University of Chinese Academy of Sciences

IoT and Automotive Electronics

MCU and ECU Designs

Chun-Zhang Chen, Ph.D.

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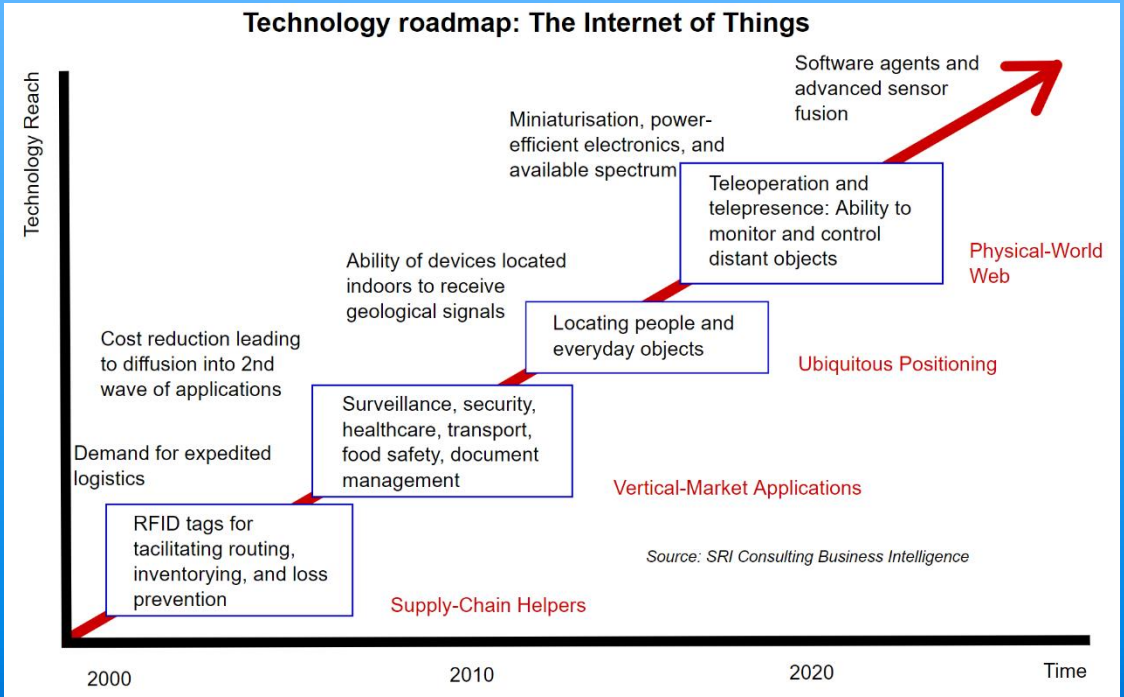
中国科学院大学2021年夏季

IoT and SoC Design

University of Chinese Academy of Sciences

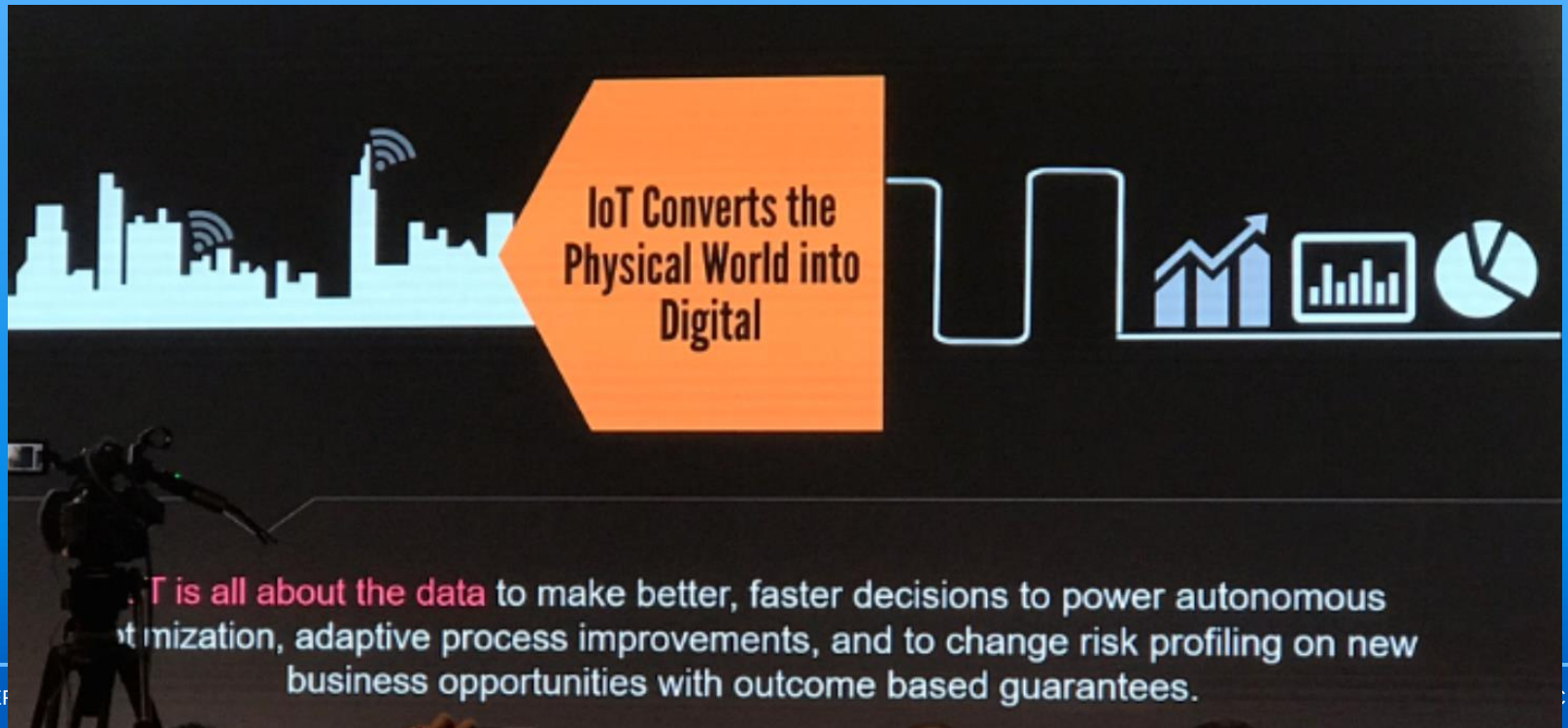
- IoT and Technology Roadmap
- 5G and Beyond
- Automotive Electronics and ADAS
- MCU and ECU Designs
- Discussion

Technology Roadmap of IoT



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



IoT and IIoT (Industrial IoT)

- Industrial IoT

Industrial 1.0, 1784.

Steam engine…

Industrial 2.0, 1840.

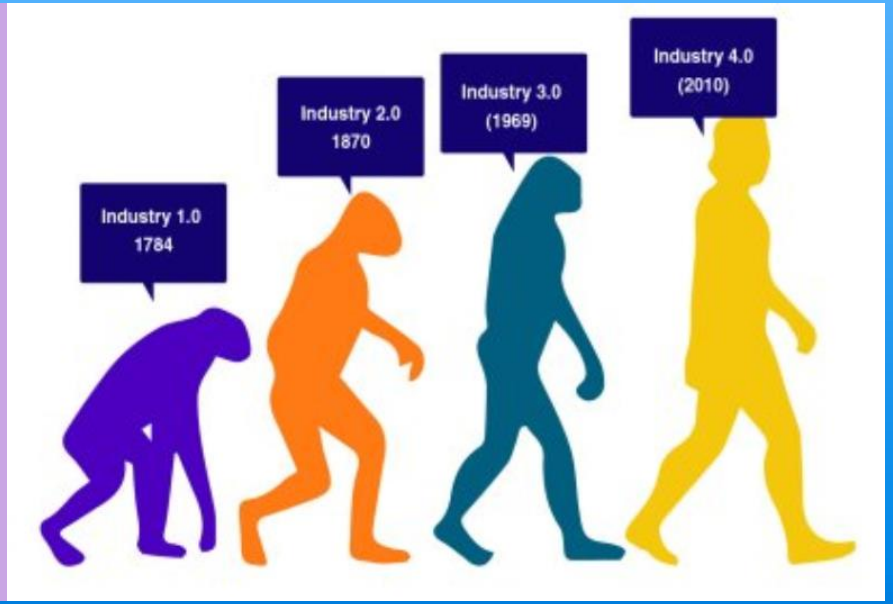
1st Assembly line production…

Industrial 3.0, 1969.

E-tech, industrial robotics,…

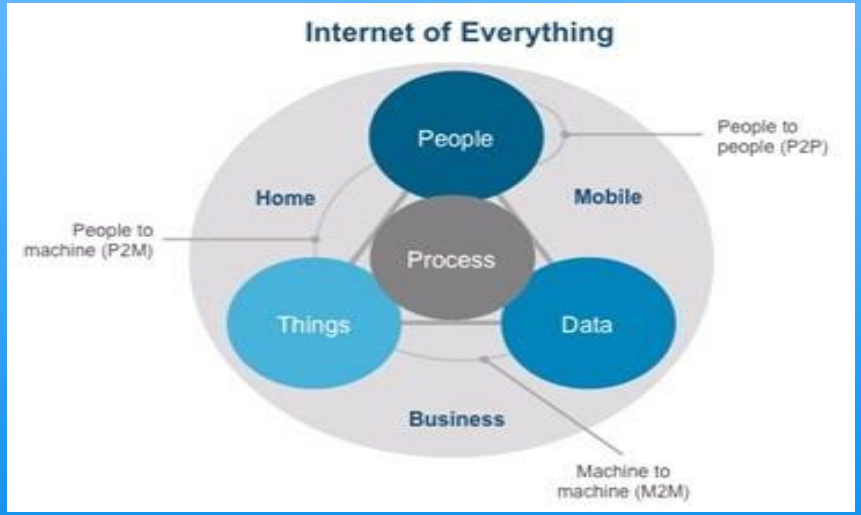
Industrial 4.0, 2010.

Smart devices…



IoT and AIoT (Artificial Intelligence of Things)

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



IoT Technologies: LPWAN (1/2)

- 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

IoT Technologies: LPWAN (2/2)

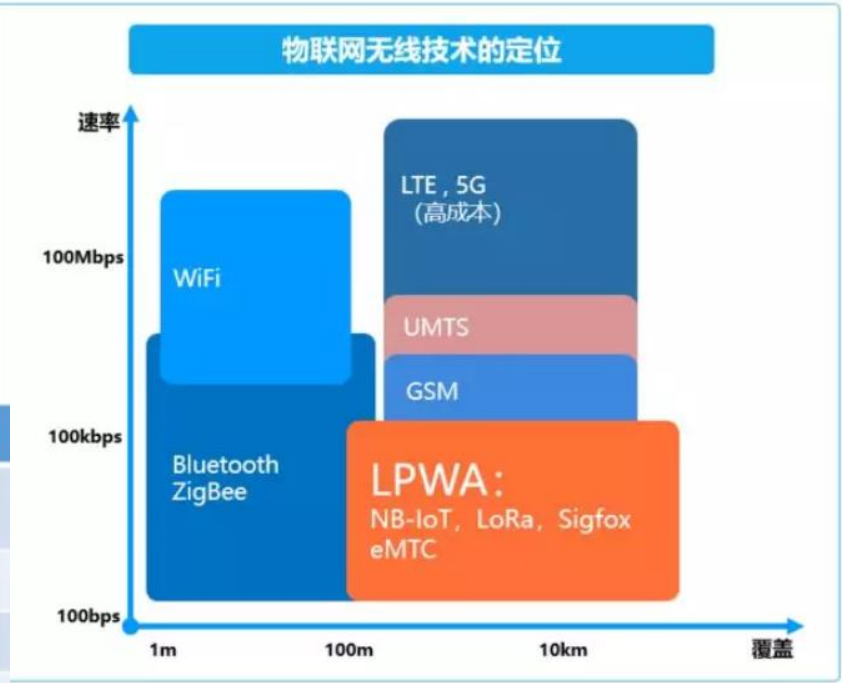
- LoRa (2015)
  - Up to 1000 devices, 5-30km
  - In testing, 100,000 devices?
- Sigfox (2009, Fr.)

- Security by GDPR (General Data Protection Regulation)

NB-IoT and 5G

- LPWAN: NB-IoT, LoRa, SigFox
- 5G: eMBB, URLLC, mMTC

指标	NB-IoT	5G
标准成熟度	已冻结，随时可用 √	eMBB已完成，uRLLC和mMTC要等到2020年底
建网成本	低 √	很高
覆盖距离	远 √	近
终端通信模组成本	低 √	高
速率	极低	极高 √
延时	高	极低 √
单位面积连接数	每小区5万	每平方公里100万 √



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?

Wireless Protocol for Short Distance Comm.

- Wi-Fi
  - 2003 Intel, 11 Mbps, 802.11b → 802.11b/g, a/c/n
- BLE (BLE(Bluetooth Low-Energy)/BC (BR, EDR)
  - BLE(Bluetooth Low-Energy), BT
  - BR(Basic Rate), EDR(Enhanced Data Rate);
  - 1994-1997 Ericsson; 1998 SIG (Norkia, Apple, Samsung)
- ZigBee (2003-), HomeRF (1997), Thread (2014)
- NFC, 13.56MHz, 20cm, 106|212|424 Kbit/s,
  - ISO/IEC 14443 (NFC card); ISO/IEC 18000-3 (RF ID)
- IrDA, RFID-Mifare, Z-wave, UWB, NFC, LiFi

8th Int'l Conference on IoT

Keynote Speakers

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- IoT 2019 (22-25 Oct, Bilbao, Spain)
  - AWS, AI+IoT
- **IoT 2018** (Santa Barbara, USA). "*SmartFarm*"
- **IoT 2017** (Linz, Austria). "!Data→Solution"
- **IoT 2016** (Stuttgart, Germany). "Smart Bldgs"
- **IoT 2015** (Seoul, S. Korea)

- **IoT 2014** (Cambridge, USA)
- **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*

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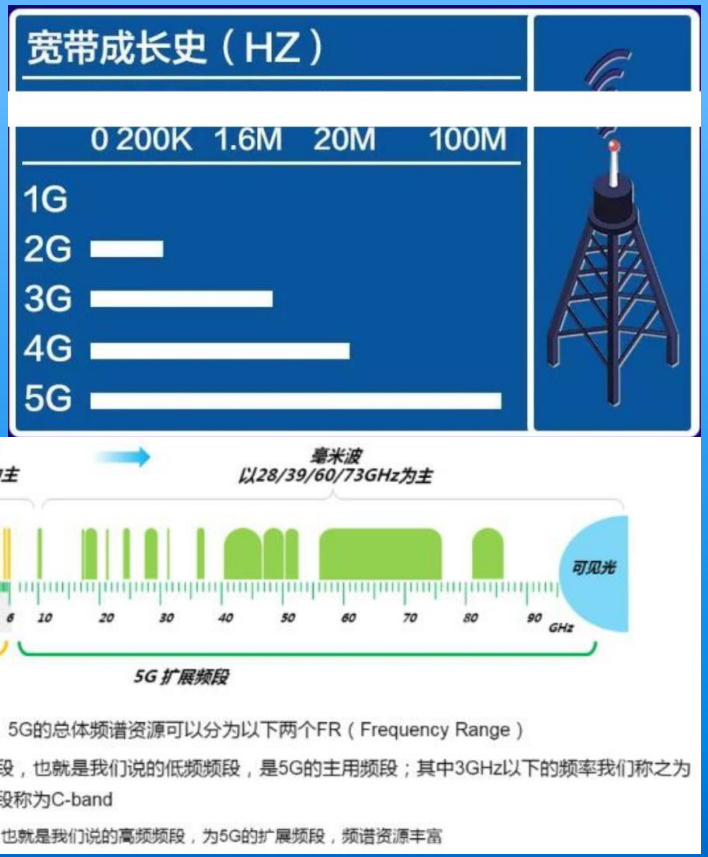
Evolution of 1G-5G



在3GPP协议中，5G的总体频谱资源可以分为以下两个FR（Frequency Range）

FR1：Sub6G频段，也就是我们说的低频频段，是5G的主用频段；其中3GHzl以下的频率我们称之为sub3G，其余频段称为C-band

- FR2: 毫米波，也就是我们说的高频频段，为5G的扩展频段，频谱资源丰富

NR 频段号
n1
n2
n3
n5
n7
n8
n20
n28
n38
n41
n50
n51
n66
n70
n71
n74
n75
n76
n77
n78
n79
n80
n81
n82
n83
n84

NR 频段号
n257
n258
n260

5G Communication

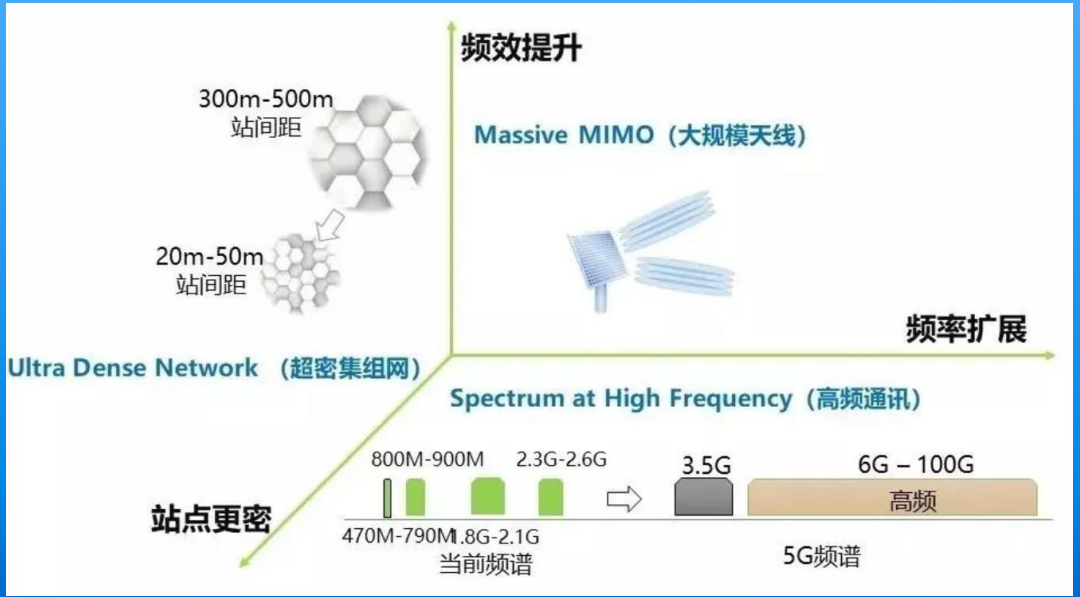
eMBB, URLLC, mMTC

- 5G: eMBB, URLLC, mMTC
  - Consumer, enhanced Mobile Broadband
  - Robotics/ADAS, Ultra-reliable low latency communication
  - Machine comm.: massive Machine-Type Communication
- Mobile Internet

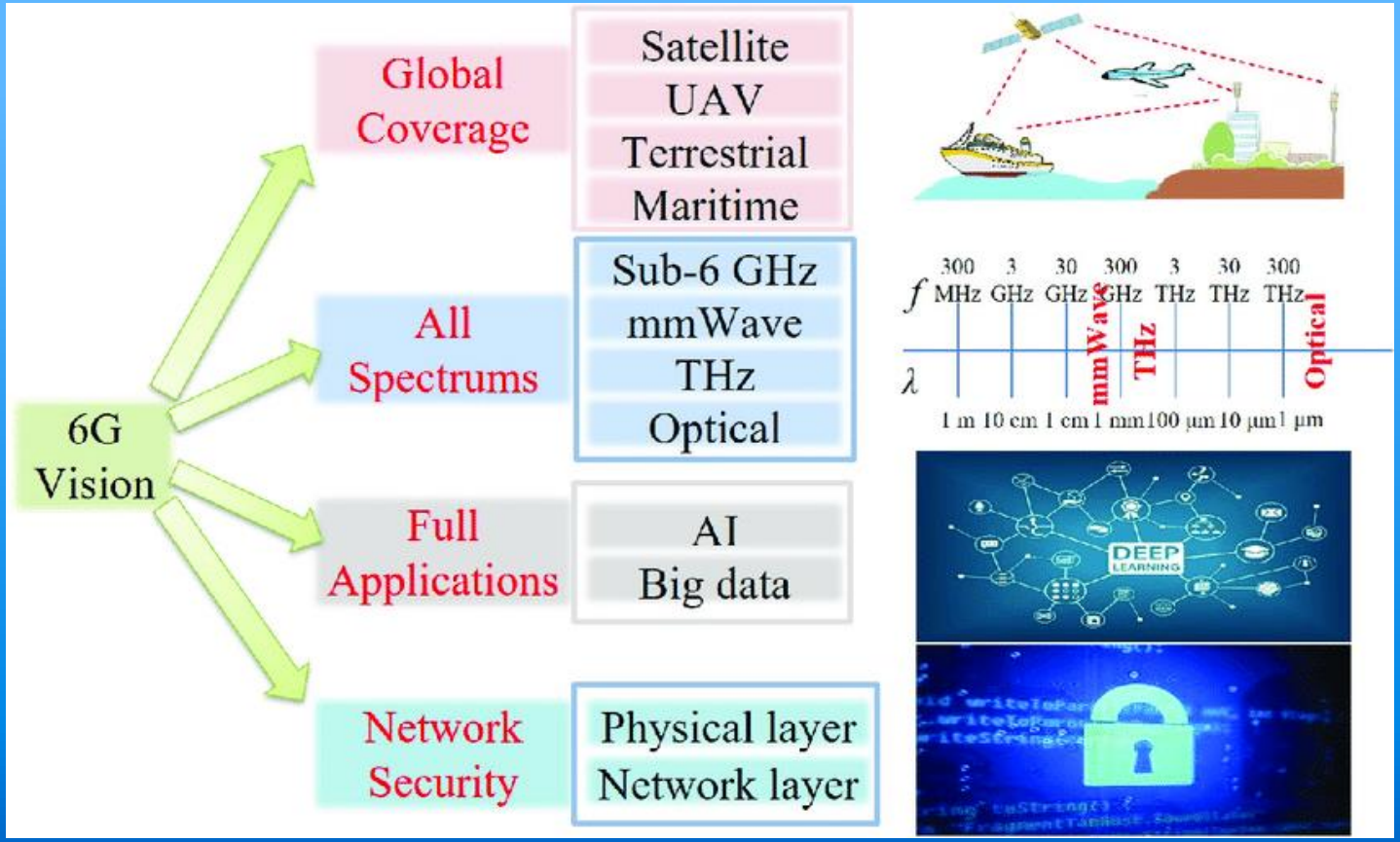
- SoC and Memory Designs
  - HPC, MEC, HBM, 5G IPs

5G and RF

- Antenna: RX, TX
- Components in RF Design
  - PA, LNA, Mixer, O
  - PLL, SerDes



Vision of 6G Wireless Communications



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ADAS Definition, ISO and ADAS

- ADAS, Advanced Driver Assistance Systems
  - AUTO connected car
- ASIL, Automotive Safety Integrity Level
  - a risk classification scheme defined by ISO 26262
- ISO 13400, Ethernet-based connectivity over Analog IP (LVDS) for ADAS
- ISO 26262, ASILs (ASIL-B, ASIL-D)
- ISO 14001, EMSs

Enable Cars …

- **to see**, auto-pilot
- **to think**, complete platform for the digital cockpit
- **to learn**, deep learning system

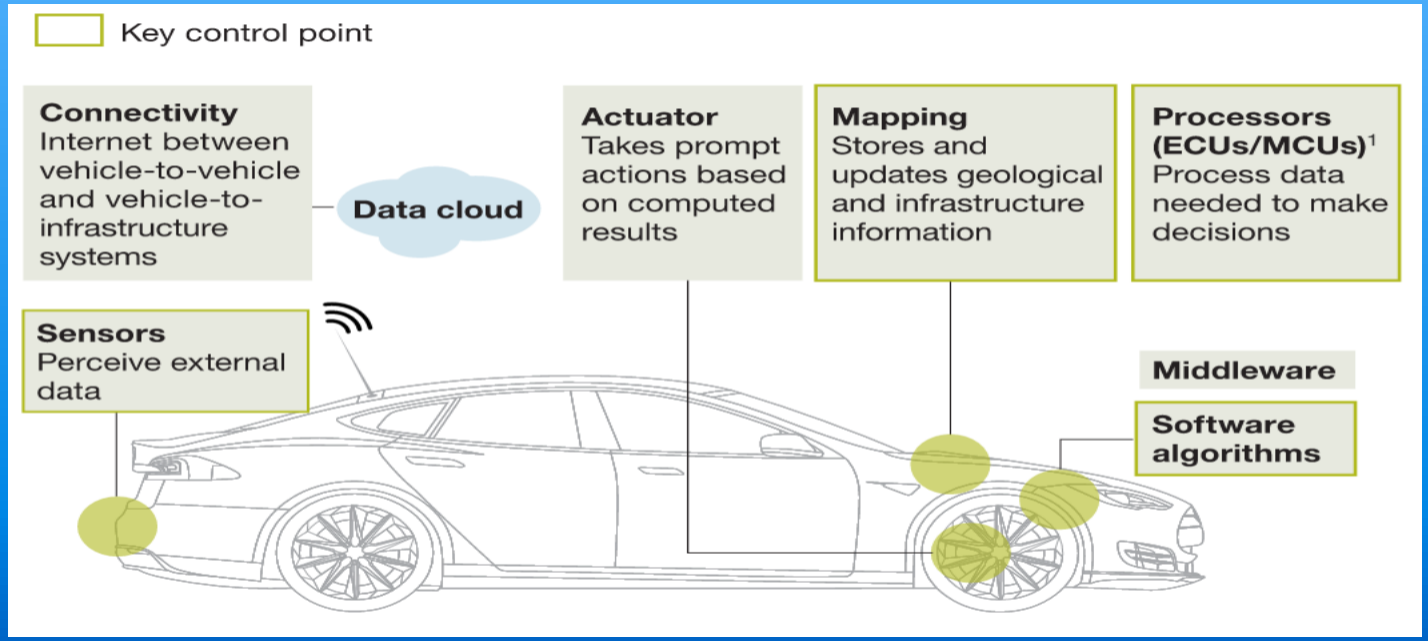
- **V2V**, Vehicle-to-Vehicle
- **V2X**, Vehicle-to-Infrastructure
  - such as mobile telephony or Wi-Fi data network systems

ADAS features

- Intelligent speed adaptation, ISA
- Adaptive cruise control, ACC）
- Lane departure warning system, LDWS
- Collision avoidance system
- Automatic parking
- Traffic sign recognition
- Blind spot detection
- Driver drowsiness detection
- Electric vehicle warning sounds

ADAS Awareness

- Four key control points …
- Processors: ECU, MCU



xEV

- Electric vehicle, EV
  - EV, xEV (spanning MHEV, HEV, PHEV, BEV, FCEV)
  - is rising at a CAGR of 27.7%, to more than $28.8bn in 2026,

AE (and/or EV)

- Overall for AE:
  - engine management, ignition, radio, carputers, telematics, in-car entertainment systems and others
- Engine electronics, ECU (engine control units)
- Transmission electronics
- Chassis electronics and passive safety
  - ABS, TCS, EBD, ESP
- Driver assistance
- Driver assistance and infotainment systems
- Electronic integrated cockpit systems
- Functional safety requirements

Tesla, Inc.

- Tesla, Inc. (2003-)
- SpaceX (2001-)
- Superloop (2013-)
- OpenAI (2015-)

Tesla Motors

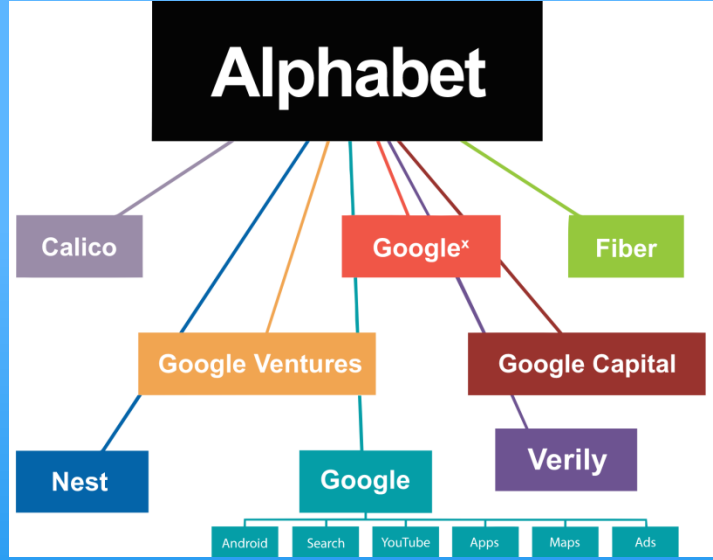
- As of March 2015, Tesla Motors has delivered about 70,000 electric cars
  - Tesla Roadster the first EV (sports car in 2008)
  - Model S (lux. sedan), Model S/X and Model 3
  - Sales today ranking: #1 BYD Auto, #2 Tesla Motors
- Founded July 2003 by Martin Eberhard and Marc Tarpenning; also Elon Musk and others are considered co-founders.

Mobileye

- Founded in 1999
  - Ziv Aviram, President
  - Amnon Shashua (Hebrew University), Chairman and CTO
  - Vision tech, 2004: EyeQ2 Chip,
    - a camera and software to detect car
    - 2010 Goldman Sachs inveted, $37M
- Took over by Intel March 2017 ($15B)

Waymo/Google Car

- Waymo car (← Google car)



Alphabet

"Do the right thing"

WAYMO

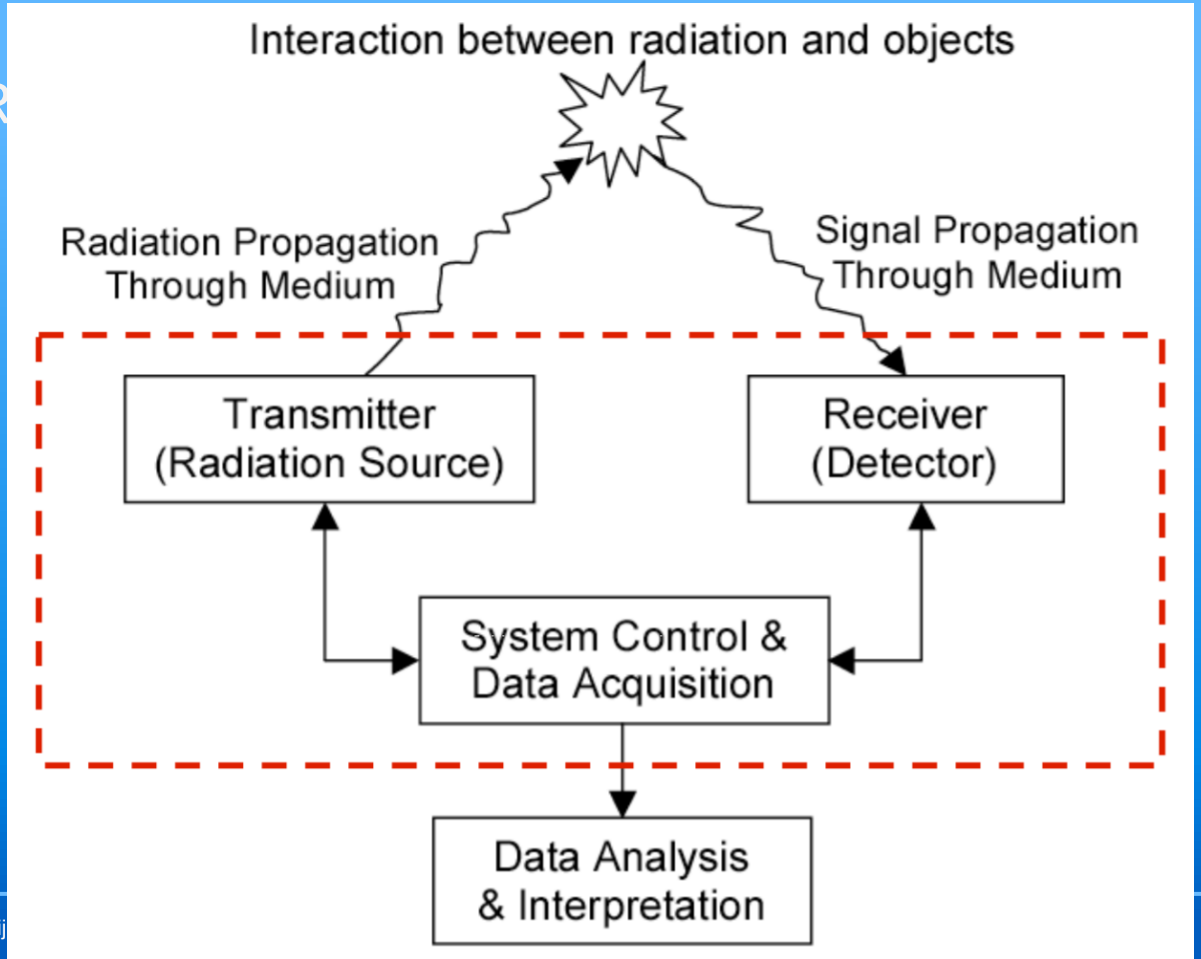
Types of ECU – G.U.I.

Multiple Modules – up to 80 ECUs in a single car

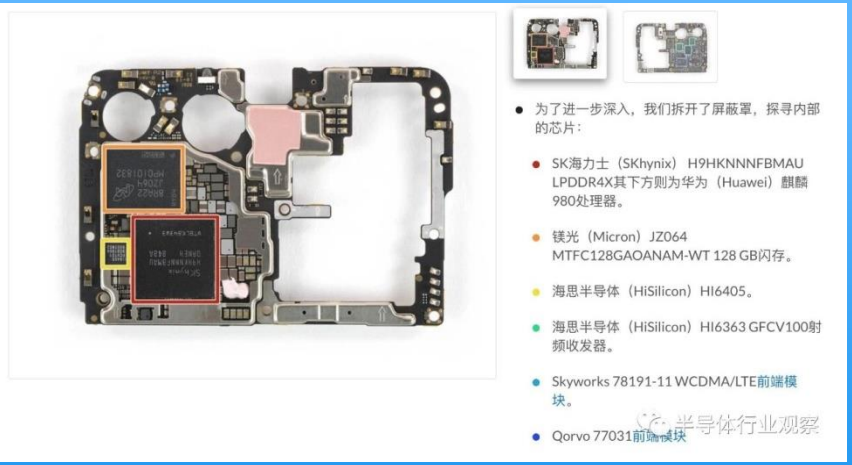
- ECM, Electronic/engine Control Module
- PCM, Powertrain Control Module
- TCM, Transmission Control Module
- BCM, Brake Control Module
- CCM, Central Control Module
- CTM
- GEM
- BCM
- SCM

Lidar (LIDAR, LiDAR, and LADAR)

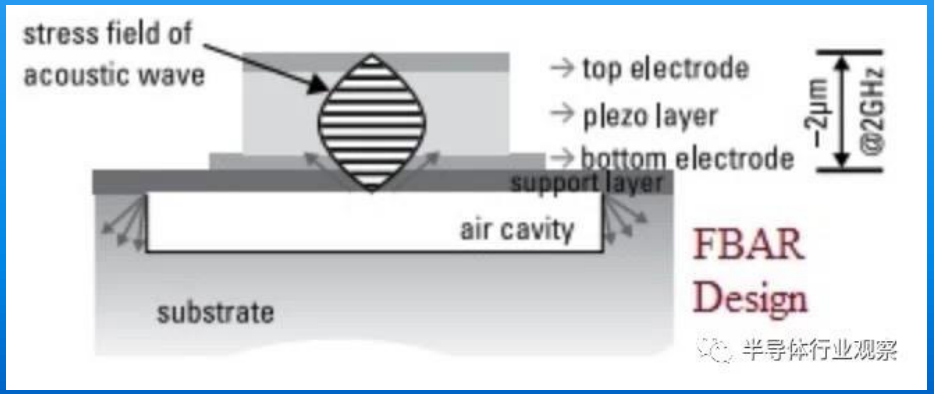
- LiDAR

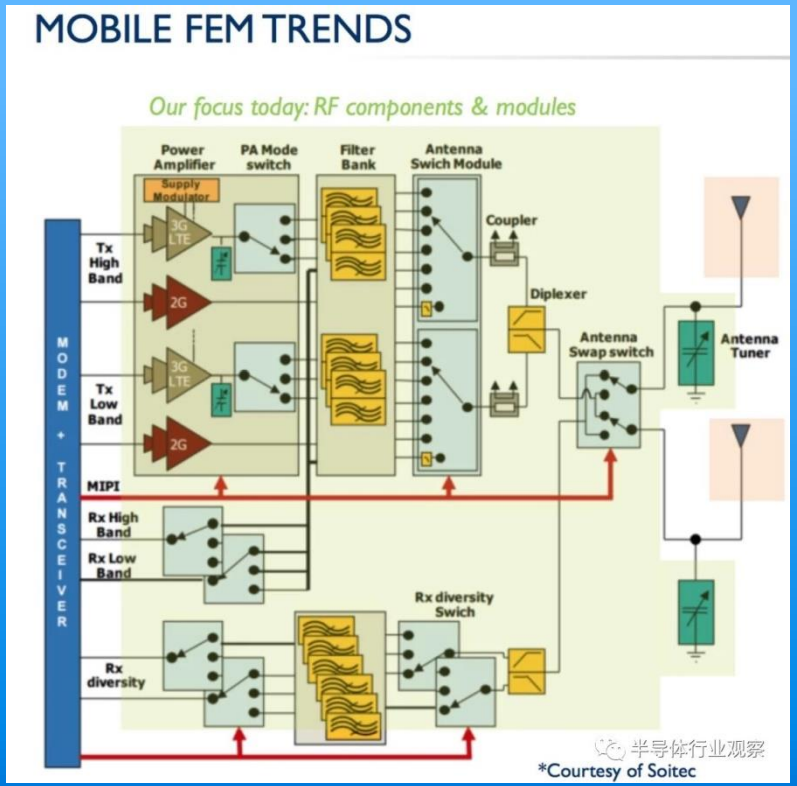


4G/5G RF Chips



- 为了进一步深入，我们拆开了屏蔽罩，探寻内部的芯片：
  - SK海力士（SKhynix）H9HKNNNFBMAU LPDDR4X其下方则为华为（Huawei）麒麟980处理器。
  - 镁光（Micron）JZ064 MTFC128GAOANAM-WT 128 GB闪存。
  - 海思半导体（HiSilicon）HI6405。
  - 海思半导体（HiSilicon）HI6363 GFCV100射频收发器。
  - Skyworks 78191-11 WCDMA/LTE前端模块。
  - Qorvo 77031前端模块





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MCU Market in IoT Applications

- Controller: PCs, SmartPhones
- Basic Framework: Routers and Servos
- Nodes: Video, Traffic Lights, E Appliances

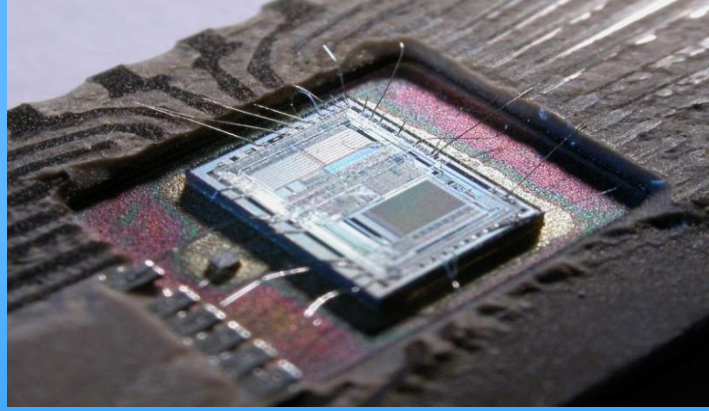
MCU Snapshot - a Platform for IoT

Applications:

Automotive
IoT/Wearables
Appliances
Smart Card
Medical
Industry Control

- 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

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

Top 10 MCU Manufacturers for 2020

- ADI
- Infineon [+Cypress]
- Maxim Integrated
- Microchip
- NXP
- ON Semiconductor
- Panasonic
- Renesas Electronics
- ROHM Semiconductor
- TI

Automotive and IoT

- Some key technology
  - Wireless solutions for the Automotive IoT
  - Automotive Ethernet Application
  - LIDAR
- Reliability

ADAS IC (1/3)

- QCOM/NXP
  - 820A based platform, SNPE engine
- Intel/Mobileye/Altera
  - FPGA + XEON Processor
  - Mobileye EyeQ series are in use by 10+ auto makers
- Renesas
  - R-Car product, ARM Cortex-A57/A53 … Video Codec, GPU, ISP

ADAS IC (2/3)

- Infineon
  - 24/77/79GHz Radar
- TI
  - Jacinto series, TDA series
- NVIDIA
  - Tesla (GPU ← Mobileye)

ADAS IC (3/3)

- ADI
  - Blackfin series
- Fujitsu

- Toshiba
  - Visiconti, Visconti2
- Xilinx

MCU Supplies and TSMC

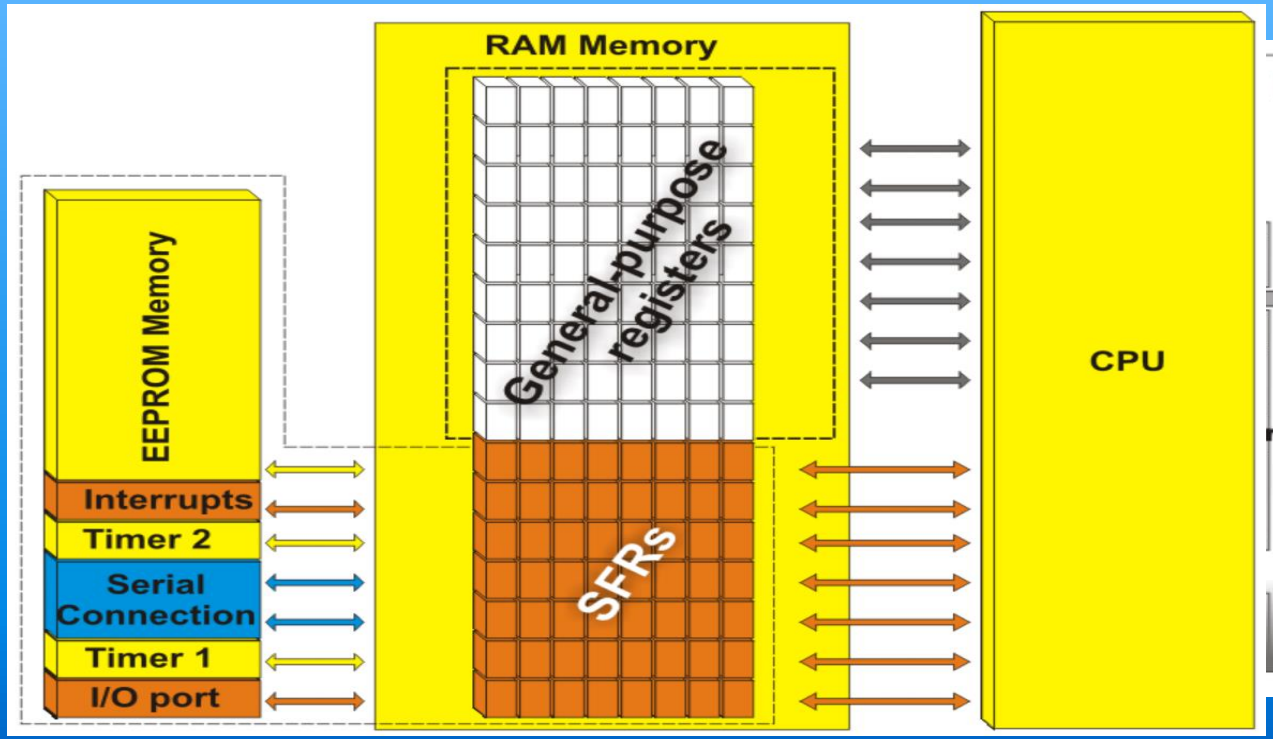
汽车 MCU 供应商及其对台积电依赖程度

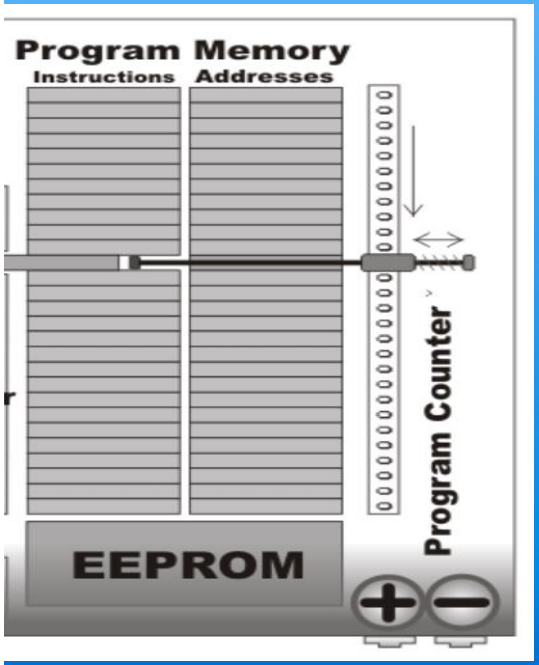
供应商	供应份额	工艺节点				
		16nm	28 nm	40/45 nm	65 nm	110/130 nm
瑞萨电子	30%		MCU——从 2016 年起外包给台积电	MCU——从 2012 年起外包给台积电		MCU——从 2005 年起外包给台积电
恩智浦半导体	26%	MCU——外包给台积电	MCU——从 2016 年起外包给台积电			
英飞凌	14%	MCU——从 2017 年起外包给台积电		MCU——外包给台积电	MCU——32 位 TriCore 在 2013 年外包给台积电	MCU——在 2011 年外包给台积电
赛普拉斯（英飞凌）	9%			MCU——在 2016 年外包给联华电子		
德州仪器	7%			MCU——外包给台积电和联华电子	DSP——自己生产	
微芯科技	7%			多家代工厂	多家代工厂	
意法半导体	5%		大部分内部生产，小部分外包（可能 TSMC）	大部分内部生产，小部分外包（可能 TSMC）		
总计	98%					

资料来源：IHS markit，信达证券研发中心

MCU 8051

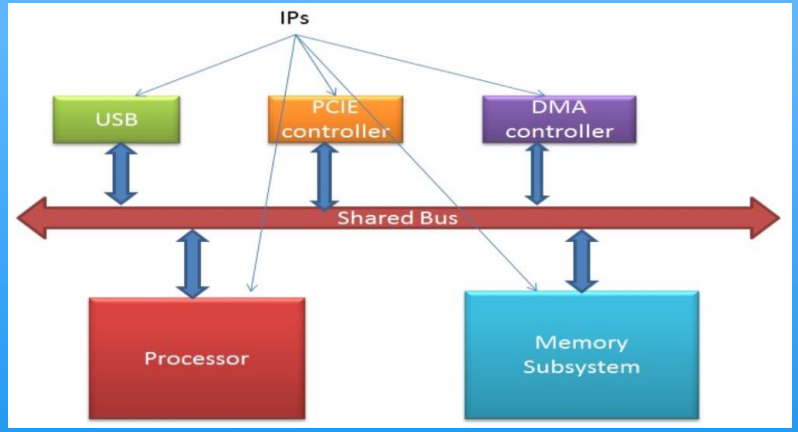
- Architecture and Programming of 8051 Microcontrollers





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



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

MCU Design Houses

General Purpose MCUs* + Secure MCUs Ranking (IHS Markit March 2018)

Rank	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1	**Renesas**	**Renesas**	**Renesas**	**Renesas**	**Renesas**	**Renesas**	**Renesas**	**Renesas**	**NXP**	**NXP**	**Microchip**
2	Panasonic	Panasonic	Panasonic	Samsung	Atmel	Atmel	ST	ST	Renesas	Microchip	ST
3	Microchip	Infineon	Samsung	Atmel	Infineon	Microchip	Microchip	NXP	ST	ST	NXP
4	Toshiba	NEC	Microchip	Microchip	Microchip	ST	NXP	Microchip	Microchip	Renesas	Renesas
5	NEC	Microchip	Atmel	ST	Samsung	Infineon	Atmel	Atmel	Infineon	Infineon	Infineon
6	Freescale	Samsung	Infineon	Infineon	ST	Samsung	Infineon	Infineon	Atmel	TI	TI
7	Atmel	Atmel	NEC	Toshiba	TI	NXP	TI	TI	TI	Cypress	Cypress
8	Infineon	Toshiba	ST	TI	NXP	TI	Samsung	Freescale	Cypress	Samsung	Samsung
9	Samsung	Freescale	Toshiba	Fujitsu	Toshiba	Fujitsu	Freescale	Samsung	Samsung	Silicon Lab	Silicon Lab
10	NXP	ST	Fujitsu	Freescale	Freescale	Freescale	Cypress	Spansion	Huada	Huada	Nuvoton
11	Fujitsu	Fujitsu	Freescale	NXP	Fujitsu	Toshiba	Spansion	Cypress	Silicon Lab	Toshiba	Toshiba
12	ST	NXP	TI	Panasonic	Cypress	Cypress	Toshiba	Huada	Toshiba	Nuvoton	Huada
13	TI	TI	NXP	Cypress	Panasonic	Sharp	Huada	Toshiba	Datang	Datang	Cobham
14	Sharp	Sharp	Cypress	Nuvoton	Sharp	Huada	Silicon Lab	Silicon Lab	[illegible]	[illegible]	[illegible]
15	Cypress	Cypress	Sharp	Sharp	Nuvoton	Melfas	Sharp	Panasonic	Panasonic	Intel	Maxim

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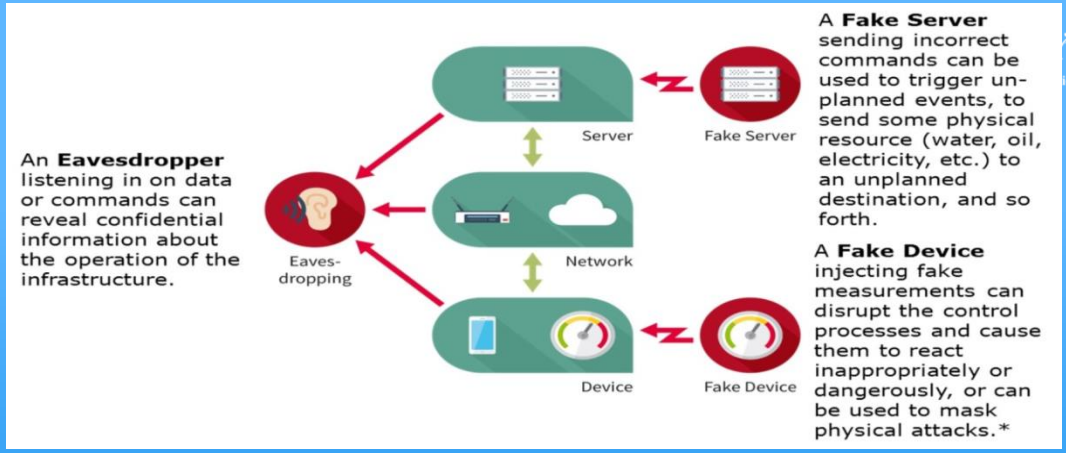
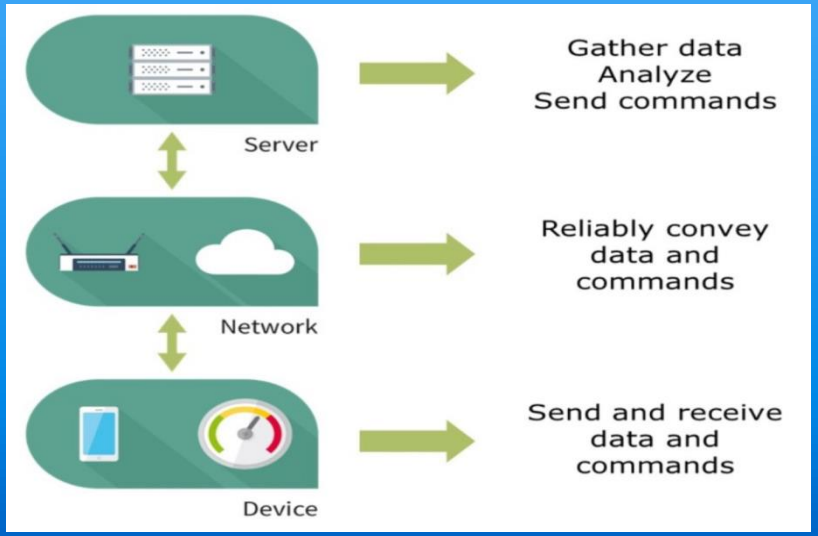
Wearable Market

- 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)

Security in IoT

- Security matters
- Partners of choice
- Security solutions





IoT and Internet Protocol

Technology, Compatibility and Security

- Total number of IP addresses:
  - IPv4, $2^{32}= 4.3x10^{9}$
  - IPv6, $2^{128}= 3.4x10^{38}$
- Privacy and Security
- Comparability of Internet Protocol
  - Ex. SIP, Session Initiation Protocol –
  - controlling voice/video over IPv4 → ? IPv6

OSI (Open Systems International) Model

- OSI Layers
  - *Application Layer*
  - *Presentation Layer*
  - *Session Layer*
  - Transport Layer
  - Network Layer
  - ***Data Link Layer***
  - ***Physical Layer***
- Function of OSI Layer
  - *Network Process*
  - *Data presentation/Encryption*
  - *Interhost Communication*
  - E2E Connections & Reliability
  - Path determination & Logic IP
  - MAC, Physical Addressing
  - Media, Signal… Transmission