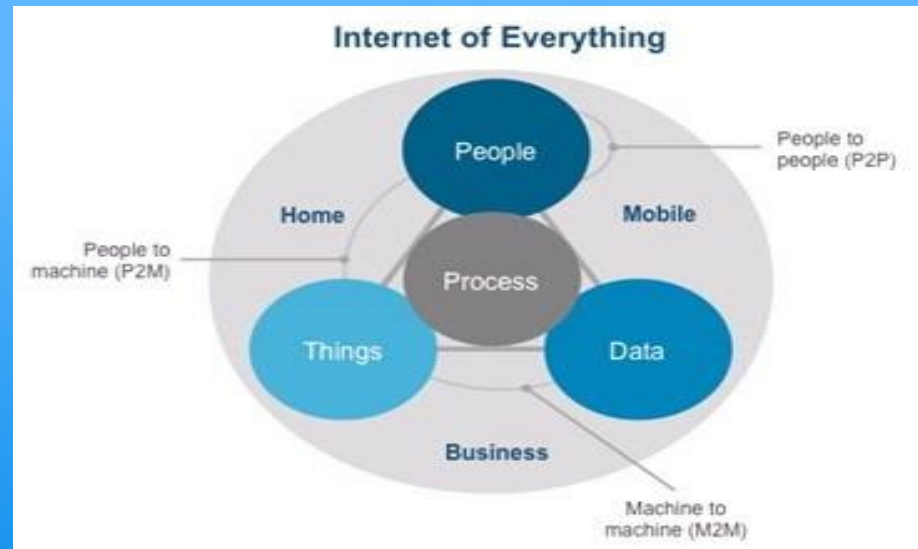
IoT and MCU/IP ▷

3D IC/MEMS/Wearable ▷

Discussion ▷
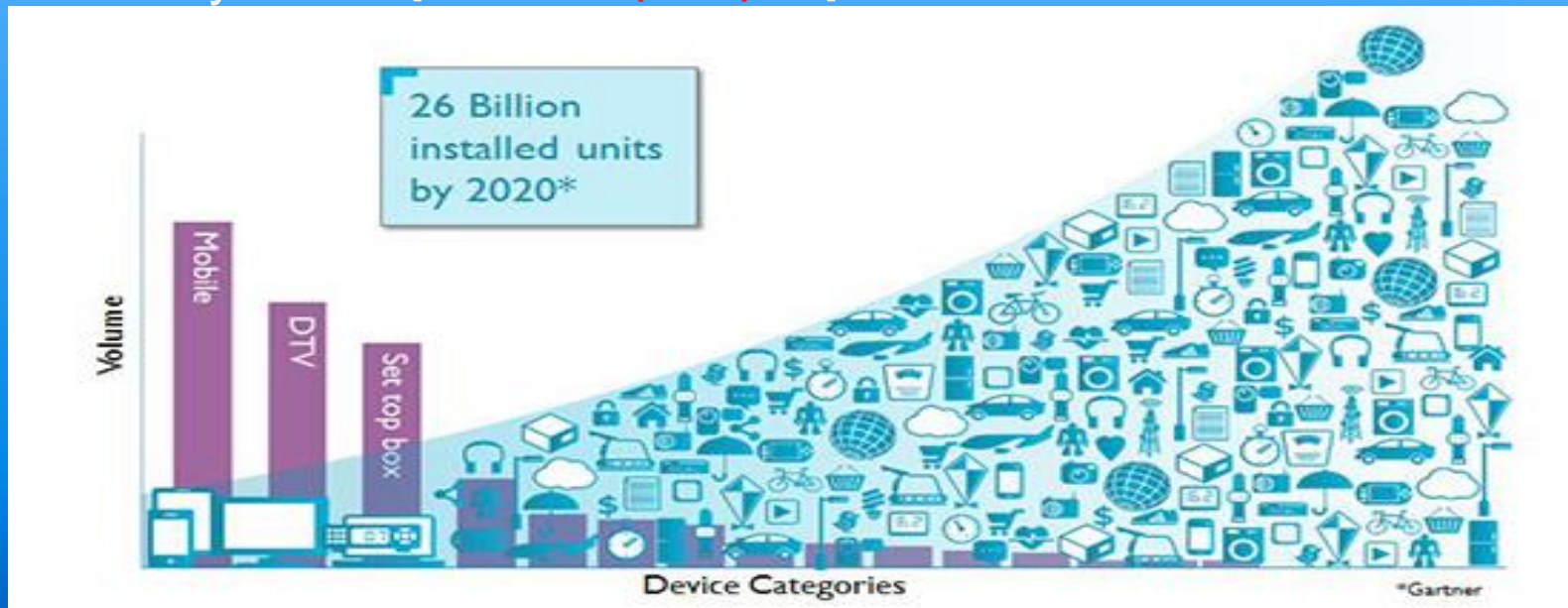
Hot Topics of IoT

- Internet of *(for)* Things – IoT
  - P2P, M2M, P2M
  - Billion Things/ Everything
  - Internet of Vehicles
- IoT Applications
  - Consumer: SHome, Med/Hlth
  - Enterprise/biz: Devices
  - Infrastructure: Manuf., Agr. E./Env.
- Internet+, Ind. IoT (IIoT)
  - Green Energy/Smart Grid
  - 3rd/4th Industrial Revolution

Internet of Everything

People to people (P2P)

People to machine (P2M)

Machine to machine (M2M)

People · Process · Things · Data · Home · Mobile · Business
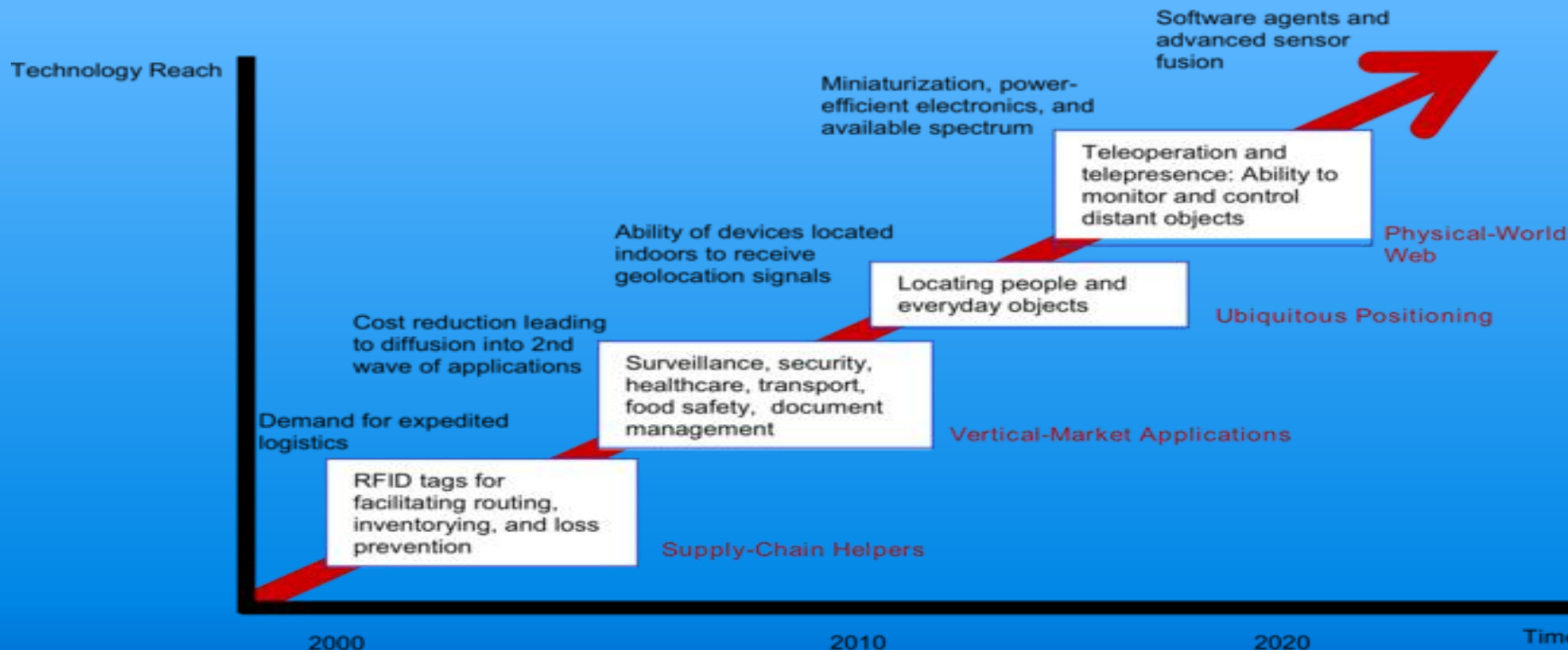
Connected Devices in 2020

● Gartner, Inc. forecasts that 4.9 billion connected things will be in use in 2015, up 30 percent from 2014, and will reach 25 billion by 2020. [Ref. 11, **12(IEEE),** 13]

Technology Roadmap of IoT

TECHNOLOGY ROADMAP: THE INTERNET OF THINGS

Technology Reach

Software agents and advanced sensor fusion

Miniaturization, power-efficient electronics, and available spectrum

Teleoperation and telepresence: Ability to monitor and control distant objects

Physical-World Web

Ability of devices located indoors to receive geolocation signals

Locating people and everyday objects

Ubiquitous Positioning

Cost reduction leading to diffusion into 2nd wave of applications

Surveillance, security, healthcare, transport, food safety, document management

Vertical-Market Applications

Demand for expedited logistics

RFID tags for facilitating routing, inventorying, and loss prevention

Supply-Chain Helpers

2000   2010   2020   Time

Source: SRI Consulting Business Intelligence

The Internet of Things
12-13 May 2015, San Francisco,
Essential IoT Training Program alongside Internet of Things World 2015

Telecoms Academy TRAINING EXCELLENCE

2ND ANNUAL
Internet of Things WORLD

- The world's largest & most comprehensive IoT event

- 4000+ Attendees

- 250+ Speakers

Internet of Things
Internet of Your Things
Internet of Every Things

- High Level VIP/CIOs Conference

Integrating IoT Technologies and Standards & Creating a Sustainable IoT Framework

◆ **Assessing the range of enabling technologies for IoT**
◆ **Overcoming interoperability challenges**
◆ **Which wireless standards will be most pertinent**
◆ **How can the different standards be integrated?**

8th Int'l Conference on IoT
Keynote Speakers

- **IoT 2018 (Santa Barbara, US)**
  - *SmartFarm, UCSB*
- IoT 2017 (Linz, Austria)
- IoT 2016 (Stuttgart, Germany)
- IoT 2015 (Coex, Seoul, S. Korea)
- IoT 2014 (MIT, Cambridge, US)
- IoT 2012 (Wuxi, China)
- IoT 2010 (Tokyo, Japan)
- IoT 2008 (Zurich, Switzerland)

- **IoT Asia 2019, 27-28 Mar. S'pore**
- IoT Asia 2018, 21-22 Mar.S'pore
- IoT Asia 2017, 29-30 Mar. S'pore
- IoT Asia 2016, 30-31 Mar. S'pore
- IoT Asia 2015, 8-9 April, Singapore
- IoT Asia 2014, 21-22 April, S'pore

- *IoT China 2016, 16-18 Nov, CD*
- *IoT Expo China 2015, 20-21 Aug, SZ*

www.iot-conference.org

DAC and IoT
San Francisco, CA June 24-28, 2018

About DAC   Exhibit At DAC

- Design
- EDA
- ESS and Auto
- **IoT**
- IP
- Security

MONDAY KEYNOTE

Living Products: Building Connected Devices that Learn and Evolve

Monday, June 25 | 9:20am - 10:00am | Room 3008

Sarah Cooper, GM of IoT Solutions

Amazon Web Services, Inc., Mountain View, CA

- Rikky Muller, UCB

The Internet of Things can sometimes seem vast and unmanageable, …

Design ▶
There is no other way to improve your "design IQ" in such a short amount of time than to attend the Design Track.

EDA ▶
In addition to the traditional EDA topics ranges from physical design to system architectures, DAC 2016 features high-quality papers on design research, design practices, and design automation for...

ESS & Auto ▶
The Embedded Systems and Software sessions at DAC provide a forum for discussing the challenges of embedded design and an opportunity for leaders in the industry and academia to come together to...

IoT ▶
The Internet of Things can sometimes seem vast and unmanageable. Let the IoT sessions at DAC simplify it for you.

IP ▶
The IP track provides creators and users of IP with an open forum to exchange information on state-of-art IP products, tools and methodologies to create, incorporate and validate IP in SoCs.

Security ▶
Security topics will be featured through invited special sessions, panels, and lecture/poster presentations by both practitioners and researchers to share their knowledge and experience on this...
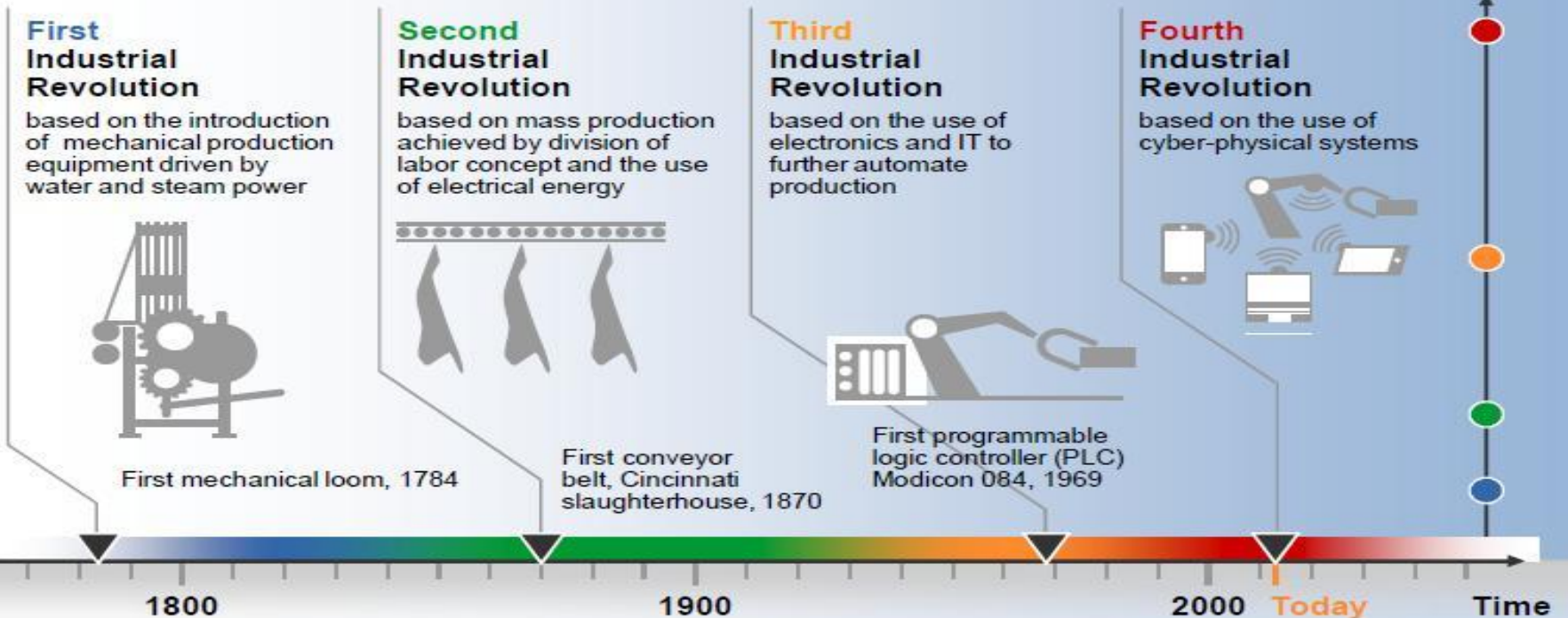
IMS – Intelligent Manufacturing System

- IM in US, 1980s; IMS (1990) by Andrew Kusiak (U. Iowa)
  - "Big Data on IM" (8/6/14 at UCAS); ANN for IMS
- Industry 4.0 in Germany (IP/IoT)
- 02/2014, Made in China 2025 – 2035 – 2049
- IMS and associated topics
  - Journal, Research & Business, Solution, Software

From Industry 1.0 to Industry 4.0

First Industrial Revolution
based on the introduction of mechanical production equipment driven by water and steam power

Second Industrial Revolution
based on mass production achieved by division of labor concept and the use of electrical energy

Third Industrial Revolution
based on the use of electronics and IT to further automate production

Fourth Industrial Revolution
based on the use of cyber-physical systems

Degree of complexity

First mechanical loom, 1784

First conveyor belt, Cincinnati slaughterhouse, 1870

First programmable logic controller (PLC) Modicon 084, 1969

1800   1900   2000   Today   Time

IoT & SoC Design

- **Background of IoT Tech:** Internet of Things

- **IoT and LPWAN:** NB-IoT, IPv6

- **IoT and MCU/IP:** Low Power & Size, 3D NAND

- **3D IC/MEMS/Wearable:** Healthcare/Medical, Fitness/Wellness

- **Discussion:** Vendors, Players

AI-Big Data and SoC Design

IoT needed Technologies - LPWAN

- LPWAN: NB-IoT, LoRa, Sigfox
- NB-IoT (2016-, via GPRS)
  - Low data rate, low power, low bandwidth
  - Global 900MHz (UniCom 900/1800MHz, TelComm 800MHz)
    - Registered, SIM/eSIM supported
    - 2G Shutdown in 2018; GPRS/GSM needed in long-term
    - Bandwidth 200kHz,
    - Down 160-250kbps, up 160-250(MT)|200(ST)kbps
    - Connection points is 50-100x of current Wi-Fi
    - 20dB gain, is 100x of LTE

AI-Big Data and SoC Design

IoT and LPWAN

- LoRa (2015)
  - Up to 1000 devices, 5-30km
  - In testing, 100,000 devices?
- Sigfox (2009, Fr.)

- Security by GDPR (General Data Protection Regulation)

Wireless Protocol for Short Distance Comm.

- Wi-Fi
  - 2003 Intel, 11 Mbps, 802.11b → 802.11b/g, a/c/n
- BLE/BC (BR, EDR)
  - BR(Basic Rate), EDR(Enhanced Data Rate); BLE(Bluetooth Low-Energy)
  - 1994-1997 Ericsson; 1998 SIG (Norkia, Apple, Samsung)
- ZigBee (2003-), HomeRF (1997), Thread (2014)
- IrDA, RFID-Mifare, Z-wave, UWB, NFC, LiFi

5G Communication

- Mobile Internet

- 5G standards

- SoC and Memory Designs
  - HPC & MEC
  - HBM & RapidIO

IoT and Internet Protocol
Technology, Compatibility and Security

- Total number of IP addresses:

  - IPv4, $2^{32} = 4.3 \times 10^9$

  - IPv6, $2^{128} = 3.4 \times 10^{38}$

- Privacy and Security

- Comparability of Internet Protocol

  - Ex. SIP, Session Initiation Protocol –

  - controlling voice/video over IPv4 $\rightarrow$? IPv6

What happened to IPv6 – Will the IoT

- … we were all supposed to have abandoned IPV4 and moved to IPV6 by now (12/31/14)

- These 'things' have been predicted (presumably by the same people who predicted the arrival of IPV6) to grow to an army of **50 billion** by 2020.

- The measurement activities below track different aspects of IPv6 deployment on the global Internet:

  - http://www.worldipv6launch.org/measurements/

IPv6 Ready Logo Program

- Spiceworks Report (2014):

  - http://www.spiceworks.com/voit/reports/the

INTERNET-ENABLED "THINGS" CURRENTLY CONNECTED TO NETWORKS

58% Video equipment (security cameras)
43% Electronic peripherals (projectors)
35% Sensors (RFID or badge readers)
31% Physical security (locks, gates)
29% Controllers (lighting, thermostats)
23% Appliances
13% Wearable devices (smart watches, headsets)
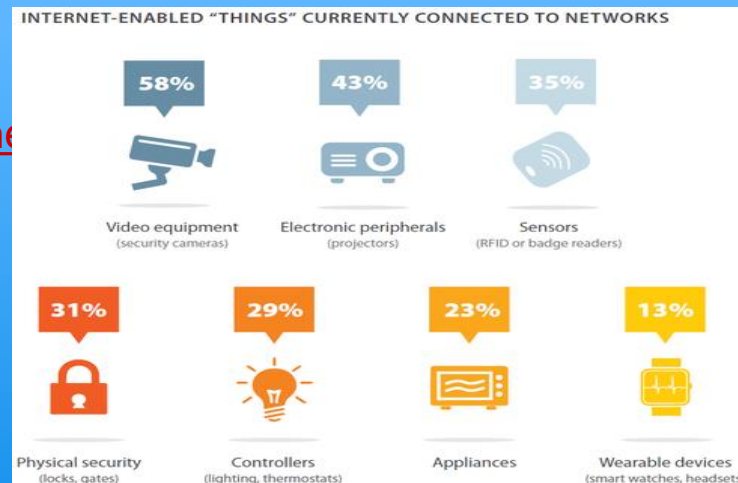
- As service providers bring IPv6 connectivity to the home, users need to make sure the appliances and other devices they buy are capable of using IPv6 as a transport.

IPv6 for IoT

IPv6 Adoption

We are continuously measuring the availability of IPv6 connectivity among Google users. The graph shows the percentage of users that access Google over IPv6.

Native 3.34% • 6to4/Teredo 0.02% • Total IPv6 3.36% | April 05, 2014

Global IPv6 Adoption

Switzerland	48%
France	36%
Germany	47%
Japan	35%
USA	43%
Internet core	77.73%
Global content	46.81%
Users	19.76%

Discover how your country compares >

CISCO

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MCU Market in IoT Applications

- Controller: PCs, SmartPhones

- Basic Framework: Routers and Servos

- Nodes: Video, Traffic Lights, E Appliances

MCU Snapshot - a Platform for IoT

- 1971-1976, Intel 4004 w/ RAM, ROM, MCS-4
  - 4-bit, later 8-bit 8008
- 1976-1980 MCS-48 8-bit CPU parallel I/O etc
  - RAM, ROM, <4kB, w/o serial I/O
- 1980-1983, 16-bit, address 64kB
- 1983-late 80s, 16-bit MCS-96 series, up to 120k transistors
- 1990 applied to many areas
  - measure & control, smart meters, complete set, smart interface
  - mobile, auto GPS, PDA, toys, smart appliance, medical
  - total >100k engineers in China are on MCU

Applications:

Automotive
IoT/Wearables
Appliances
Smart Card
Medical
Industry Control

MCU vs MPU

- CPU → MPU, MCU, DSP
- MCU is an embedded design
- The first MCU in 1971, TMS 1000
  - By Gary Boone & Michael Cochran of TI
  - ROM, RAM, processor, clock
- Early MCU has 2 ROM types
  - EPROM, ceramic packg. w/ quartz window
  - PROM (OTP), less expensive
- MCU in 1993 w/ EEPROM and Flash by Atmel
- Used in auto, a mid-range auto has 30+ MCU
  - washing m., microwave o., telephone
- Need programs fit in
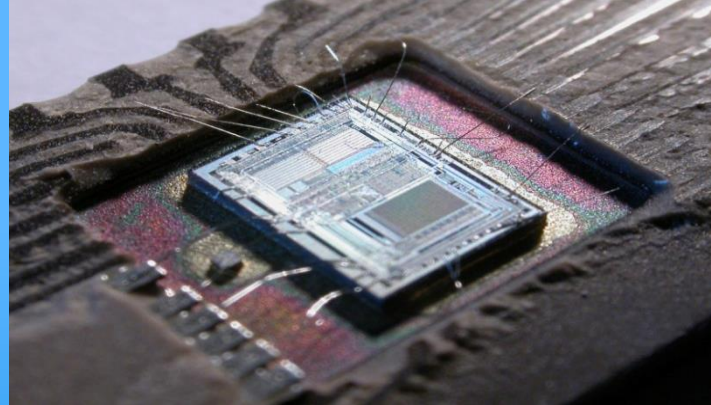
● Architecture and Programming of 8051 Microcontrollers
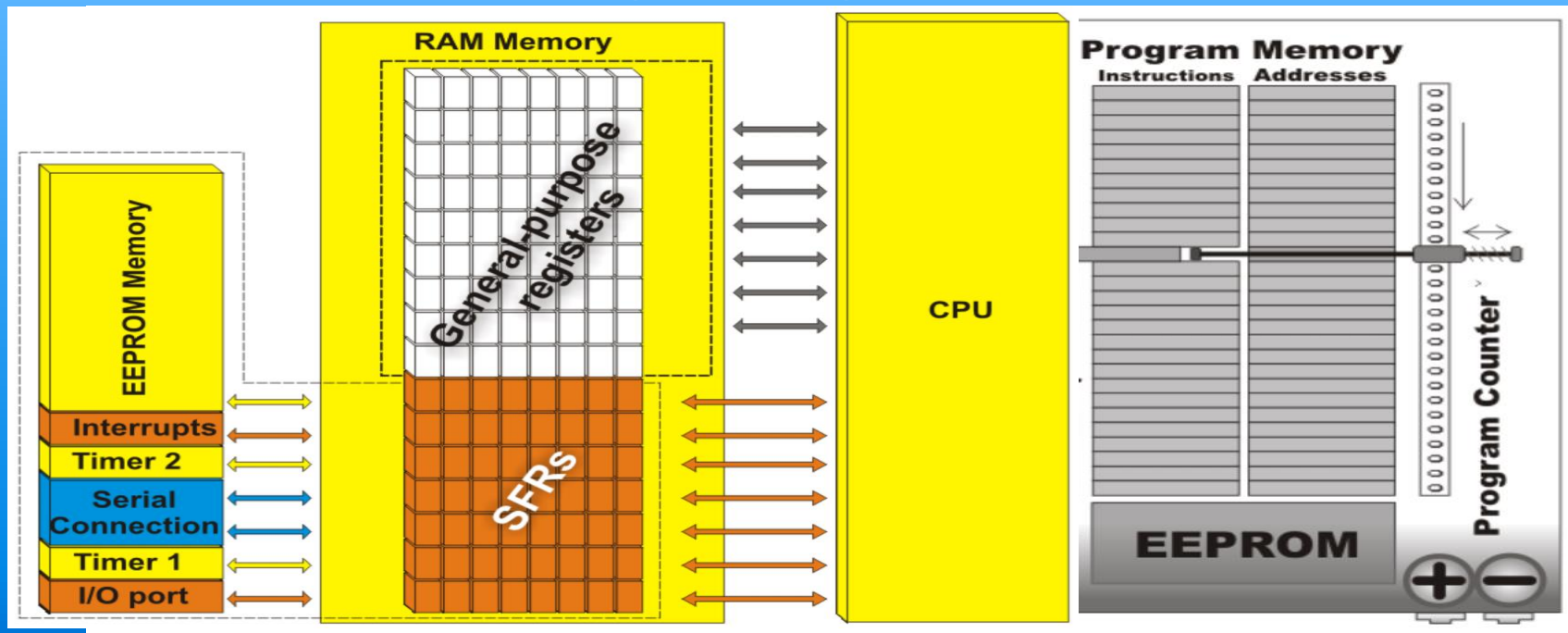
MCU Application in 2013 Market Segment
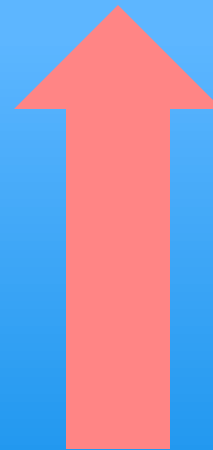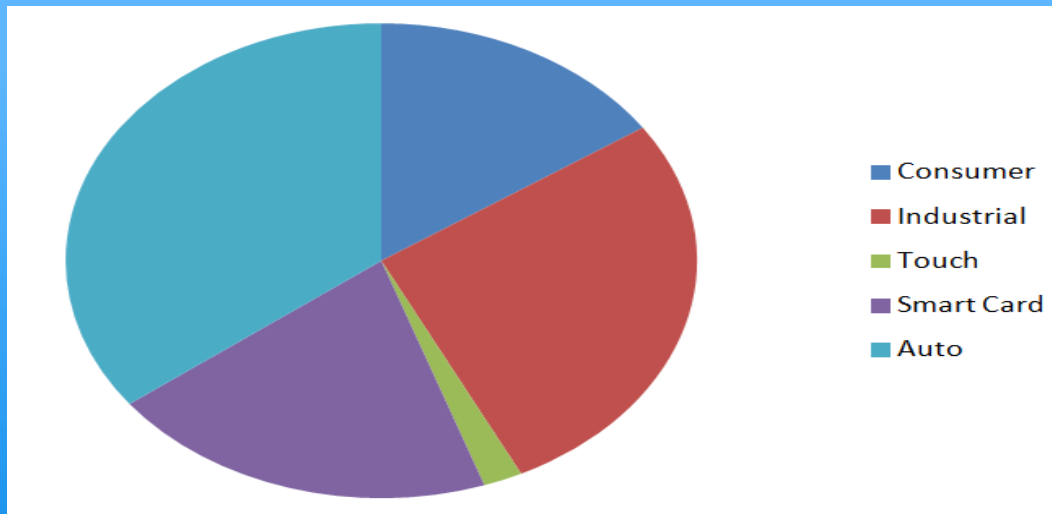
Category	Revenue, $M
Consumer	2350
Industrial	4112
Touch	303
Smart Card	3026
Auto	5342
Total	15133

Category	Market %
Consumer	15.5
Industrial	27.2
Touch	2
Smart Card	20
Auto	35.3
Total	100

IP for IoT – Design and Reuse

- Analog & Mixed Signal
- Memory Controller & PHY
- Graphic & Peripheral
- Interface Controller & PHY
- Processor & Microcontroller
- Memory & Logic Library
- **Security**
- **Multimedia**
- Wireline Communication
- **Wireless Communication**
- Automotive, Platform Level IP, Network-on-Chip
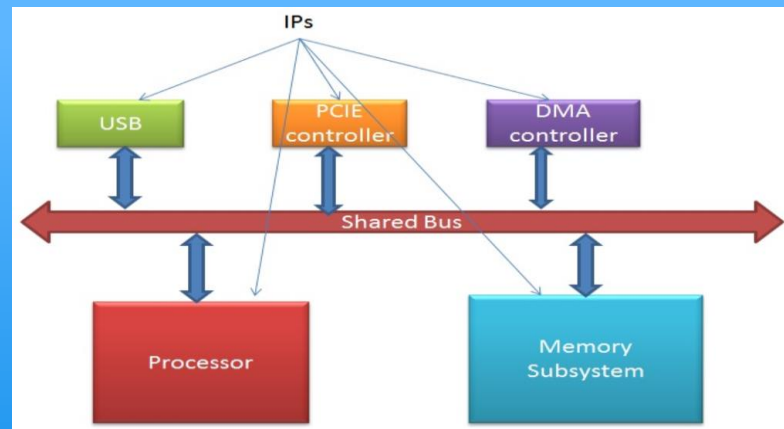
IoT IP Example

- Features of IP

  - **Low-Power, Cost-Sensitive IoT,**

  - **Mobile, Automotive, Industrial and**

  - **Environmental Applications**
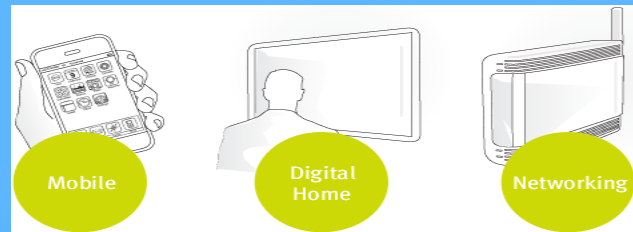
Designware IP Subsystems

- Interface IP Subsystems
  - Configurable, customizable and pre-validated
  - DDR, PCIe, USB and Ethernet
- Audio IP Subsystems
  - Integrated HW and SW subsystem w/ "drop-in" functionality
  - 24-bit, DTV, STB
- Sensor and Control Subsystem
  - Integrated HW and SW subsystem
  - Complete, configurable to process D and A sensors etc

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Advantage of 2.5D/3D Pkg'd MEMS/ASIC

- SiP support advanced three dimensional interconnect structure for MEMS and ASIC integration

  - Post-CMOS through-silicon vias (TSV)

  - Front-to-front contact array

  - Vacuum compliant lateral interconnect

  - Fine-pitch solder balling
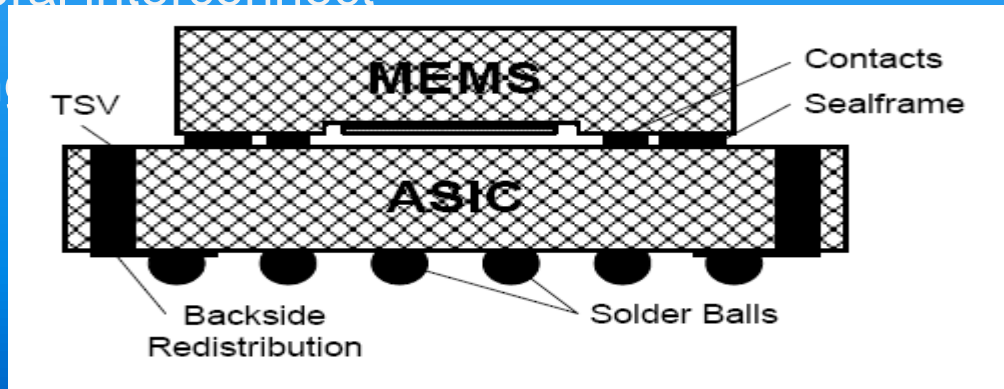
IoT and IC Design

- IoT Components

  - Sensors

  - **MEMS**

  - Other components

S4700 15.0kV 11.9mm x250 SE(U)   200um
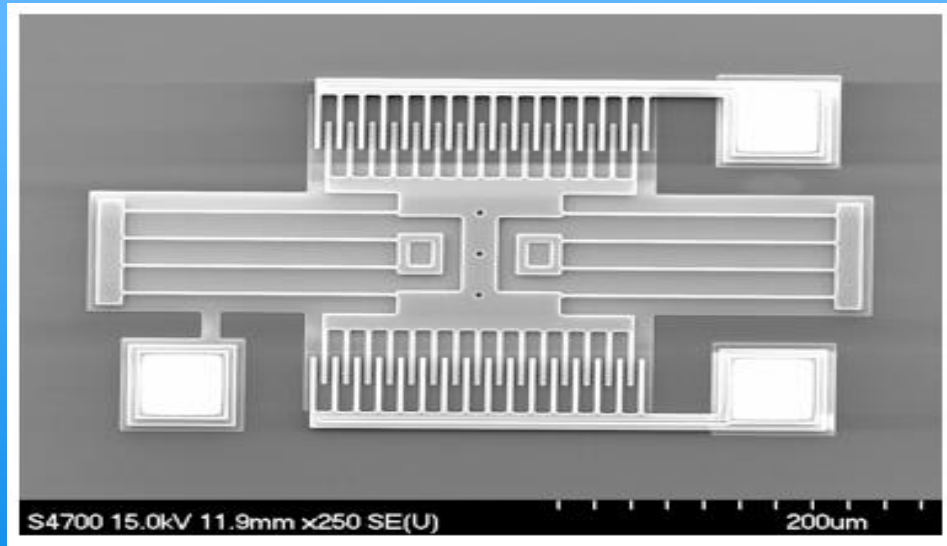
Digital MEMS microphones to overtake analog

Millions of US dollars

Analog / Digital bar chart for years 2010–2015.
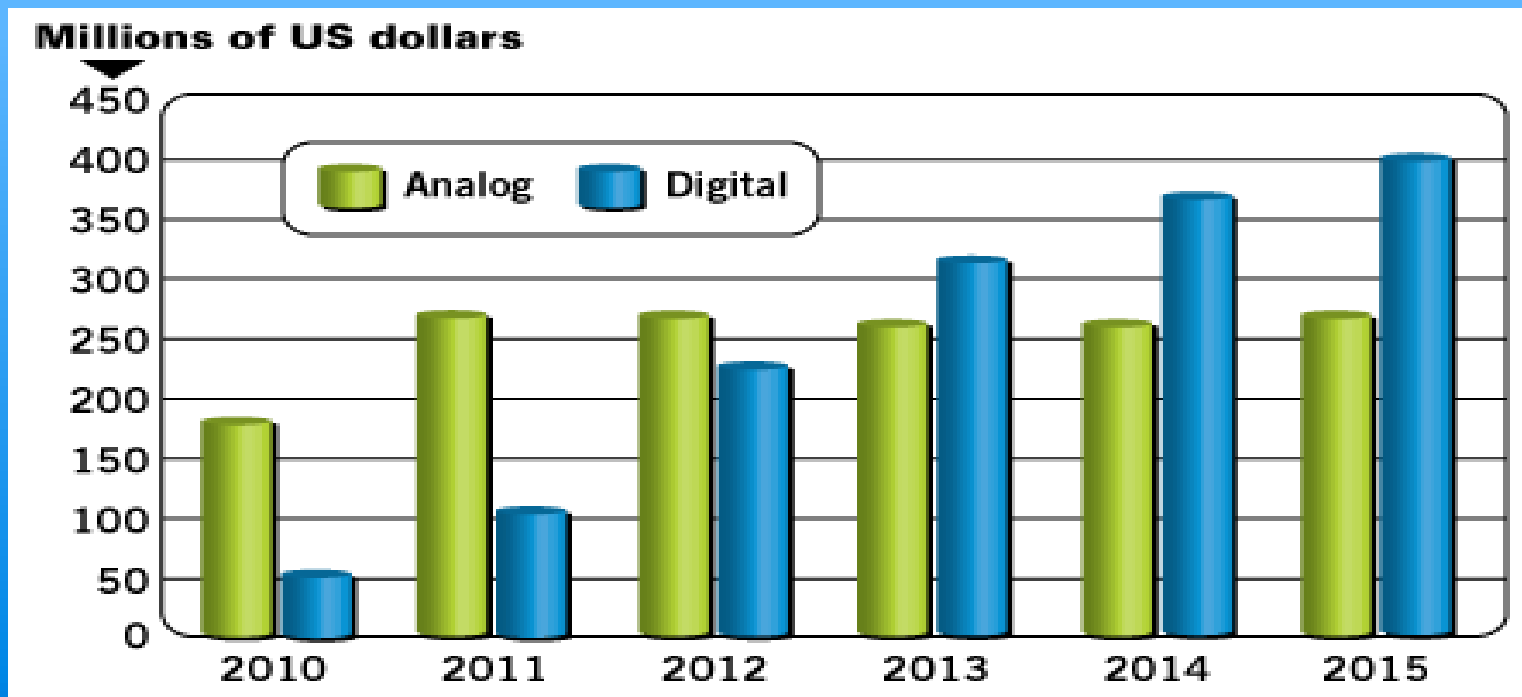
Source: Solid State Technology, 2012

Wearable Market

- MEMS.journal: Market to expand 7x

- Statistics & Studies: It's all about the wrist

- Wearable Tech World: Market influencers …

- By 2021, 5.05×10^6 wearable Devices are needed (Gartner)

Big Data and Medical
The big-data revolution in US health care

- Right living

- Right care

- Right provider

- Right value

- Right innovation
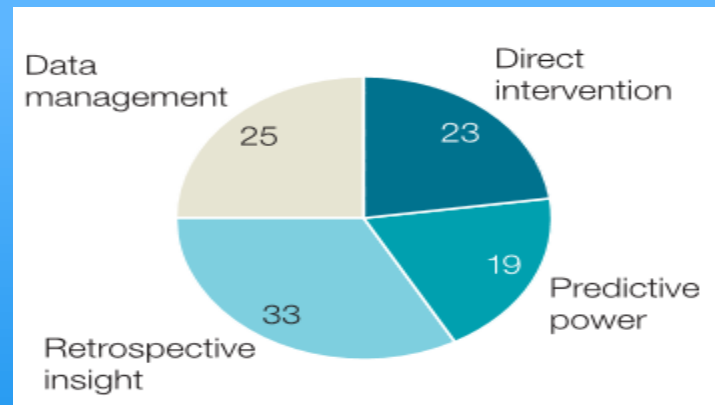
The biggest value of BD to humankind is medical

In 2014, semicon. patents reduced by 5%; according to Tangseng Luters "2015 Innov. Report", pharm. and biotech patents increased by 12% and 7%!

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Bluetooth (QCOM) and IoT

- BT: CSRmesh, aptX, cVc Noise Canc. Tech., TrueW-

- Wi-Fi: SoC (27 products), ex. QCA9994,

  - 802.11ac Wave 2; 11ac, 11n, 11a/b/g; 1.733Gbps; MIMO 4x4
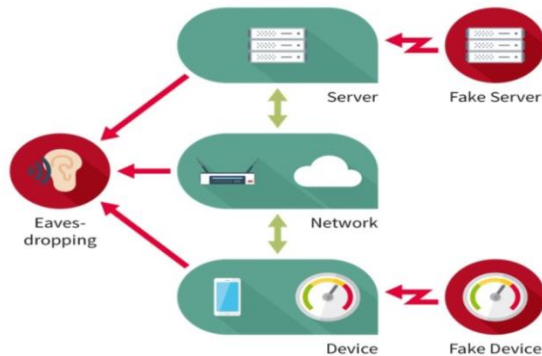
- RF: TruSignal Antenna Boost Tech

NB IoT ICs and Applications

- IoT IC Designers
  - Who are they?
- Potential Applications for NB IoT
  - Electric meters? Water? N Gas?
  - Smart parking meters/Street lamps?
  - Elevators IoT?
  - Smart logistics? S. Agriculture?
  - S. Manufacturing?
  - Garbage buckets? Hydrants?
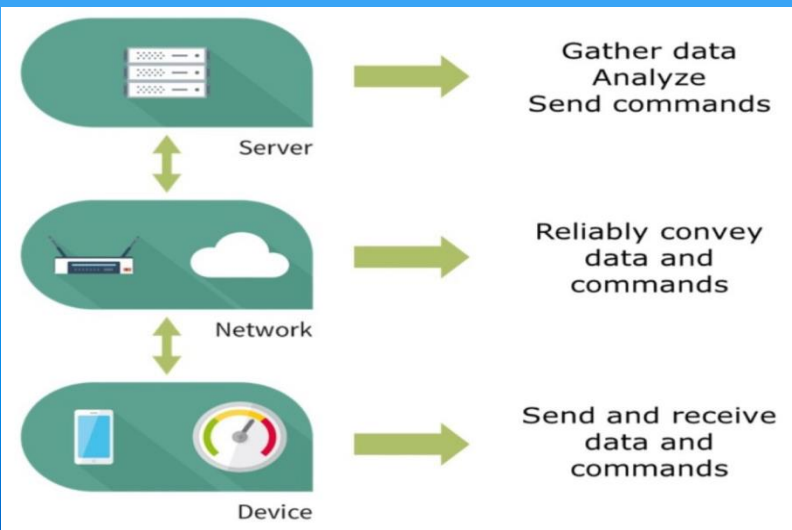 - S. home? S wearables? S construction? S. smoke detectors?

AI-Big Data and SoC Design

Security in IoT

- Security matters

- Partners of choice

- Security solutions

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Summary

Cisco: Internet of Everything (IoE)

Samsung ARTIK

QCOM