



# Market and Packaging Trends in IoT & WE

Prepared for MEPTEC Discussion

Market Intelligence

Feb. 11, 2015

# IoT and WE Devices -- Discussion Outline

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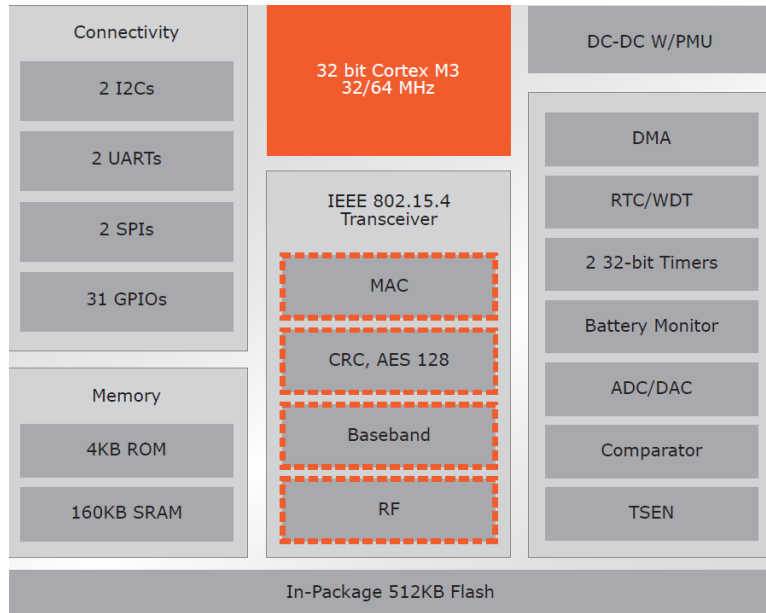
- ▶ Product Examples
- ▶ Definitions
- ▶ Applications and Services Will Dominate IoT Revenues
- ▶ Driving IC Industry Evolution
- ▶ IC Market
- ▶ Packaging Trends and Revenues by Type
- ▶ IC Landscape and Vendor Groups
- ▶ Key Insights for MEPTEC members

# IoT Solutions – WB and WL Packaging -- OEM Development Kits Mandatory

Marvell's 88MZ100 Zigbee SoC for Home is in 48-pin QFN

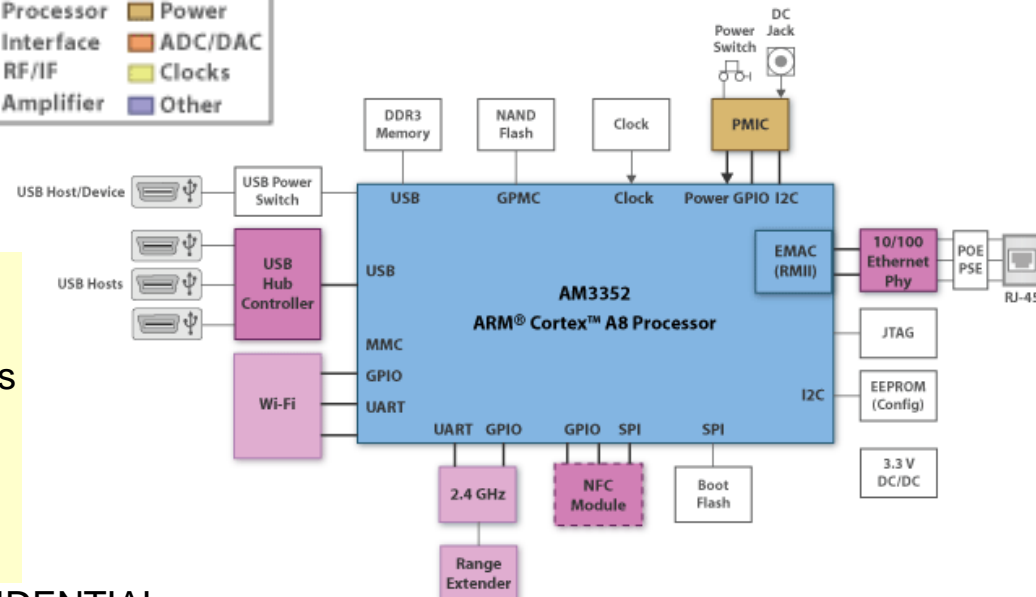
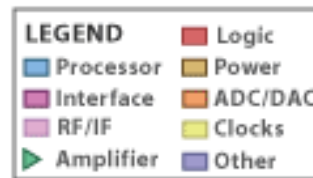
(LED lighting control, smart metering, healthcare monitoring)

- ▶ MRVL offers Wi-Fi, BT and ZigBee MCUs with EZ Connect SW (service discovery, web-services framework and firmware upgrades) – MFi-certified (i.e., Apple)



BRCM WICED Wi-Fi Development Kits

- BRCM provides to OEMs a WICED SW Development Kit to create secure low-power turnkey HW solutions to enable Wi-Fi connectivity - MFi-certified

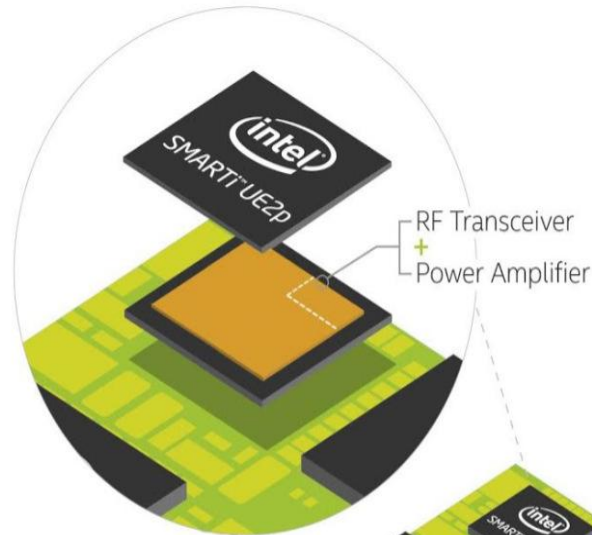
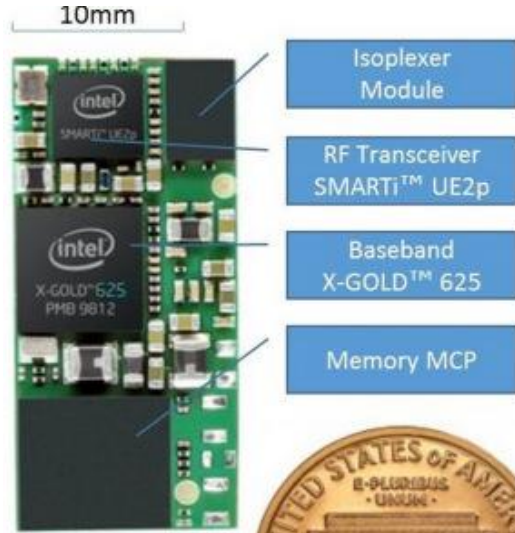


TI's IoT Gateway links Building/Home energy systems

use ZigBee to any Wi-Fi router -- consumers can monitor/control their smart energy devices via SPs or Ts

- ▶ TI uses its Sitara ARM Cortex-A8 processor (45nm WB)
- ▶ IoT gateway enables local management of communications, data processing and applications instead of relying on intelligence in the cloud - MFi-certified

# Intel's XMM 6255 Modem for IoT and Luxury Bracelet WE



Intel® XMM™ 6255  
 SMARTi™ UE2p  
 Transceiver Chip  
 X-GOLD™ 625  
 Baseband Processor Chip



Swiss-based u-blox (<\$100M revenue) developed a **low-cost 3G IoT module** based on Intel's XMM-6255 3G platform

XMM6255 is fabricated on **65nm CMOS** that supports 3G/2G connections – **two FC packages**

- The modem supports a (slow) downlink speed of 7.2 Mbps using single antenna only (reduces complexity, cost and size – RF PA is integrated with XCVR – simplifying the entire FEM)
- XMM's 6255 modem is built for **low signal strength in a network -- it can work in parking garages or a home basement**

Intel has partnered with fashion house Opening Ceremony to create a smart bracelet called the MICA

- Intended for "My Intelligent Communication Accessory"
- The bracelet has **3G** capabilities, and is designed to operate discretely and independently of an SP



# Google Nest Thermostat ~\$32 IC BOM -- Legacy Packaging Dominates

- Programmable and self-learning
- Optimizes heating and cooling (energy saving)
- Motion, temperature, light and humidity sensors
- Wi-Fi- and ZigBee-enabled
- Rechargeable battery

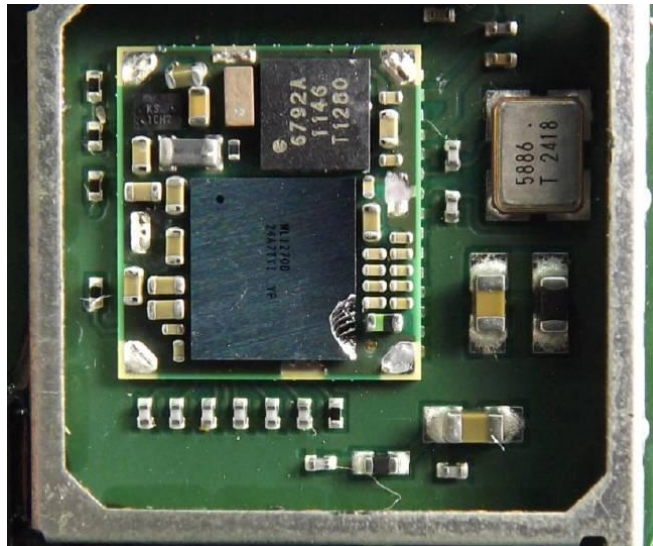
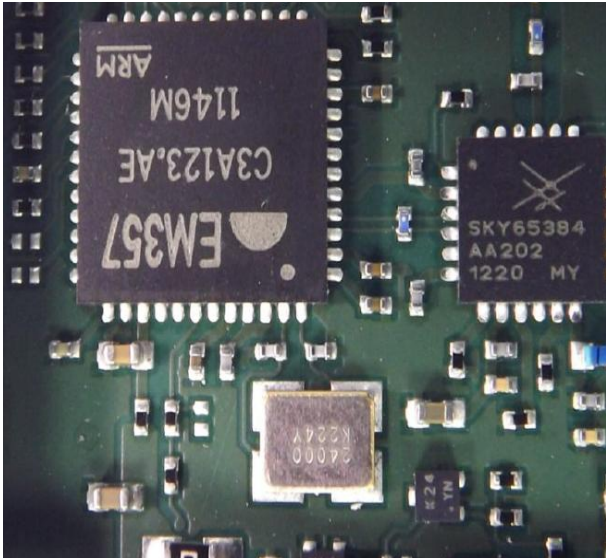
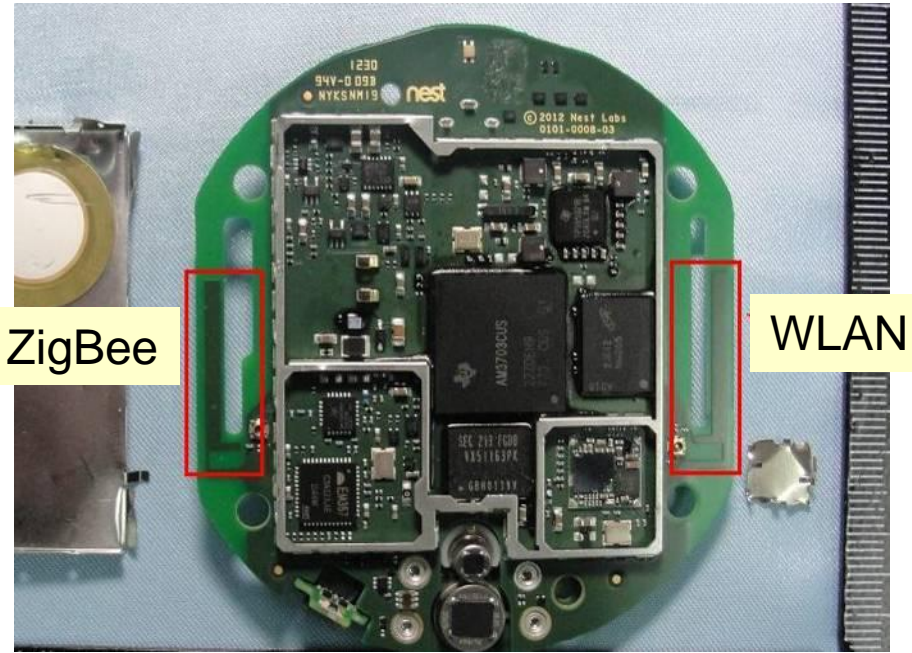
\$249 price ~\$69 BOM components (display ~\$12)

Total IC ~\$32

- TI processor – Sitara (ARM Cortex-A8) ~\$7.5 (WB)
- TI PMIC with USB

Si-Labs ZigBee SoC  
Skyworks ZigBee PA

TI Wi-Fi bgn SoC ~4.7  
TriQuint Wi-Fi FEM



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## MediaTek in IoT and WE – A Major Player in IoT and WE ICs

- ▶ In Sept 2014 MediaTek launched a developer program to jumpstart WE and IoT Devices
    - Aster (MT2502) – a WB (FBGA) 3G processor for WE with silicon-integrated PMU, MCU, BT-LE and memory and with companion Wi-Fi and GPS ICs
    - It is offered with the LinkIt OS designed for WW and IoT devices to connect other devices or to cloud applications
- MediaTek's strategy is to expand on its excellence in providing reference platforms

MediaTek Aster MT2502 SoC	
Size	5.4mm x 6.2mm
Package	143-ball, 0.4mm pitch, TFBGA
CPU	ARM7 EJ-S 260MHz
Memory	4MB RAM integrated
Storage	4MB Flash integrated
PAN	Dual Bluetooth 4.0
WAN	GSMS and GPRS dual SIM modem
Power	PMU and charger functions Low power mode and sensor hub function

- ▶ MTK has also introduced an innovative NFC alternative (Hotknot) -- potentially has many applications, including in WE
    - Hotknot is an internally invented technology – it has lower cost than NFC
    - Hotknot is already offered in its Argo IC
    - It is offered in China “nearly free” in order to build infrastructure to get China's major Internet players -- such as Alibaba and Tencent – to adopt it for mobile payments
- The new technology demonstrates MediaTek's confidence and innovation leadership
- The ambitious strategy could indeed be successful
    - ▶ MediaTek has a 40+ % MS of touch driver ICs sold in China – via its company Goodix
    - ▶ Another Taiwan-based company, FocalTech, owns another 40% MS – negotiations for mutual benefit

# Remote Diagnostic – Patient / Consumer Monitoring

Cellscope  
Imaging



Mobisante  
Ultrasound



Everist Genomics  
Cardio Monitor



Lionsgate  
Oximeter



The migration of medical electronics device use from hospital, office, and lab-based to distributed low-cost personal use

The migration is following the same evolutionary path that the computing and communications markets have taken over the last thirty years

Glucose and blood pressure monitoring is the most frequently used medical monitoring (at present)

Numerous vendors

- Nonin (blood oxygen and pulse)
- iBGStar (glucose)
- Withings (Wi-Fi weight scale)
- iHealth (blood pressure)
- DexCom (glucose - embedded)
- Vitadock (glucose and blood pressure)
- BodyTel (glucose)
- Lionsgate (oximeter, pulse)
- lapka (EMC)



# Definition of Internet of Things

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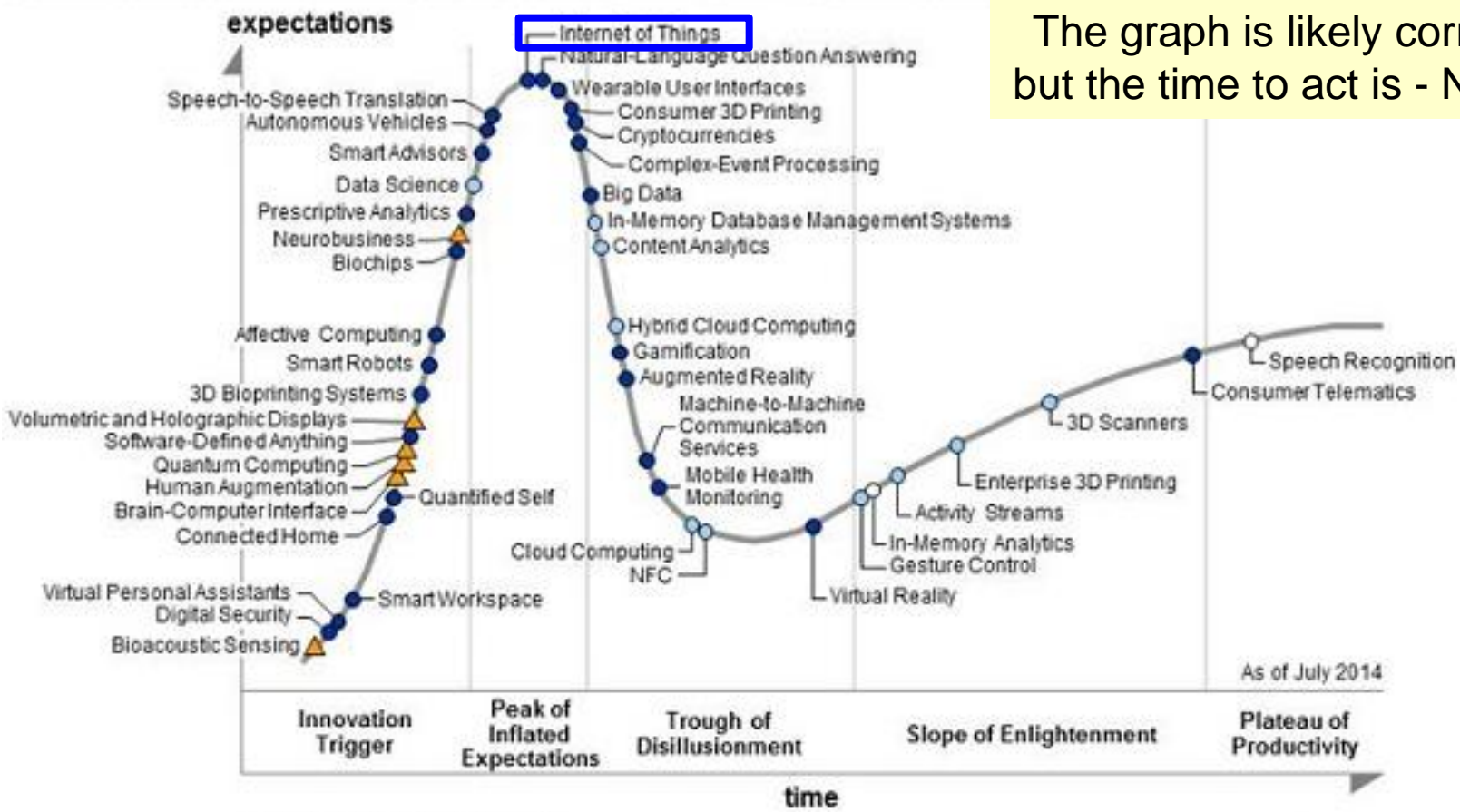
- ▶ IoT is the interconnection of devices through the Internet
  1. Devices can connect to a “host” of other devices
    - ▶ The term "host" is a computer that has full 2-way access to other computers on the Internet
  2. Each device is either providing data from sensors and/or is containing actuators that can control some function
  3. Data can be consolidated and processed in the Cloud
  
- ▶ IoT consists of three categories of devices
  - **Edge devices** – by far the largest category in unit volume
    - ▶ Typically one or more sensors/actuators, a processor and wired or wireless communication
    - ▶ Some (or all) have an IP address and are publicly accessible
      - Unless access is restricted via access / authentication control and security mechanisms
  - **Hubs and access points** – wireless devices likely have limited range and must be consolidated
    - ▶ Competition in such IP gateways is already intense
  - **Large data-centers (Cloud)** – which network, process and analyze data (“Big Data”)
  
- ▶ IoT relies on the infrastructure created for the Internet
  - Mandatory migration from IPv4 ( $2^{32} = \sim 4.3\text{B}$  and already exceeded) to IPv6 which has  $2^{128}$  unique Internet addresses
  - Many government, industry and enterprise applications have specialized requirements (hostile environments, long life cycles, high security and safety requirements)
  - Intranet devices morphing into Internet devices
  - Previously custom / specialized remote devices and networks tied into IP gateways



# IoT -- At the “Peak of Inflated Expectations” – Gartner Nov. 2014

- ▶ IoT first appeared on Gartner’s well known “Hype Cycle” curve in Aug. 2011
  - Peak of Inflated Expectations --- The media generates a lot of publicity at this stage, usually involving a few success stories but mostly reporting on failures
  - Gartner expects that IoT will not reach a productivity plateau until 5 to 10 years from now.

The graph is likely correct but the time to act is - NOW

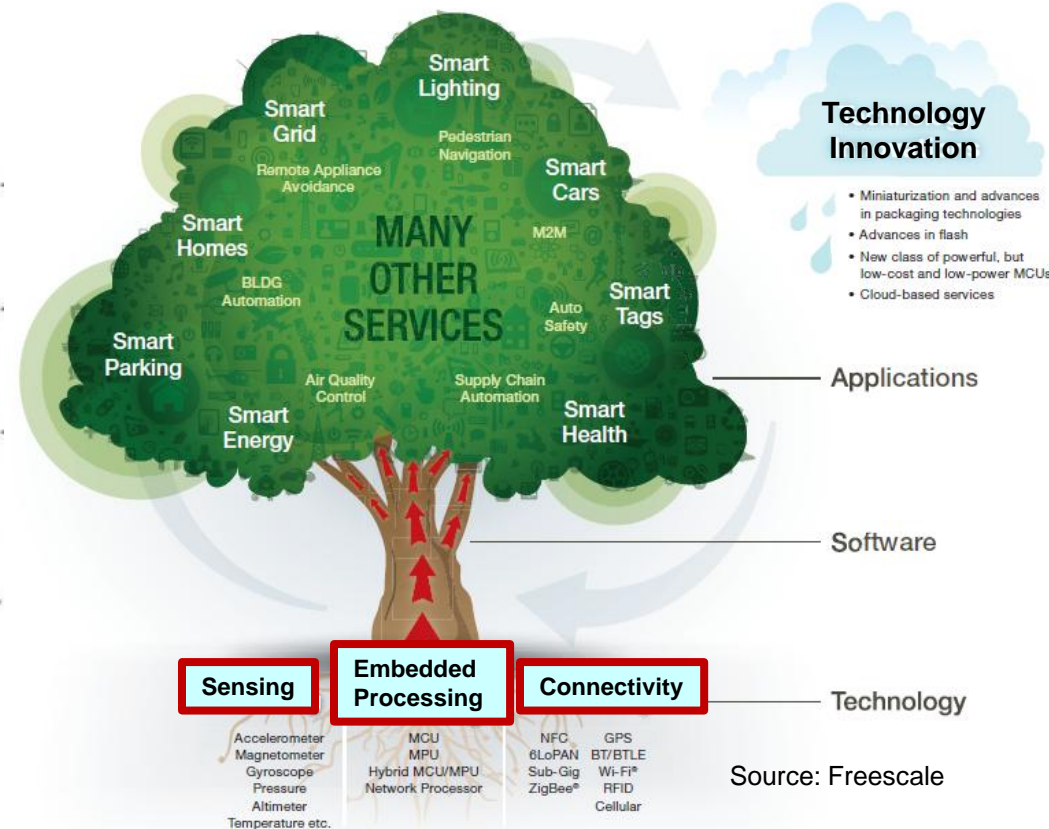


# Applications and Services Will Dominate IoT Revenues

Gartner IoT Forecast [for 2020](#):

- 26B IoT-ready devices
- **\$318B** -- total market
- **\$31B HW** and \$17B Networking

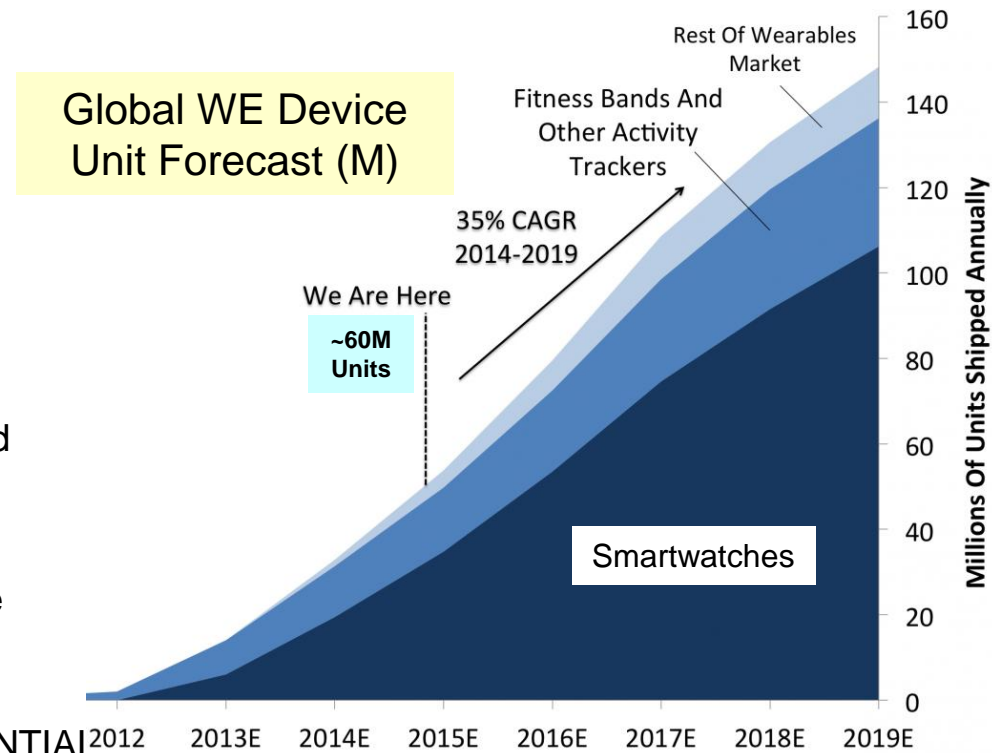
IoT -- Different Services, Technologies, Meanings



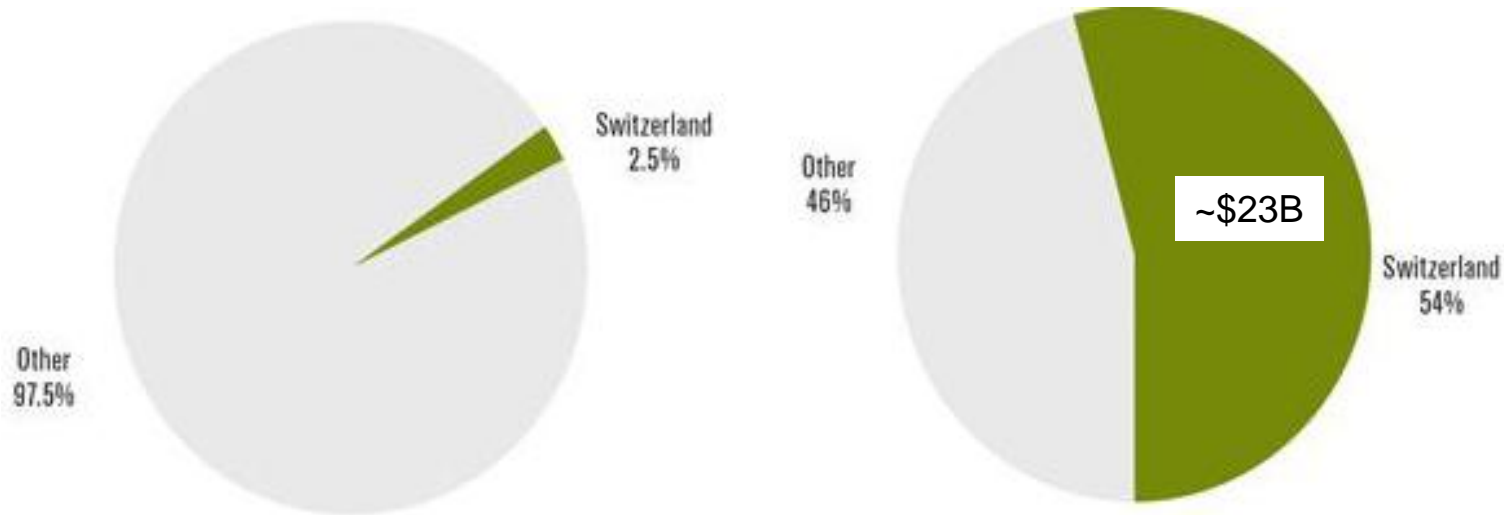
- ▶ MI's IoT model excludes current mobile devices – SPs, Ts, and NBs
- ▶ An unresolved future trend for IoT edge devices is:
  - General purpose (larger volume, higher cost)
  - Highly specialized low cost edge devices – “Specialization is for insects” (R. A. Heinlein)

# IoT – Driving the Evolution of the Semiconductor Industry

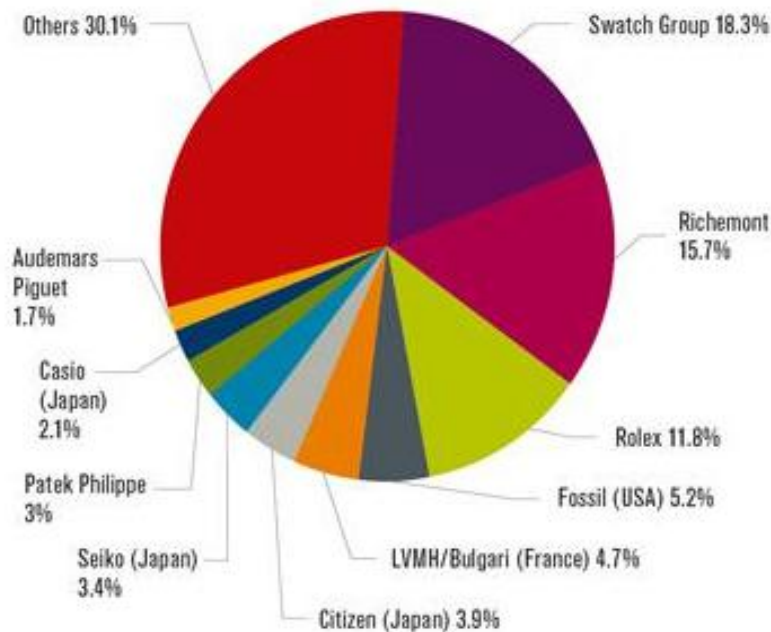
- ▶ For most of us IoT implies small edge devices - with sensors, some processing and an antenna
  - Connecting everything and everyone
  - The nature of edge devices is that they are small and sensor-centric
- ▶ Today there is an estimated 7B people and 1,500B “things” – most of them connectible
  - Eventually many / most of the “things” will be connected
  - In 2015 25B+ devices will likely already be Internet connected
- ▶ At this year’s CES (Consumer Electronics Show in January) IoT has totally dominated
  - IoT will likely be the primary driver in the evolution of the semiconductor (IC + OSD) industry
  - Many of the winners will have familiar names
- ▶ **Wearable Electronics (WE)** is an important special segment of Consumer IoT
  - Driving packaging requirements (miniaturization)
  - Typically BT-connected companion devices to SPs (Smartphones)
  - At present the main WE applications are fitness and health monitoring – none are a must-have – yet
  - Some are still skeptical about WE potential
    - ▶ Don’t be – e.g., Smartwatches will likely eliminate growth of single-function product(s)
    - ▶ At present the momentum is around WE



# Swiss Watch-Making Industry – Source FH, VLGS



## Global Watch Manufacturers by Revenues



Global Position of the Swiss Watch-making Industry  
 2.5% of Units  
 54% of Revenues

~\$700 ASP (Swiss) vs. \$3 (China OEM)  
 ~30M Units (Swiss) vs. 1.2B total watches



# IoT as The New Industry Driver -- Best Power-Cost-Performance-Area

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Primary drivers will be low cost, low power (including storage and harvesting), standards, security

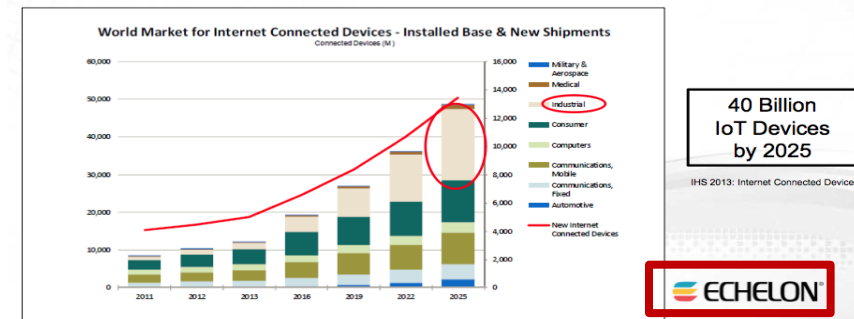
- ▶ In most applications (not all) extreme power-awareness
  - Power monitoring and metering in IC architectures are not limited to battery-operated devices
  - All the way to the Cloud there is a push for low-power architectures (in servers, routers, connectivity), including GaN-on-Si power conversion
- ▶ ~10X cost and power reduction in IoT devices is the necessary prerequisite for success
  - Cost reduction of IoT devices has already been enabled by the growth of mobile devices
    - ▶ Including and especially MEMS sensors
- ▶ Leading network and cloud service providers are supporting IoT -- Cisco, IBM, GE, Amazon
  - Applications (SW) and Services will account for 82% of total IoT revenues – Gartner
  - Big Data analysis of processes, devices and people -- increases efficiency and safety
    - ▶ Aging population, government initiatives, consumers always find money for convenience
- ▶ Communications infrastructures are being impacted by growing security requirements
  - Power grid, avionics, mobile networks, medical telemetry, transportation, other
    - ▶ Securing an entire “smart” building or safety in “smart” cars is a major concern
  - Security is the primary area affected by the migration of edge devices onto a public network
    - ▶ A remote, miniaturized and power-conscious IoT device can offer an ideal gateway for a security attack
    - ▶ Adding highly secure HW and/or SW functionality increases IoT device cost (and if in HW – power use)
- ▶ Take-off of IoT requires standardization, especially for wireless connectivity
  - Only a small number of standards enable synergies between devices -- reducing development cost
  - In wireless connections RF and analog can exceed 75% of total power consumption
    - ▶ On-chip memory (Flash, SRAM) can consume up to 50% of the power and space

## A Caveat on IoT Devices – Act Now - with Caution

- ▶ Echelon was formed in 1986 by Mike Markkula, the first (angel) investor and Apple's ex-CEO
  - “A 25 cent IC inside a networked light bulb....”, etc., etc. vision – of developing devices and platforms
    - ▶ “an IP on everything” – Vint Cerf, Internet pioneer in 1996
  - In 2014 Cisco stated that it wants to “capture our share” of the \$14.4 trillion (T) IoT market....
    - ▶ “50B connected devices with trillions of connections among them....”
- ▶ In its 2013 annual report Echelon states:
  - “Our platform is embedded in more than 100M devices, 35M homes, and 300,000 buildings and powers energy saving applications...”
  - Echelon revenues: \$29M in 3Q12 -- [\\$18M in 3Q13](#) ← after 27 years
- ▶ In 2014 Echelon concluded that the IoT will not be felt as a direct, personal experience
  - “It will be mostly invisible -- components and subsystems in factories, warehouses, fleets of trucks and buses, office buildings....”
- ▶ ~50% of people on Earth live on <\$2.5 a day
  - And ~80% of people live on <\$10 a day
  - 125 sensors/person is an ambitious objective
    - ▶ Driven by urban population explosion
- ▶ Consumers can't function without SPs, Ts, and PCs
  - Once outside the really personal computer domain, the desirability of connected devices drops dramatically
    - ▶ More than 50% of consumers no longer use activity trackers
  - IoT progress will likely be very challenging

### Industrial Internet of Things

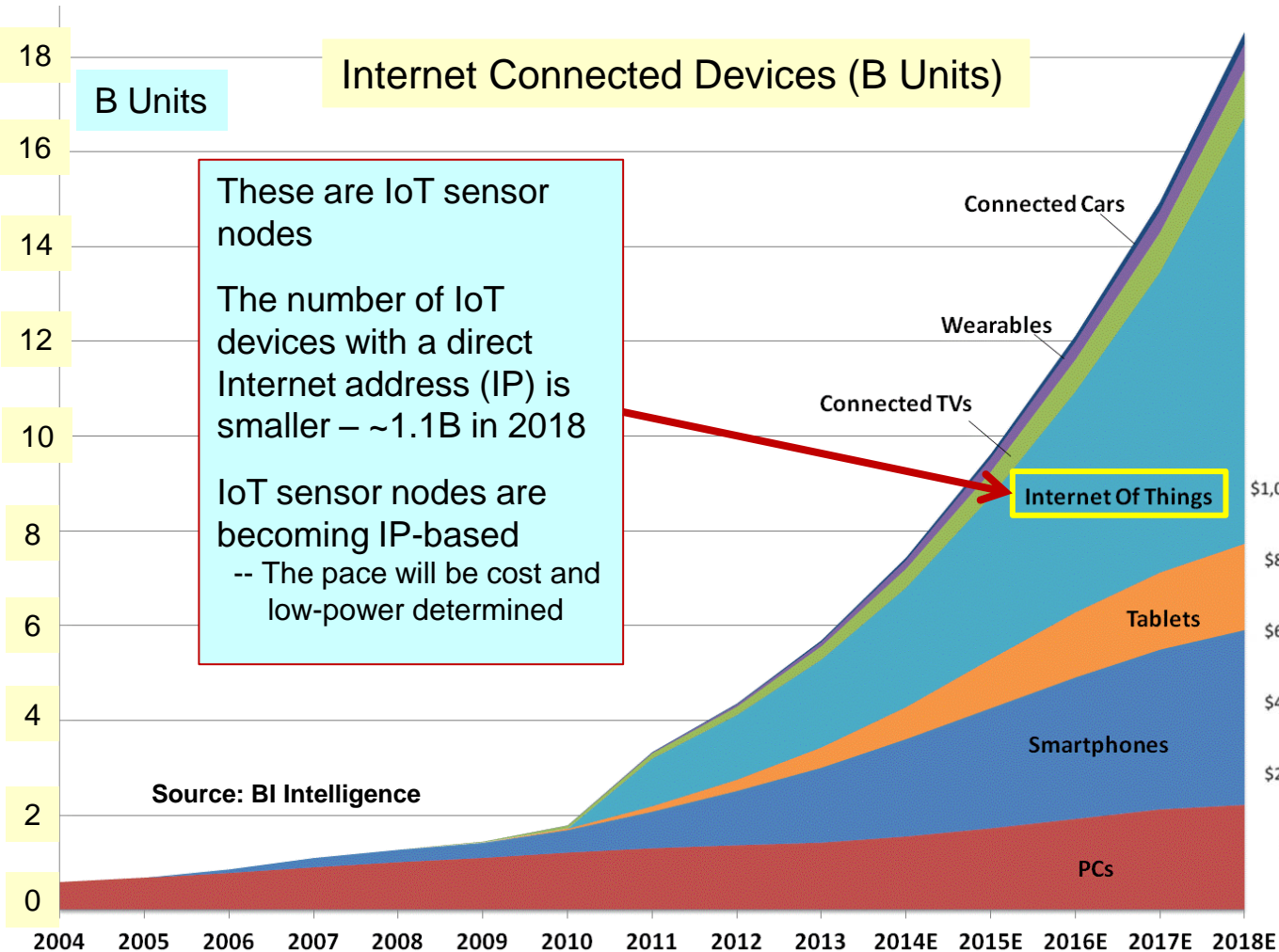
- Internet of Things: A network of physical objects that interact with each other to share information and take action
- There are several sub-segments within IoT, with Industrial applications having the most demanding uses



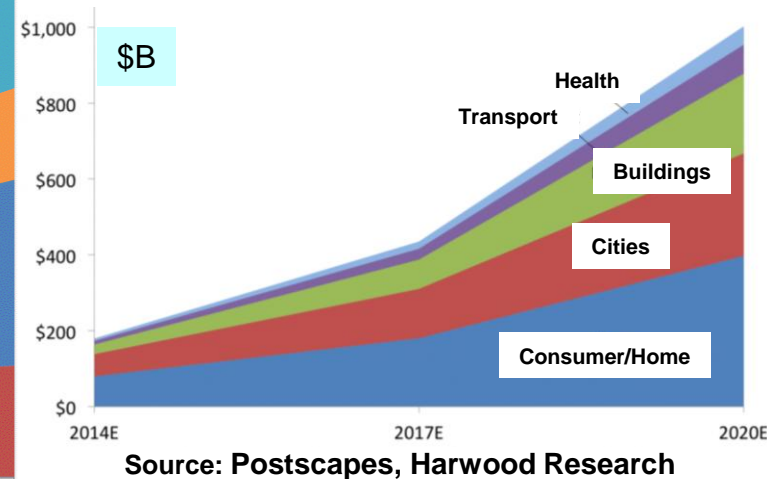
- ▶ In Echelon's case – migration from **Intranet** (private resource) to **Internet** (publicly accessible) of Things

# Internet Connected Devices – IoT Dominates by 2017

- ▶ The number of IoT nodes will exceed the number of mobile devices (SP+T+NB) in 2017
- ▶ By 2020 IoT networks will impact ~6% of the global \$100T economy (source: AT Kearney)
  - The IoT technology/business will likely be quite disruptive – there will be winners and losers
  - GE estimates the “Industrial IoT” has a \$10-15T potential in 20 years; Cisco forecasts \$19T by 2020



By some (overly optimistic) forecasts total IoT revenues will approach \$1T by 2020  
-- Home/Consumer is the largest IoT segment  
-- Industrial (Cities, Buildings, Manufacturing) + Government segments together are larger and faster growing than Consumer + Home



# IoT Market -- An IP Address Not Always Required

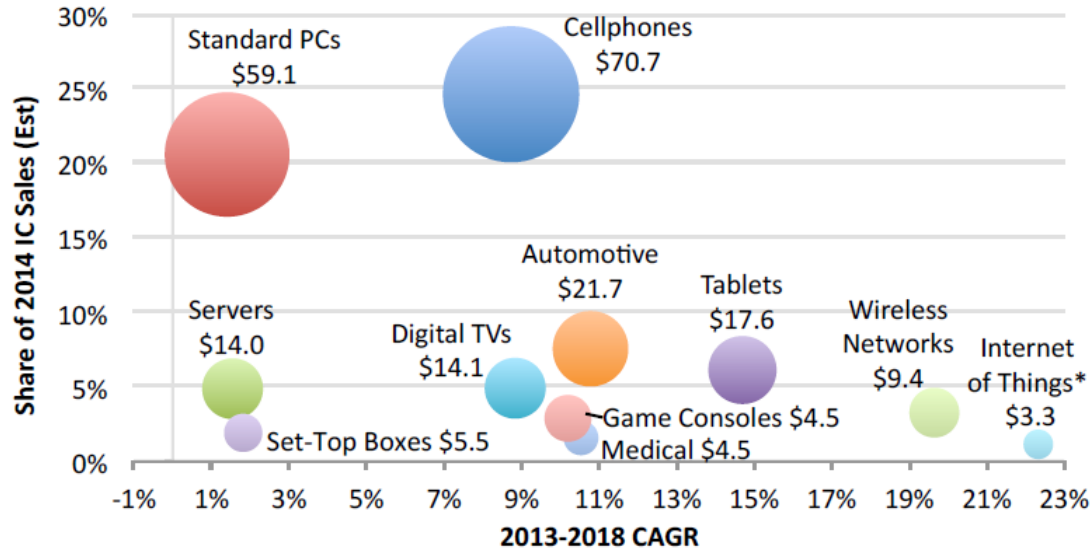
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- ▶ The IoT market is not entirely new
  - We exclude currently existing devices – SPs, Ts, NBs, servers, residential gateways
  - An IoT device doesn't need to have an IP address
    - ▶ By 2018 there will be ~1.1B units sold and by 2020 ~2.1B units sold **with an IP address**
    - ▶ Many will be **IoT gateway** devices – the current focus area of most mobile processor vendors
  
- ▶ One of the leading proponents of cellular IoT devices without an IP address is Qualcomm
  - QTI added its AllJoyn intellectual property (a cellular **peer-to-peer mesh-network** technology) to the AllJoyn IoT Alliance of 50 companies, including MSFT and Cisco
    - ▶ Mesh networks are not a new concept – they have been available in Wi-Fi for a long time (rarely used)
    - ▶ CSR recently announced a BT-based peer-to-peer CSRMesh technology -- in Oct. 2014 QTI acquired CSR
  - QTI's AllJoyn technology could be used with iOS, Android and Windows based IoT devices
  
- ▶ The majority of IoT connections may use unlicensed (“free”) frequency technologies
  - Instead of cellular or Wi-Fi technologies (cost and power/battery life) – estimates as high as 80% (**not likely**)
    - ▶ ARM and Cisco have adopted -- “6LoWPAN” technology (IPv6 over Low power Wireless Personal Area Networks)
    - ▶ Other PAN technologies include various versions of BT, Wi-Fi and ZigBee wireless protocols
  
- ▶ Security is an important requirement in IoT devices, in addition to low cost and power
  - Intel believes it has a major advantage over competitors in the security area (McAfee)
    - ▶ This could be powerful in the potential Wintel ecosystem and as MSFT-Intel strengths in Cloud security



# IC Insights – 2014 IC and End-Systems -- Size and Growth Perspective

## IC End-Use Markets (\$B) and Growth Rates



Among eleven end-applications, IoT is projected to have the highest growth (22%+) – followed by ICs for Wireless Connectivity and Ts

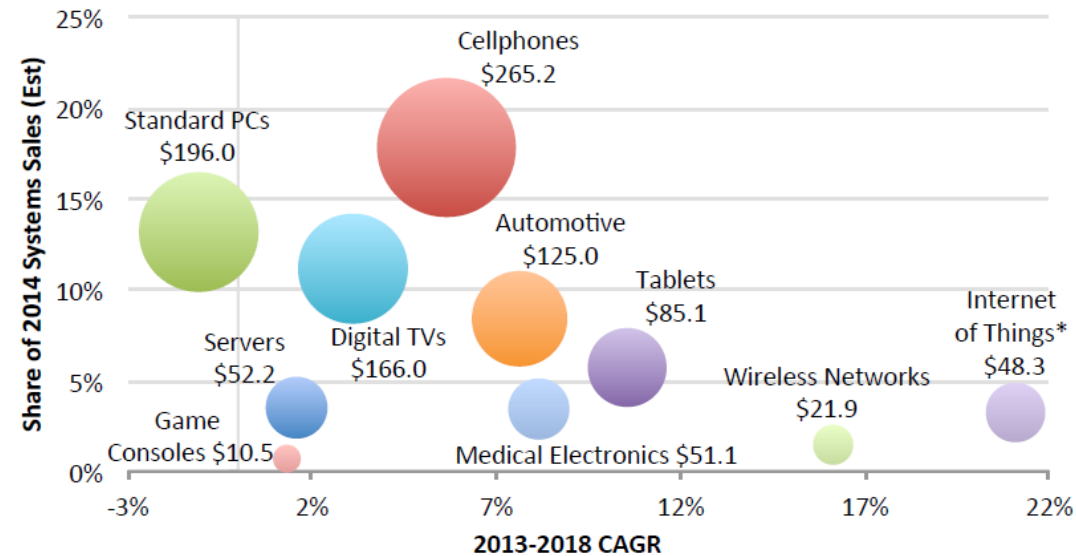
Not visible in the charts is the high unit growth of -- MCUs -- Sensors (MEMS and non-MEMS)

\*Covers only the Internet connection portion of systems

In 2014 SPs accounted for 18% of global electronic systems sales

PCs accounted for 13% -- SPs are now 1.35 times larger than PC system revenue

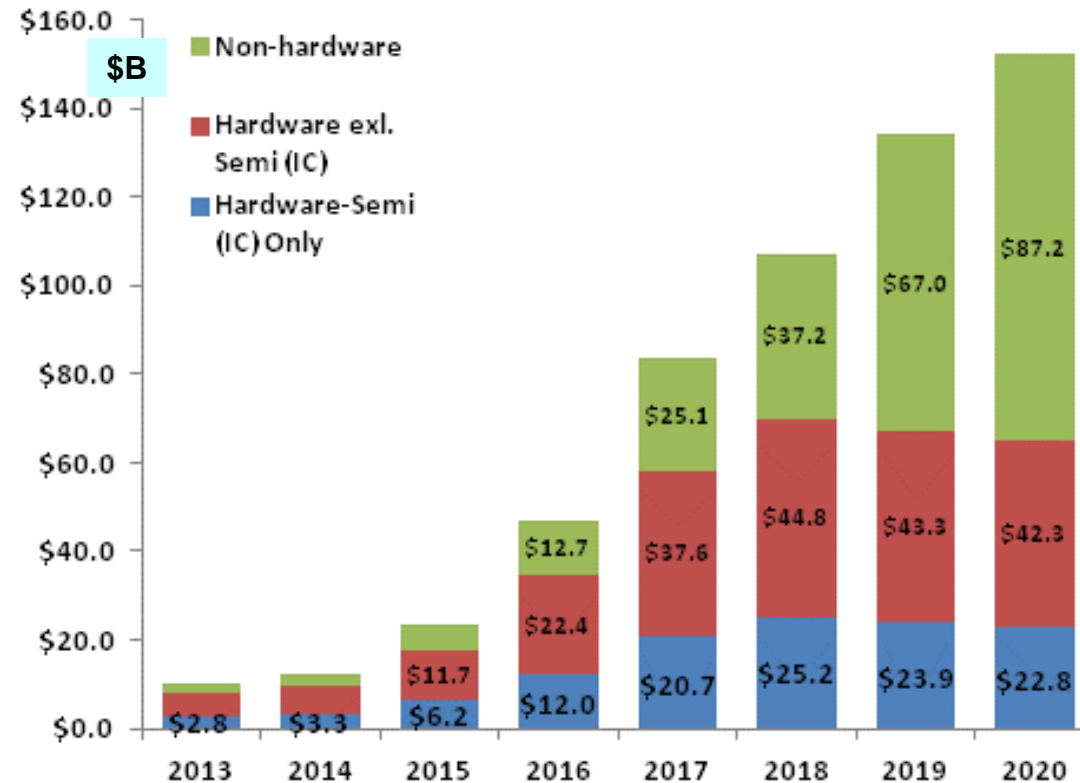
## End-Use Systems Markets (\$B) and Growth Rates



\*Covers only the Internet connection portion of systems

# IoT Revenue TAM Projection -- 2013-2020 (B\$)

- ▶ IoT HW and IC content are **projected to peak in 2018** as the market requires more integration for cost and power reduction
- ▶ Estimates of semiconductor content – mostly IC and MEMS and some discretes (IC for short) -- were made by analyzing tear-downs and BOM analyses
  - The IC content ranges from 34% to 36%
- ▶ IoT revenue is primarily modeled on IHS-Suppli and Yole revenue and unit projections



	2012	2013	2014	2015	2016	2017	2018	2019	2020	14-20 CAGR
HW	7.0	8.2	9.5	17.9	34.4	58.3	70.0	67.2	65.0	38%
Non-HW	1.5	1.8	2.5	5.8	12.7	25.1	37.2	67.0	87.2	80%
HW - IC Only	2.4	2.8	3.3	6.2	12.0	20.7	25.2	23.9	22.8	38%
IoT TAM \$B	8.5	10.0	12.0	23.7	47.2	83.4	107.2	134.2	152.2	53%

# IoT Market Summary – High MCU and MEMS IC Growth

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- ▶ IoT is a high growth IC market (2014-20 revenue CAGR of 38%)
  - IoT IC TAM is projected at ~\$23B in 2020 (from \$3B+ in 2014)
  - Packaging TAM is estimated at ~\$2.5B in 2020 (from ~\$360M in 2014)
  
- ▶ The total IoT market is projected to be much larger by 2020
  - \$318B by Gartner; \$150B+ by IHS-Suppli and Yole
  - IoT SW and Services are projected to account for 60 to 80%+ of total IoT revenues by 2020
    - ▶ Both HW and semiconductor IoT revenue growth is projected to slow down beyond 2018 (functional integration)
  
- ▶ Two types of IC will be the primary drivers of IoT semiconductor growth
  1. Specialized low-power MCUs (embedded processors)
  2. Sensors and actuators (MEMS and Image sensors)
    - ▶ Packaging outsourcing of MCUs and MEMS has been limited in the past
    - ▶ It is expected that the outsourcing trend will increase in the IoT market (new entrants and new packaging approaches)
  
- ▶ IoT will increasingly require highly integrated SoC and SiP/module packaging
  - WB will likely continue to dominate
  - Also -- FO and FI WLP and FC in SiP or SoC solutions – increasingly with passives
  - Trend -- Connectivity, PMIC, memory, other functions to be integrated into SoC or SiP/module

## IoT Market Summary – 25B+ Units by 2020

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- ▶ The MCU market in 2014 is \$20B in revenue and 19B in units (\$1.07 IC ASP)
  - MCU OSAT TAM is < \$0.9B in 2014
- ▶ The 32-bit MCU segment in 2014 is \$11.6B revenue and ~3.5B units
  - IoT units are projected **to be ~25B+ units in 2020**
    - ▶ Most IoT units will use a new class of 32-bit embedded processors (primarily MCUs)
    - ▶ IoT MCUs will grow at least 2X faster than overall 32-bit MCUs
  - The competition between **ARM and Intel architectures will extend into the IoT** market
- ▶ 2015 vendors of IoT embedded processors are well known:
  - **MCU**: FSL, STM, TI, NXP, Renesas – but also Microchip, Si-Labs, Atmel
  - **Mobile / Network processors**: QTI, Intel, MediaTek, MRVL, BRCM, Huawei, Samsung
- ▶ The IoT market consists of numerous vertical segments that require specific solutions, have different OEMs, and will grow at different rates over the next decade
  - Accelerated growth segments in the next 2-3 years will include
    - ▶ **Home automation** – Roku, Sonos, Kwickset, NetGear, Control4, Savant, Nest, Belkin, QTI-AllJoyn, DropCam, Lutron, Revolv
    - ▶ **Connected car / fleet tracking** – Apple, Nokia, Nuance, MSFT, Google, Garmin / Digi, Trimble, Sierra, Gemalto, Telit
    - ▶ **WE devices** – Apple, Intel, MSFT, Xiaomi, Samsung, Philips, Verizon, QTI, Garmin, LG, Huawei
    - ▶ **Smart-City segments** -- waste water, public waste bins, traffic, parking lot, energy infrastructure, security



# IoT Market Summary – Intense Ecosystem Competition

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- ▶ IoT will continue product disruption in Consumer and Industrial sectors
  - By 2020 IoT networks will impact ~6% of the global 100T+ economy
  
- ▶ Ecosystem competition
  1. Intel IA (x86) versus ARM [processor architecture](#)
    - ▶ Apple, Google, Samsung, MSFT, Xiaomi, Sony, other ecosystems
  2. IoT [Interconnect networking standards](#)
    - In June 2014 Intel formed the Open Interconnect IoT Consortium – competing with QTI's AllJoyn Alliance
      - ▶ Joined by BRCM, Atmel, Dell, Samsung (soon MSFT likely)
      - ▶ Google, Apple (AirPlay), others may create their own IoT standards
  3. [SP control of Home Automation](#) (Health and other Consumer)
    - ▶ At present Android (Google) versus iOS
    - ▶ Within Android – Google versus Samsung (Samsung Home) versus China OEM ecosystems
  4. Intel's x86 architecture must establish a viable position in Consumer and Industrial IoT markets
    - ▶ 25B IoT processors span: [IoT/WE across SP/other to Cloud/Server/Telecom markets](#)
    - ▶ Anticipate Intel in China and Intel-MSFT actions

# IoT Market Summary – Rise of SiP Modules

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- ▶ Most of the IoT devices analyzed use standard even legacy products in WB packaging
  - In cellular IoT devices a notable trend is the use of CMOS PA technology
    - ▶ This allows PA integration with PMIC and, in the case of Intel, with XCVR
  - Use of QFN dominates – low cost and thin
    - ▶ No POP or stacked die (except memory)
  - Use of SiP packaging (including TSV) – to integrate sensor, logic and memory into a single package
  
- ▶ In 2015 and beyond new IoT packaging approaches are expected to be launched in order to lower system cost
  - Designs of ultra low-power SoC and SiP solutions will likely be application-focused rather than processor-focused
    - ▶ MCUs, including specialized IoT MCUs, are less compute-demanding than SP processors
  
- ▶ IoT and WE markets increasingly require modules
  - FO and FI WLP and FC SiP modules
  - MEMS and Non-MEMS SiP modules, including silicon photonics

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# Appendix

# IoT Update Highlights – Source: Business Intelligence (Dec 2014)

