Wireless Connectivity Market

Prepared for MEPTEC Discussion

Market Intelligence
February 2014

Discussion Outline

- Two Types of Wireless Connectivity
- Wireless Connectivity Overview
  - $4.7B IC Revenue - with PC and access points (same packaging) $6.3B – in 2012
- Major Change in Wireless Combo Landscape – Combos peaking in 2014
  - Processor-integration of Combo – only a small IC remains (“Combo XCVR”)
- Wireless Connectivity OSAT market – 2012 – 2017
  - 2013-17 --- unit CAGR 9% -- OSAT revenue CAGR 2% ~$0.7B
- Processor-integrated Combos – Significant IC BOM reduction
- Wireless Connectivity – Units and OSAT Revenue by Type and Package (2010-2018)
- Internet of Things – Forecast Scenarios
  - IoT Connectivity OSAT SAM -- $100M by 2018
  - BT versus Wi-Fi in IoT and WE

Two Types of Mobile Connectivity

- Mobile Connectivity is wireless "plumbing" that connects mobile devices to the cloud

1. Cellular connectivity – a vast and growing IC market – the core of every phone
   - FP BBs
   - SP – SA BB and IP (BB+AP)

2. (Other) Wireless connectivity - ~1B Wi-Fi ICs shipped in 2012
   - Wi-Fi
   - BT
   - GPS
   - FM
   - NFC

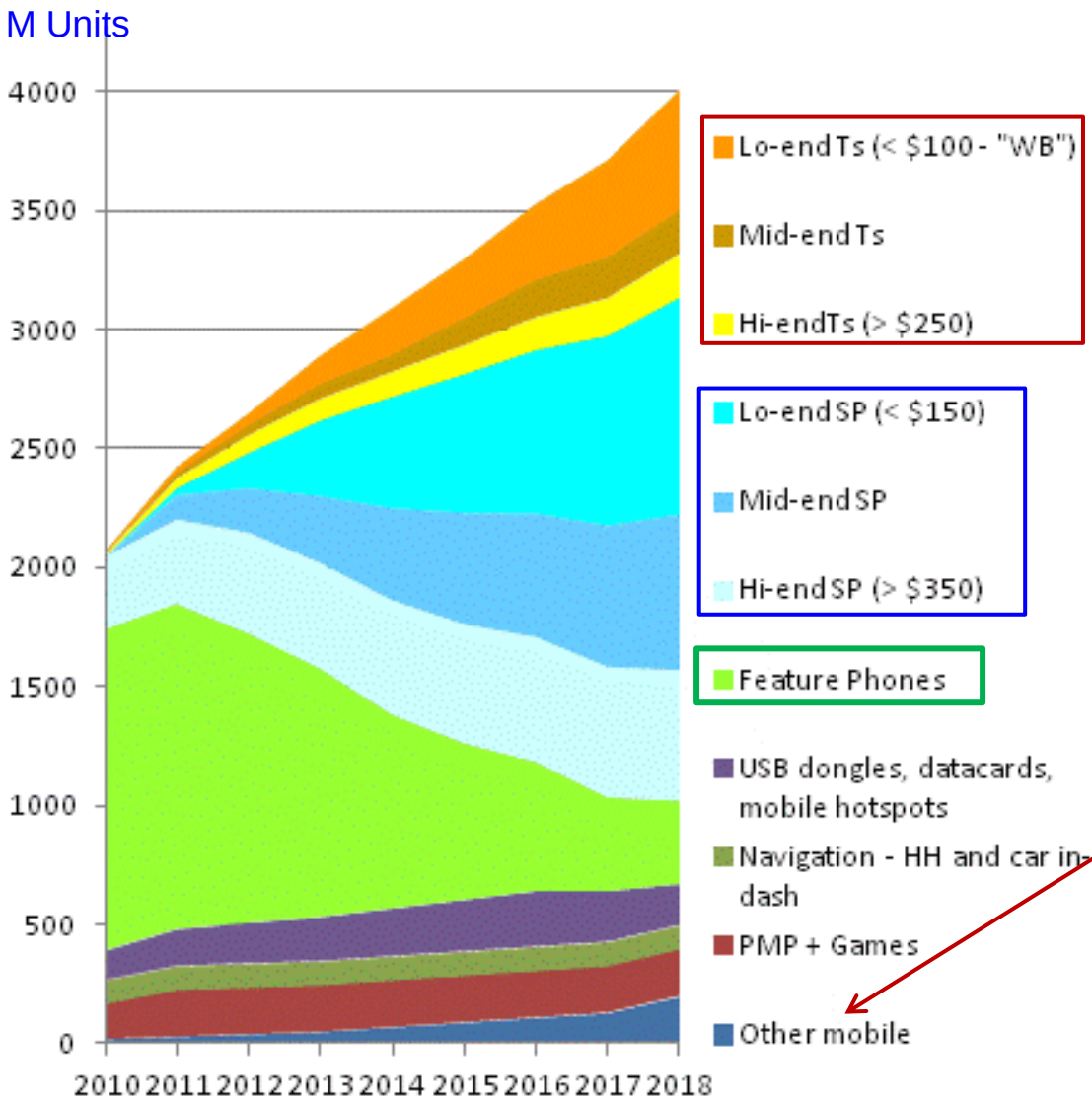
   These functions can be discrete (SA IC) or combined (Combo IC)

- Wi-Fi connectivity for access points and PCs (NB and DT) is not included in the Mobile category
  - Different products (e.g., number of antennas) and technology
- From a packaging point of view they are the same segment – except for large pitch (pitch conversion) – hence access point and PC connectivity are included in our analysis / discussion

Overview of Mobile Device Categories – Unit Projections

Mobile Devices -- 2.9B units in 2013 (6% 13-17 CAGR)

~0.5B of total are other than SP and T



	2013	2014	2015	2016	2017	2018
Other mobile (including IoT)	50	70	90	110	130	200
PMP + Games	200	200	200	200	200	200
Navigation - HH and car in-dash	100	100	100	100	100	100
USB dongles, datacards, mobile hotspots	182	198	214	230	210	170
Feature Phones	1046	814	659	544	394	350
Hi-end SP (> $350)	440	480	500	525	550	550
Mid-end SP	280	385	465	516	590	650
Lo-end SP (< $150)	320	470	585	690	800	916
Hi-end Ts (> $250)	90	104	120	137	158	182
Mid-end Ts	64	72	115	159	173	183
Lo-end Ts (< $100 - "WB")	120	199	250	320	410	510
Total	**2892**	**3092**	**3298**	**3531**	**3715**	**4011**

Source: Gartner, Linley, MI

The "Other" category may grow faster than projected below

– "Node" connectivity will likely be SiP-packaged (MCU, MEMS, RF ← BT mostly)

– Internet traffic will likely be very low

- A joke although it is close – "All smart meters in the US generate less Internet traffic than five teenagers"

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Mobile Device Categories -- with PCs and Access Points Added

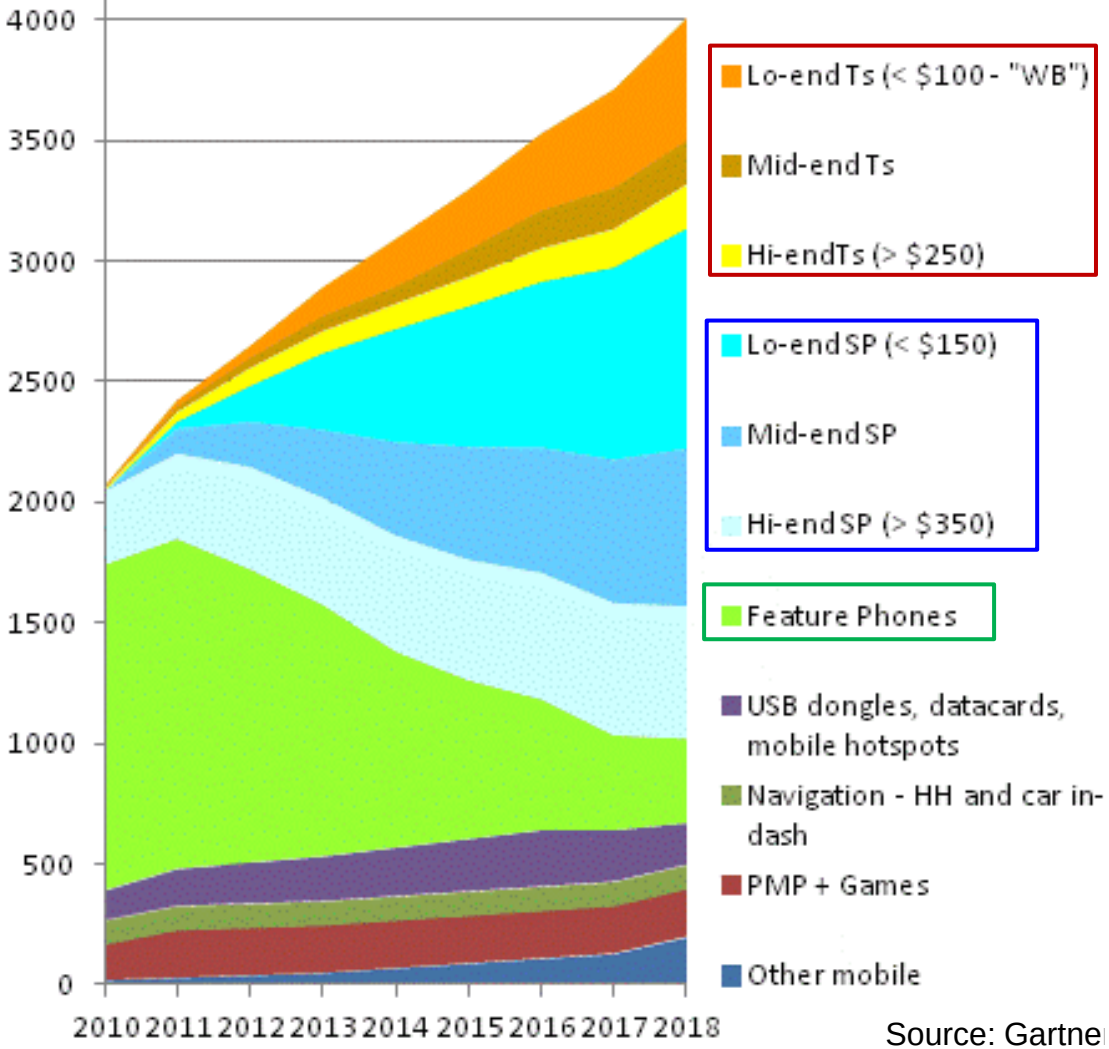
More expensive ICs – OSAT ASPs similar to Mobile

Mobile Devices

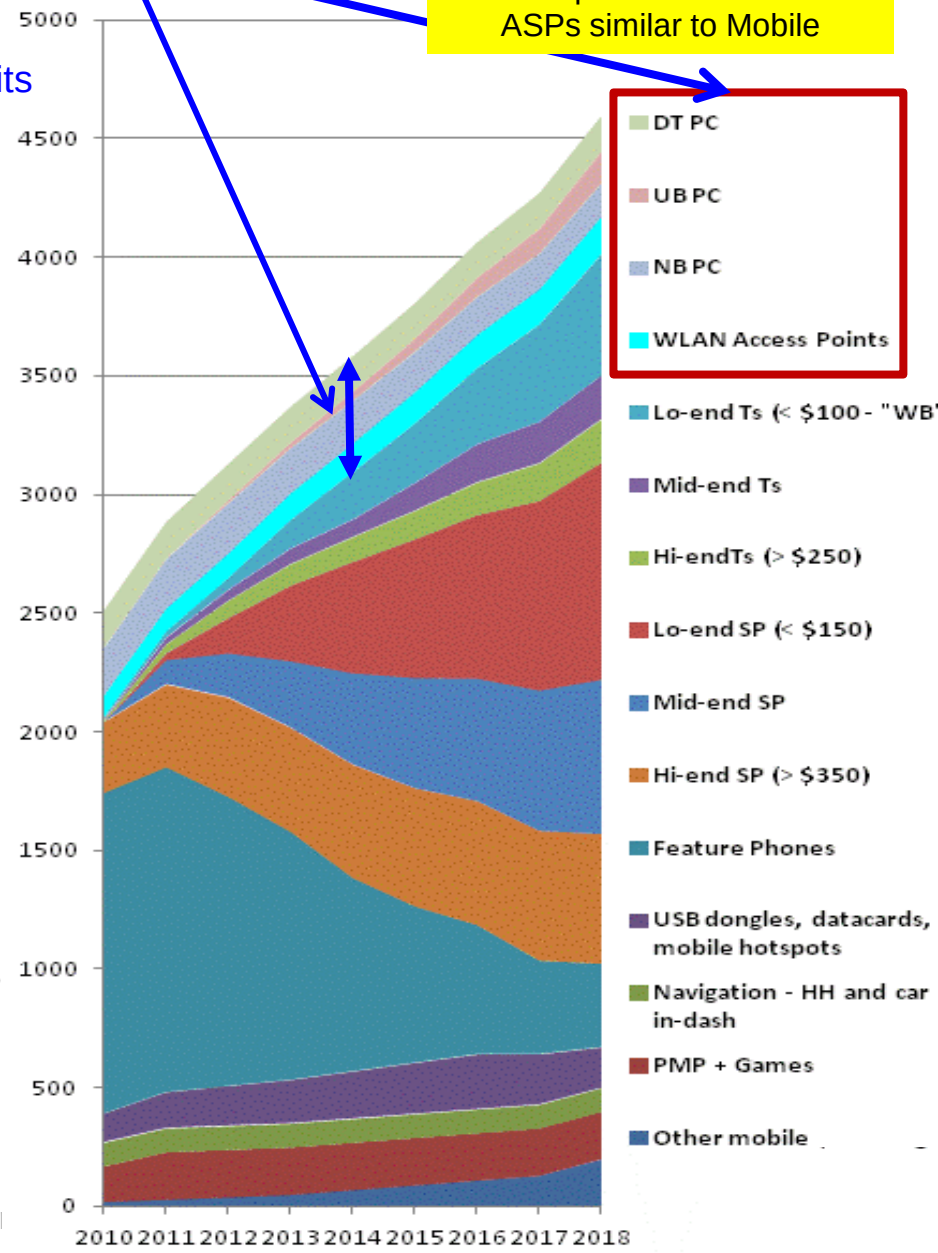
2.9B units in 2013

0.5B other than SP and T in 2013

M Units



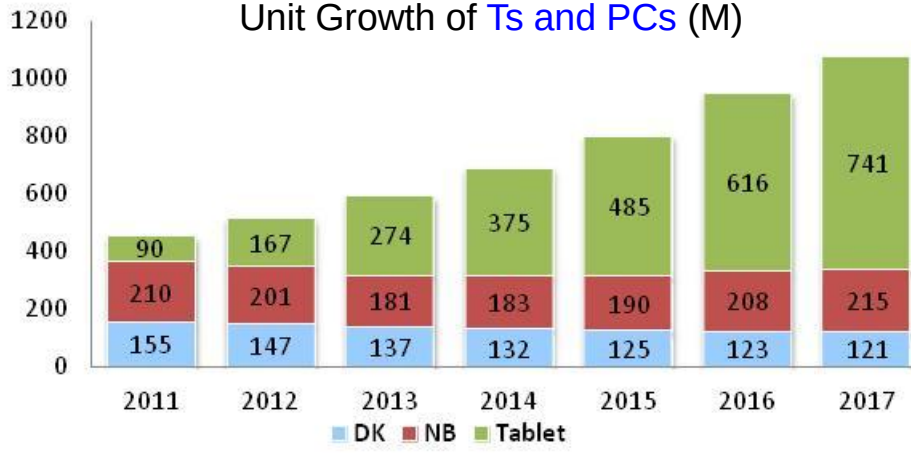
M Units



Source: Gartner

Rapid Tablet Adoption to Continue – 13-17 CAGR 28%

- Tablet adoption is expanding beyond Consumer into enterprise and education segments
  - In emerging markets T is often the user's first computing device – continues to affect PC purchases
- The forecast (shown below) is more aggressive than many other forecasts
  - Main reason for conservative forecasts is due to their persistent underestimates of white-box T market
  - White-box Ts are approaching First Tier quality at a reasonable price



Source: IDC, Gartner, Barclays & MI Estimates, Jan 2014

Phablets are emerging as an alternative to SP and T

– Cannibalization has so far been limited (mostly in Mid-end Ts)

-- SPs and Ts are becoming screens for Internet / Cloud access

Differences between PCs and Ts are driven by their main intended use (generation versus consumption)

– Differences continue to blur – Google's Chromebook is a netbook, 2-in-1 PCs, two processor "PC," other

Definition used:

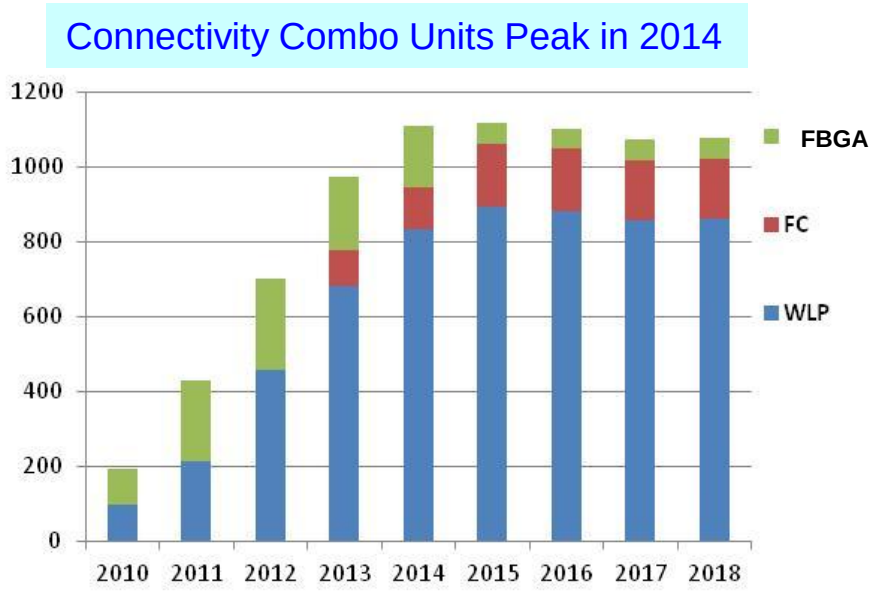
-- PCs -- keyboard in NB PCs is not detachable

-- Ts – keyboard, including dock, can be added (at present text input mostly)

Two Landscape Changes in Wireless Combos

1. Connectivity Combo units anticipated to peak in 2014 – 2014-18 CAGR = <1%>
   - This is a truly major industry change – due to integration of Combos into IP-processors trend
     - In 2011 / 2012 most analyses still projected Combo unit 2012-16 CAGR at 18%
   - The change will impact Combo vendors

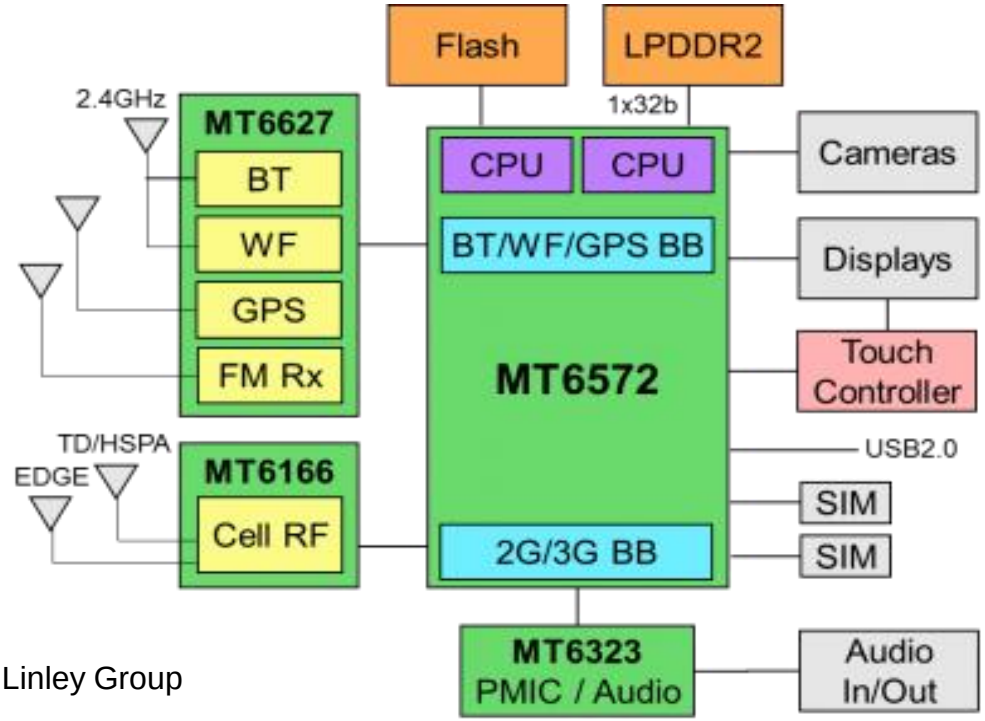
2. Connectivity Combo migrated from 65nm to the 40nm node
   - WLP continues to dominate
   - Because of die size reduction the FC package has largely replaced FBGA for pitch conversion
   - Pitch conversion for low-cost PCB boards (largely for Emerging Markets) accounts for about 20% of Combo units



Source: Composite

Linley Group – "Best Mobile Processor" in 2013

- In January 2014 the prestigious Linley Group awarded "Best MP in 2013" to MediaTek
  - Choosing MediaTek's MT6572 2-core 28nm IP targeting $80 and below SPs
  - HV production in May 2013 "this chip stands well above its competitors - bringing innovation and value to the rapidly growing market for low-cost smartphones"
  - "This processor was the first low-end chip to integrate a full set of smartphone connectivity functions: Wi-Fi, Bluetooth, GPS, and FM radio"
    - This level of integration reduces several dollars off the total system cost—a huge savings in an $80 SP
    - Qualcomm and Spreadtrum released low-cost processors with a similar level of integration



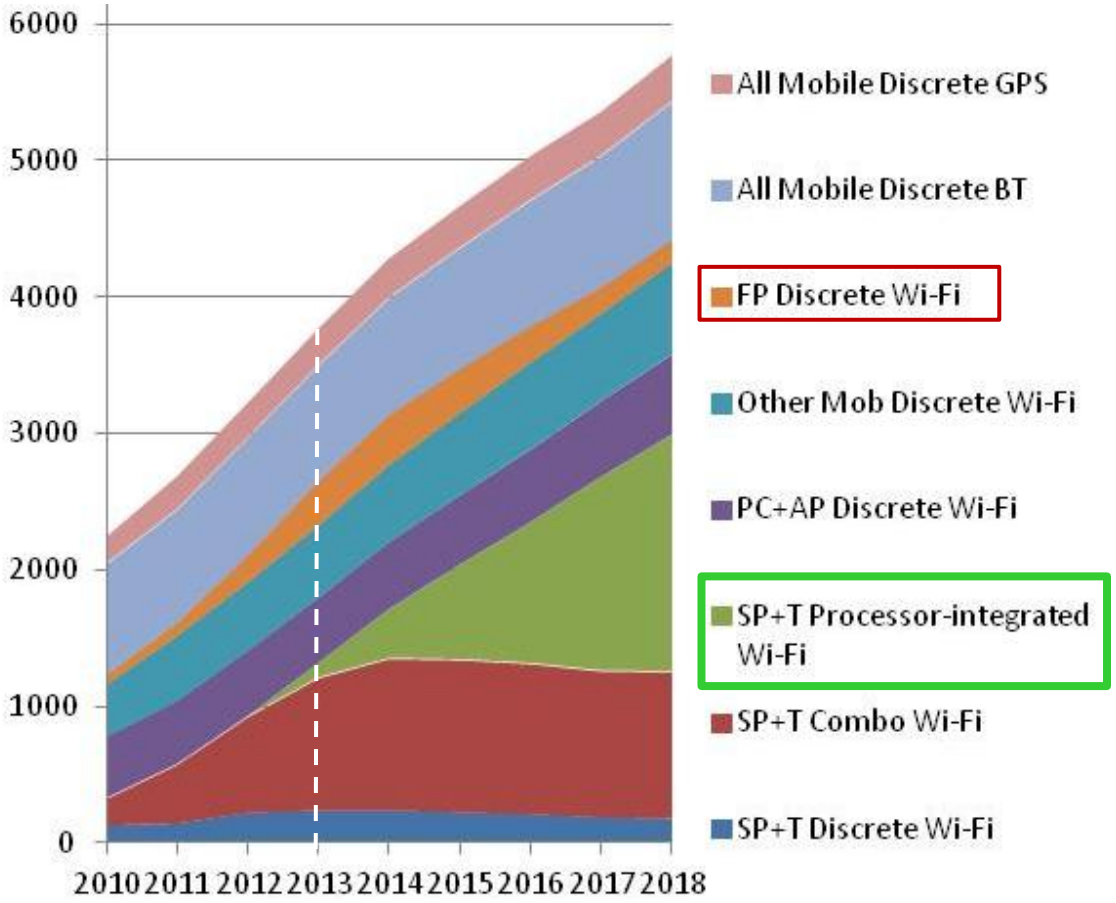
Source: Linley Group

Connectivity Combos – Units are Peaking in 2014

Combos:

-- 2014-2018 unit CAGR <1%>

-- OSAT revenue <4%>



Primary source: Linley Group

Connectivity Combos dominance is ending

-- Processor integration benefits are

- Nodal scalability
- Power and silicon (cost) reduction
- Reduction of components
- For IC vendors – platform control

-- Combo composition is changing also

- from WF+BT+FM functional combination
- to WF+BT+FM+ NFC and/or WF+BT+FM+GPS

-- Use of discrete WLAN is very low in SPs and Ts

- The primary use of discrete WLAN is in PCs and access points

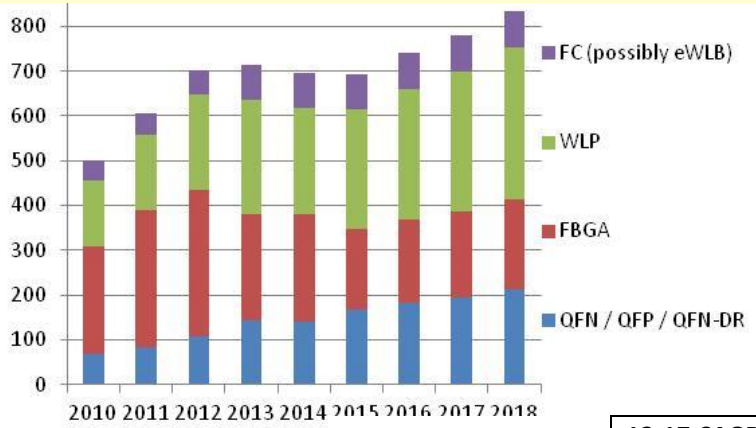
Connectivity -- Units and OSAT Rev by Package and Type

Wireless Connectivity Units by Package (M)

	13-17 CAGR
QFN / QFP / QFN-DR	13%
FBGA	-2%
WLP	11%
FC (future eWLB likely)	7%
Total Units	9%

	13-17 CAGR
Combo Wi-Fi	2%
MP-integr Wi-Fi	92%
Discrete Wi-Fi	0%
Discrete BT	3%
Discrete/Combo GPS	5%
Total Units	9%

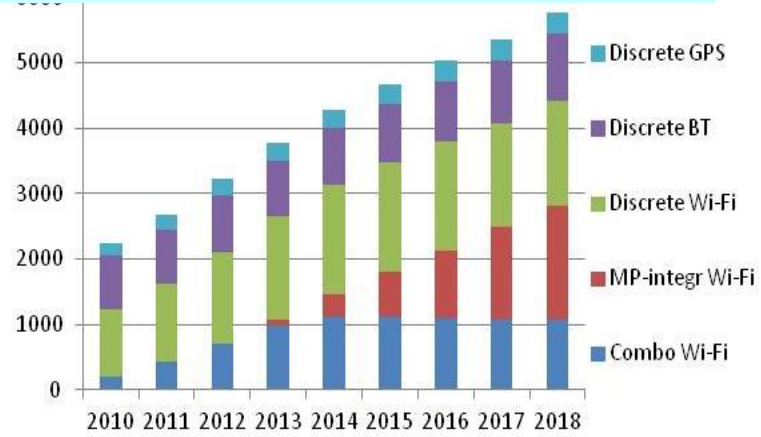
Wireless Connectivity OSAT Rev by Package ($M)



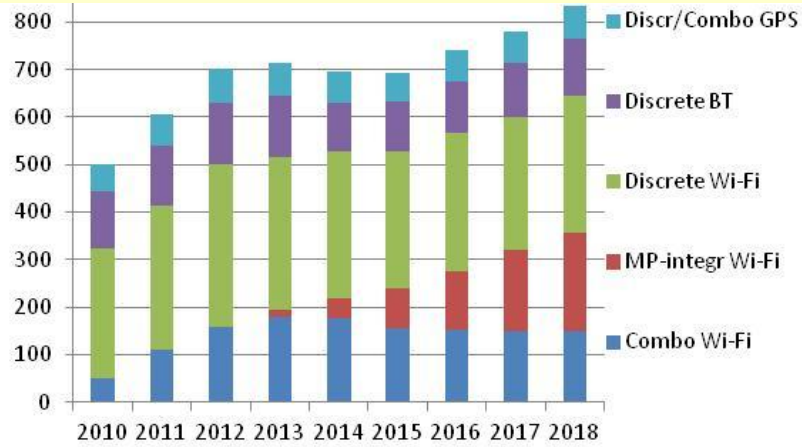
	13-17 CAGR
QFN / QFP / QFN-DR	8%
FBGA	-5%
WLP	5%
FC (possibly eWLB)	1%
Total OSAT Rev	2%

	13-17 CAGR
Combo Wi-Fi	-4%
MP-integr Wi-Fi	81%
Discrete Wi-Fi	-3%
Discrete BT	-2%
Discr/Combo GPS	-1%
Total OSAT Rev	2%

Wireless Connectivity Units by Type (M)



Wireless Connectivity OSAT Rev by Type ($M)



Wireless Connectivity OSAT Packaging ~~$700M Market

- Wireless Connectivity OSAT market remains an important segment of the Mobile IC market

Revenue SAM = ~OSAT	2013	2014	2015	2016	2017	2018	13-17 CAGR
Wireless Connectivity	713	696	694	741	780	835	2%
IoT Wireless Connect.	17	25	42	60	80	106	44%

- WB and WLP will continue to dominate Wireless Connectivity packaging

Wireless Connectivity OSAT Rev by Package ($M)

	13-17 CAGR
QFN / QFP / QFN-DR	8%
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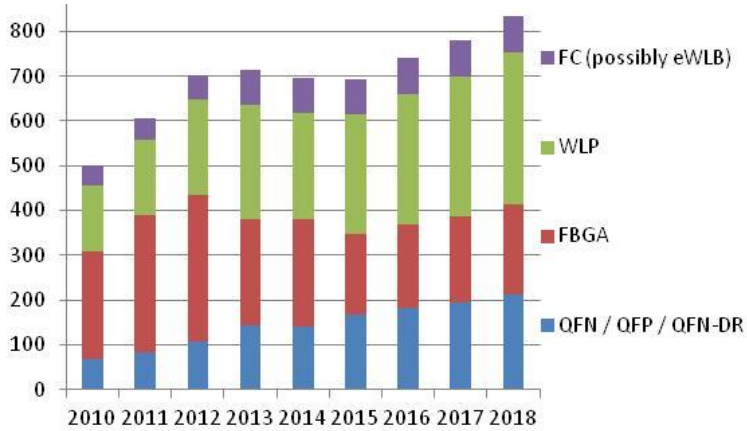


  - The above is also true for the embryonic IoT market -- dominated by QFN and modules (die in WLP)

- There is an increasing interest in module packaging
  - Modules may become a preferred packaging choice in the IoT and WE markets
  - Leading OSATs have module/SiP packaging capabilities

Connectivity Processor-integration – Limited OSAT Impact

- System economics of processor integration is particularly favorable in the Mainstream segment where Combo is integrated into an IP-processor
  - Platform vendors (Qualcomm, MediaTek, Spreadtrum) versus stand-alone Combo vendors
  - SA Combo growth has ceased – the market will remain significant in size because of continuous new standard introduction

- Processor-integration of WLAN Combos represents a major change in wireless connectivity
  - Processor-integration significantly reduces system cost and power
    - More than $4 or 10-15% reduction of IC BOM in Mainstream SPs
  - OSAT implications are much more limited
    - About $0.17 (when in FC) versus ~$0.08 (remaining Combo-residual RF IC)

- A new connectivity segment has emerged – "Combo XCVR" (a la cell BB XCVR)
  - WLP at QTI, QFN at MTK

- Leading platform and AP vendors are likely to adopt a processor-integration approach

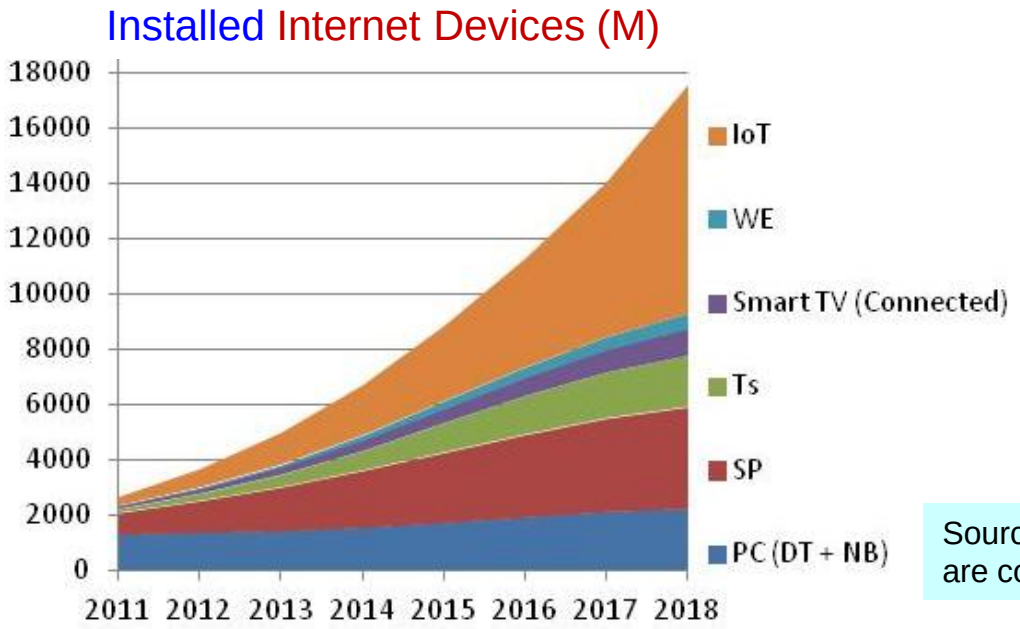
- IoT is a high-growth emerging segment
  - Primary connectivity IC suppliers will be the same as in wireless connectivity
  - All three main IoT components (connectivity (BT), processor and sensor) will be WB, WLP or module packaged

Internet of Things

(IoT = IoE = M2M)

Internet of Things (IoT)

- The IoT refers to devices that can monitor their environment, report their status, receive instructions, and even take action based on the information they receive
  - Unlike SPs or Ts, IoT devices have a limited user interface and exist solely to collect and send data to other devices
  - The three basic functionalities in IoT devices are sensor, wireless connectivity and processor



IoT is projected to eventually become the largest growth opportunity in the history of business
-- Smart systems (fusion of computing, communication and sensing)
-- Connecting and interacting with people, things (M2M), information, places ➔ IoE

Sources of this optimistic IoT projection are composite - BII, Gartner, IDC, SA

- Qualcomm Swarm Lab at US Berkeley projects 1000 radios per person on Earth by 2025
  - Trillions of connected devices
- Bosch projects 7 trillion devices in sensory "swarms" – 1000 sensors per person
  - At present advanced cars have up to 100 sensors, medical diagnostics uses 10s of different sensors

Descending Trillion Sensor by 2020 IoT Hype Mountain

- IoT will more likely become 1.2B+ unit market by 2018 – most IoT growth after 2020
  - In a Base Case model installed base of IoT in 2018 is ~3.5B devices
  - 1.2B+ additional IoT connectivity devices is addition to ~4.5B wireless connectivity units by 2018
  - Primarily in fragmented vertical commercial and consumer applications
    - In 2013 there will be 4.5B 32-bit MCUs and 1.3B AP (SP+T) shipped (25% and 20% 12-18 CAGR)

IoT Unit Growth Scenarios (M)

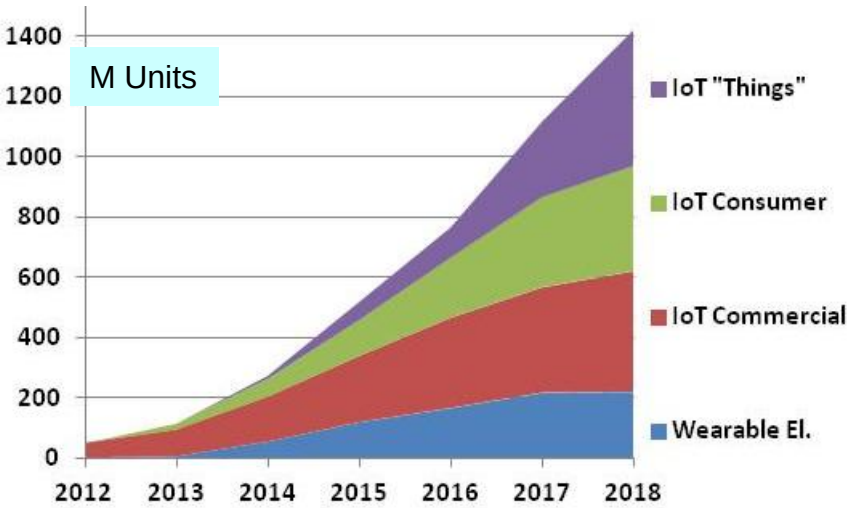
	2011	2012	2013	2014	2015	2016	2017	2018	14-18 CAGR	
Hi Case	300	360	490	666	906	1233	1677	2668	41%	Composite: Gartner, IDC, BII, SA
Base Case	70	100	140	220	400	600	850	1200	53%	MI
Lo Case	70	100	140	220	400	600	800	1000	46%	Linley Group

- Wireless connectivity in IoT is dominated by WB (large PCB pitch) and modules (allow 0.4mm WLP)
  - Qualcomm IoE platforms introduced in Sept. 2013
    - QCA4002 -- 7x7mm 58pin QFN; QCA4004 (with MCU) 8x8mm 68pin QFN – 802.11n Wi-Fi
  - BCM4390 WICED (Wireless Connectivity for Embedded Device) - introduced May 2013
    - BCM4390 SoC (die is in WLP) is packaged in a module
      - It contains 802.11b,g,n Wi-Fi -- with plans for BT, GPS, NFC and other options
      - Like many other vendors, BRCM offers WICED™ - a development system for OEMs – to facilitate adding wireless connectivity to embedded devices (MCUs with more and more A/M-S components)
  - TI SimpleLink Wi-Fi CC3000 is a "self-contained 802.11 network processor" that minimizes the effort involved in making devices internet-aware ← QFN packaged

IoT Connectivity OSAT SAM -- $100M+ by 2018 (for 1.2B devices)

	2012	2013	2014	2015	2016	2017	2018	14-18 CAGR
Total IoT (M)	100	140	220	400	600	850	1200	53%
OSAT A ($)		0.09	0.085	0.08	0.075	0.07	0.066	-6%
OSAT T ($)		0.03	0.028	0.027	0.025	0.023	0.022	-6%
OSAT ASP ($)		0.12	0.113	0.106	0.1	0.094	0.088	-6%
IoT Conn. SAM (M$)		**17**	**25**	**42**	**60**	**80**	**106**	**44%**

- IoT wireless connectivity OSAT is a high-growth new segment – WB and, if in module, WLP
  - An additional $100M+ is in 32-bit MCU packaging – nearly all in WB
  - There is an additional $100-$200M MEMS packaging – mostly WB and SAM is function of sensor type and number of sensor
- In general demand for modules is increasing



		2012	2013	2014	2015	2016	2017	2018	14-18 CAGR
	Wearable El.	0.3	5	54	119	166	217	221	**42%**
IoT	**Commercial**	100	120	150	220	300	350	400	**28%**
	Consumer		20	60	120	200	300	350	**55%**
	"Things"			10	60	100	250	450	**159%**
	Total IoT	**100**	**140**	**220**	**400**	**600**	**850**	**1200**	**53%**

Wearable electronics (WE) is an adjacent segment to IoT
– Typically WE is a "companion" device tethered to SP by BT
  - Bracelets (a sub-segment of WE) might not have any connectivity (a rudimentary display instead)

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BT in Wearable Electronics – Wi-Fi Dominance in IoT Likely

- IoT devices are typically networked in a hierarchy of networks and processing nodes
  - Sensor nodes ("motes") are connected to processor nodes (data fusion, encryption) via Zigbee or Wi-Fi which are then connected to central control nodes / cloud by 3G/4G cellular, Wi-Fi or Ethernet

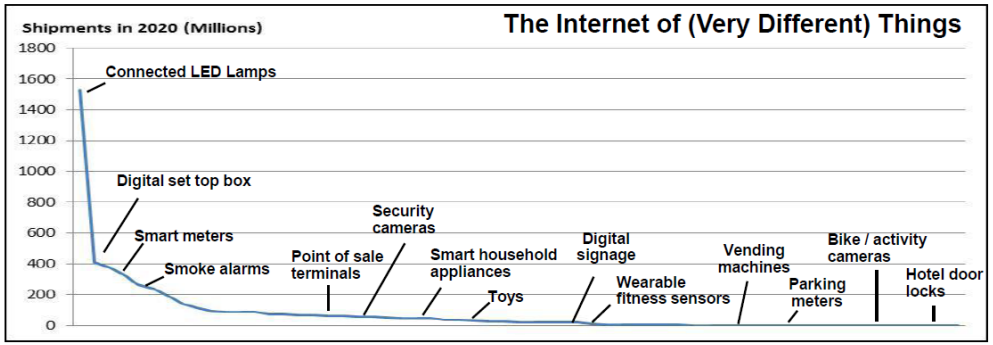
- Most MCU, Analog and Wireless Connectivity IC vendors are pursuing the IoT market
  - But also Murata (acquired Sychip – Wi-Fi S/W vendor)
  - A very large number of start-ups are pursuing IoT solutions:
    - Dust Networks (acquired by Linear)
    - Ember (outdoor municipal lights) – acquired by Silicon Labs
    - E&H Process Solutions (Switzerland) using Dust technology
    - Electric Imp (ex-Apple and Google team) – a Wi-Fi card in wall power socket

- The canonical commercial (M2M) application is smart meters
  - Electronic link allowing utility monitoring usage and increasing efficiency
    - In the US there are ~150M residential and commercial electricity meters
    - ~25% (~35M) have converted to smart meters --- worldwide there are more than 2B electric meters
- Smart parking systems monitor and guide drivers to parking spaces
  - Capacity utilization increases to ~100% (from typically 80%)
    - In the US there are more than 100M for-pay parking spots
- More than 1B vehicles and ~17M shipping containers are used WW
  - A small GPS receiver and wireless connection can track the location of valuable mobile assets
- Control of street lights – China now builds entire new cities with mandated LED lighting control

IoT – Fragmented Market – Many Types of Things (Gartner)

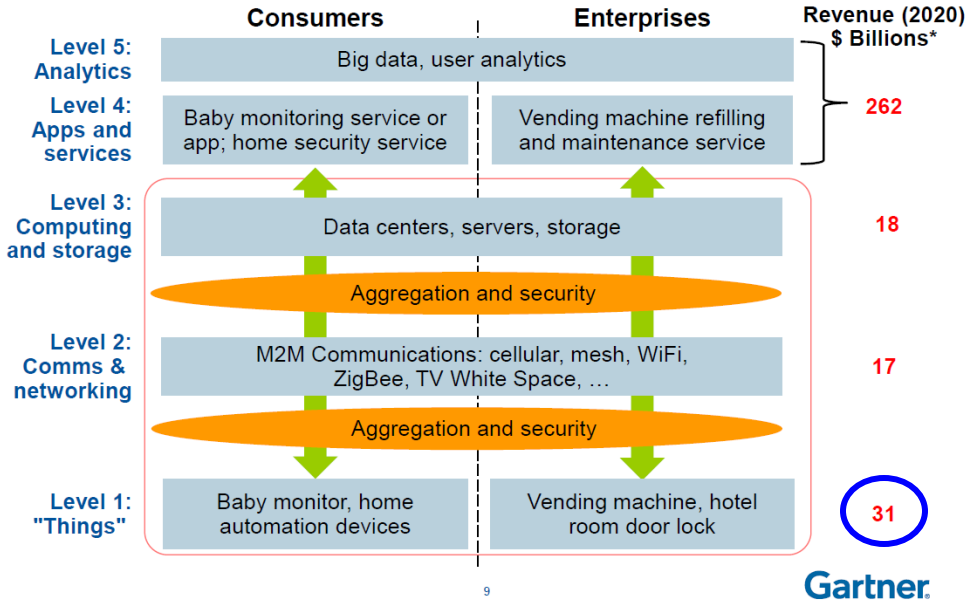
By 2017, 50% of Internet of Things solutions will originate in startups less than three years old.

- Expect 10 billion shipments in 2020
- Many smart versions of existing product markets
- Few are very high volume; most are small and fragmented
- Key challenge: where to focus?



* Preliminary, September 2013

How Gartner Arrives to $262B IoT Market in 2020



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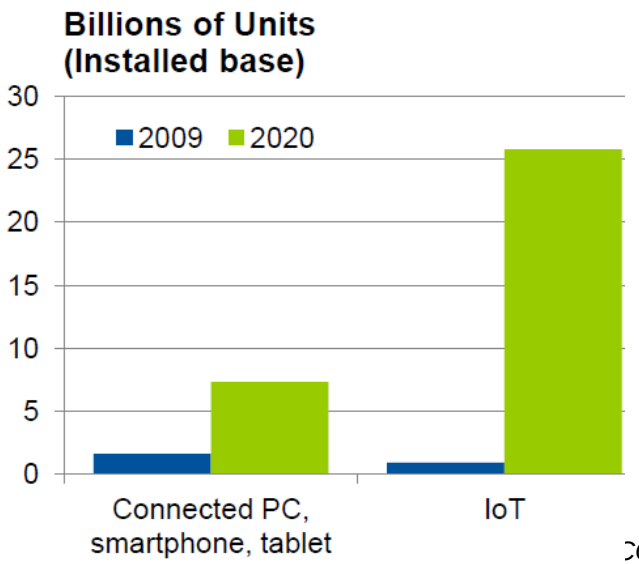

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