TECHNOLOGY

A White Paper on The Internet of Things
“The Dawn of Inanimate Consciousness”
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A White Paper on The Internet of Things – The Dawn of Inanimate Consciousness

We believe the Internet of Things has arrived and is starting to present significant investment opportunities.

Since the beginning of time, humans and animals have been clearly differentiated from the rest of the physical world by possessing some level of consciousness — a state of awareness, and an ability to react to the physical world. This is in contrast with inanimate objects or things, which heretofore are defined by having no sensory capability, nor the ability to process and act upon sensory inputs. For us Homo sapiens, this has been the case for about 200,000 years, and for the "inanimates," they've been about as useful as a box of rocks for the last 4.8 billion years.

We believe this catatonic state of the inanimate world is about to dramatically change. The development of sensor, processing, and networking technology has now reached a state where we can attach and integrate sensory and processing technology into inanimate objects. The Internet is enabling the inanimate world to achieve "consciousness" if you will. This pending technological revolution in inanimate consciousness has mind-bending philosophical, social, and economic consequences. Fortunately for us, in this White Paper we simply seek to identify the investable opportunities that the Internet of Things will drive over the next three to five years.

Against this backdrop, it's interesting to note that the Internet and TCP/IP were born just over 30 years ago. Which means the evolution of the Internet is in inning number ".00135" relative to how long we've been around. And the inanimate team is just showing up for batting practice, with an almost infinite number of potential players. Our rudimentary interface with the Internet is currently based on 19th century keyboard input technology and for the most part requires human input. This is dramatically changing to a system in which any measurable physical modality can be seamlessly sensed, processed, and acted upon even by and between inanimate objects. The potential applications are endless, and the investable opportunities, in our view, are about to accelerate.

In this white paper, we have asked seven of our senior technology analysts to investigate and describe the investable themes created by The Internet of Things, and how it impacts their respective sectors. In each section, each analyst also identifies specific companies that we think will benefit from this pending technology revolution. The following summaries represent the industries under our coverage highlighted in this report:

**Semiconductors: Processors & Components**

As IoT products are developed and brought to market, we believe the industry’s customer base will broaden exponentially, as opposed to the current narrow and well-known customer bases for large semiconductor markets (i.e., the top five customers in PC, smartphones, and servers represent 80%, 53%, and 76% of their respective markets). We believe IoT products will be designed with connectivity as the first functionality selected and the microprocessor core as a secondary decision, with connectivity speed, power dissipation, security, and analytics as the key end product differentiators. We believe IoT investors should consider which semiconductor companies’ products enable end IoT product differentiation. With design decisions moving from prioritizing processors to prioritizing input/output capabilities, we expect processor companies to focus on expanding their I/O and SoC portfolios. In addition, we believe semiconductor vendors may need to revamp licensing strategies to expand customer reach and monetize key proprietary technologies. We highlight names under coverage including: Microchip (MCHP-Buy), which already services a large and diverse customer base through a broad portfolio of low-cost low-power SoCs, embedded memory, licensing, I/O and connectivity; Ambarella (AMBA-Buy), which provides differentiated high-definition end-to-end video compression solutions; Intel (INTC-Buy) with a data center business we expect will continue to do well, as well as the Quark CPU, designed for very low-cost/low-power applications; Broadcom (BRCM-Buy) with their industry-leading portfolio of connectivity solutions; Synaptics (SYNA-Buy) with their rapidly-expanding portfolio of human interface solutions, and Marvell (MRVL-Buy).
Enterprise Storage

While we believe the impact on our coverage universe of IT hardware has yet to be fully understood/defined, we believe the appetite (or need) for enterprises to extract real-time value out of the data being created will have meaningful implications in terms of the evolution of enterprise data centers. With the number of Internet-connected objects projected to grow to anywhere from 25 billion to 50 billion objects by the end of this decade, the one thing that underpins the value of IoT will be the ability to dynamically capture, analyze (big data analytics), and store a vast array of data objects. Although we will be continually evaluating the merits/impact of next-generation memory technology as a replacement to HDDs (e.g., 3D V-NAND, Memristor, etc.), today we believe the $/GB advantage and overall capital intensity of HDDs makes this consolidated industry a key beneficiary of IoT proliferation. While the value of IoT will vary significantly depending on specific verticals and use cases, we believe many enterprises will be left to decide the different architectural requirements of being able to capture, analyze, and effectively utilize the data being created. We believe the size of investment and the compute scalability requirements of big data results in many enterprises looking at public cloud as an attractive deployment model. We believe some enterprises will turn to cloud-based big data solutions, which will likely leverage hyperscale compute clusters. In a survey published by Oracle in late 2012, it was noted that M2M projects and the leverage of cloud-based services was a “no brainer” given the ability for enterprises to minimize complexity and eliminate infrastructure costs. For enterprises that do not view public cloud as an option for their Big Data requirements, dedicated/merged appliances could be the alternative solution. We believe the dedicated appliance approach would look to capitalize on the lowest latency characteristics of converging compute and storage into a single deployed/dedicated solution. From Oracle’s Exa-series solutions to EMC’s Pivotal HD (Hadoop 2.0; Greenplum HAWQ-based) solutions, NetApp’s Open Solution for Hadoop, HP’s HAVEn (Hadoop/HDFS, Autonomy IDOL, Vertica, Enterprise Security, nApps), and others, we see each of the major hardware/software vendors focused on providing optimized solutions to address the scalability and performance requirements of Big Data.

Enterprise Software

We characterize four sub-sectors of enterprise software that will benefit from IoT: big data, middleware, analytics, and event processing. The IoT is just another component of big data and another reason why most database companies’ addressable market is likely to increase over the next decade. The explosion in data created from sensors should benefit traditional database management software providers Oracle (ORCL-Buy), SAP (SAP-Hold), Teradata (TDC-Buy), Microsoft (MSFT-Hold), and IBM (IBM-Buy), as well as a new crop of technology players that cater to the unstructured component of big data, such as Cloudera, Hortonworks, Pivotal, Cassandra, and MongoDB. For integration middleware, we see a growing need for connectivity between disparate data sources and new sensor data as a tailwind to integration middleware companies like TIBCO (TIBX-Buy), Oracle, and IBM, while development middleware, through PaaS (Platform-as-a-Service) environments will be built out by RedHat (RHT-Buy), Pivotal, Salesforce.com (CRM-Buy), Microsoft, and Google (GOOG-Hold). Analytics vendors such as Qlik Technologies (QLIK-Hold), TIBCO, and Tableau will make sense of the tidal wave of data, while event processing for automating business processes and responding to stimuli in real time will be driven by complex event processing (CEP) solutions from TIBCO, Oracle, IBM, Informatica (INFA-Buy), and SAP.

Software: Applications & Communications

We view the relationship of cloud-based enterprise software with IoT as somewhat paradoxical – while the evolution of cloud/SaaS software has its foundation within the rapid proliferation of broadband connectivity, these solutions are not, in and of themselves, elements of IoT. However, cloud software is both dependent on the IoT and is also a key driver in the proliferation of devices that comprise IoT. One of the inherent benefits of cloud-based software is that it is accessible on nearly any device with an Internet connection and, more recently, this experience is actually optimized
Technology: The Internet of Things

Industry Analysis

for such devices. We note that companies such as salesforce.com (CRM-Buy), Cvent (CVT-Buy), Intralinks (IL-Hold), and Brightcove (BCOV-Buy), among others, leverage their optimized support for connected devices as a key differentiator versus competing solutions. The proliferation of connected devices has magnified the amount of data capable of being collected by enterprises, marketers, and brands. The flip side of this equation is that the number of end points capable of receiving individualized, targeted messages is also expanding at a very rapid clip. The confluence of data and end-points, in our view, is nirvana for marketers around the globe. Applications software, as the means of analyzing data, creating targeted campaigns and adjusting such campaigns to differing mediums, such as mobile, social, email or end-device alerts, can provide a very powerful set of options to marketers. We look at Cloud-based marketing software vendors to be great beneficiaries of the Internet of Things movement. To this point, the top pick in our universe clearly becomes salesforce.com, which is in the process of cobbling together targeted marketing solutions like email, social, and mobile marketing (via the ExactTarget acquisition), Social Media monitoring (via the Radian6 acquisition), and even targeted Facebook and other social network-based marketing (via the BuddyMedia acquisition). We note there are other key beneficiaries in software, like Adobe, Marketo, and Oracle (via the acquisitions of Eloqua and Responsys). As recent as Wednesday, January 22, Responsys acquired PushIO, a push notification company capable of sending notifications to all sorts of different devices – entirely consistent with a rapidly evolving IoT strategy.

Electronic Supply Chain

With the “tens of billions” of potential connected devices implied by the IoT, we see a propagation of hardware components that are essential to the execution and implementation of wireless connectivity. The first and possibly the biggest beneficiary are sensors that are used to convert physical phenomena (including piezoelectric, pressure, temperature, motion, level, flow, image, and bio-sensors) into electric signals, or vice versa. In addition, we see a broad array of passive components as beneficiaries of the electronification of devices. We also see opportunities for EMS companies, which would have increased manufacturing of consumer electronics, including wearables such as Fitbit and Nike+FuelBand, medical devices, and industrial equipment. We note six key growth areas: (1) home appliance (8% CAGR 2014-2019) and building construction, (2) connected healthcare (9% 5-year CAGR), (3) process industries (such as petro-chemicals, manufacturing, food & beverage, a $20bn+ opportunity), (4) location-based retail, (5) automotive (7.5% CAGR 2014-2019, and currently makes up ~22% of sensor sales), and (6) consumer wearables (30% CAGR into 2018). Within our coverage universe, the most direct beneficiaries are Amphenol (APH-Hold) through the purchase of GE’s Advanced Sensor Business and its RF components; TE Connectivity (TEL-Buy) which benefits from selling connectors, wireless, and circuit protection solutions, with Auto (biggest growth market for TE) at 40% of sales; Littelfuse (LFUS-Hold) which has 13% of sales from sensors to auto, consumer goods, and industrial applications; Vishay Intertechnology (VSH-Buy) with resistors and inductor sales into autos (20% sales exposure) and industrial (30%); Flextronics (FLEX-Buy), which is expected to leverage existing relationships with Google to manufacture Google Glass, and is involved with the Nike+FuelBand, with additional opportunities in wearables a possibility.

Semiconductors: Analog & Mixed Signal

As the world becomes more digital, massive amounts of data are now being processed both by humans and machines. Digitization will significantly change the technology market through the Internet of Things (IoT) by combining technologies such as SoCs, Power, Connectivity, Software, Big data, powerful sensors and robotics; helping companies create efficiencies and intelligent automation by capturing information from any machine that can then be networked. While the traditional IT market spending environment is likely to only grow at a low single digit rate and has somewhat plateaued, the Internet of Things is creating new markets and is the next semiconductor growth opportunity with the potential for billions of connected devices. Analog, mixed-signal semiconductor technologies are
also considered to be at the center of the IoT market, with the most important product categories being low-power microcontrollers, low-power connectivity ICs (Zigbee, Z-Wave, BLE), sensors, and power management ICs. From our perspective, we believe IoT can initially be divided into 3 large categories: consumer (including retail), enterprise, and government (especially cities). In this section of the report, we will be focusing on the consumer piece of IoT and the three areas where we see the most potential near-term: **Home Automation/Connected Home, Wearables, and Automotive**. Below we outline the analog, mixed-signal semiconductor opportunity within this segment, discuss the relative size of the market, and try to present some of the challenges that may impact the adoption of this technology. Additionally, we address the underlying technology key to each segment identified and finally highlight a few key players most levered for the IoT from an analog, mixed-signal semiconductor perspective.

**Communications Equipment & Mobility**

We believe 2014 will likely be a year of early adoption for products related to the Internet of Things, while 2015 and beyond will be when we would expect meaningful revenue contribution. We note the breadth of applications that companies are working on, including ultra-low power wireless connectivity (e.g., cellular 2G, 3G, LTE, Wi-Fi, ZigBee, NFC, Bluetooth, etc.); sensors (e.g., temperature, motion, location, etc.), microcontrollers, batteries; software for autonomic computing, data interpretation; communication standards / protocols; security; applications and network infrastructure. Within our coverage, we emphasize potential exposure for **Cisco** (CSCO-Buy) and **Qualcomm** (QCOM-Buy), who have been most vocal thus far. For Qualcomm, we note exposure to wearables, through the Toq smartwatch, which while a limited release product, is a showcase for their Mirasol display technology and WiPower wireless charging solution. In the Connected Home, Qualcomm has introduced AllPlay, a platform that allows for wireless streaming of media across different brands of equipment. In Retail - Apple, through iBeacon, which is available on iPhones, and Qualcomm, with its Gimbal product offering, are both addressing location-based context-aware retail opportunities. Additionally, Qualcomm, through its open source AllJoyn framework, looks to solve issues of connecting different devices, allowing such devices to recognize one another and share information, even across brands, networks, and operating systems. For Cisco, given the large expansion predicted in connected devices (from 12.5b in 2010 to 25b by 2015E and 50b by 2020E) and the expected expansion in network infrastructure required to support IoE, Cisco has set the goal of being the connecting platform for an “Internet of Everything” (IoE) world that extends from networking to security to embedded technology. Cisco has projected the IoE market to be a $19t opportunity and positively impact corporate profits by 21% by 2022. Having dominant market share in enterprise IT networks places Cisco in prime position to capitalize on the expected proliferation of devices employing wireless sensors in an IoE world.
Semiconductors: Processors & Components – Kevin E. Cassidy

We believe the developing market of an “Internet of Things” creates a need for new business strategies for many semiconductor companies, particularly processor providers. Various research reports are predicting over 60 billion new devices may be connected to the Internet. In our view, as IoT products are developed and brought to market, the customer base will broaden exponentially. Whereas the current customer base for many large semiconductor markets is obvious (i.e., according to Gartner Research, the top five customers in PC, smartphones, and servers represents 80%, 53%, and 76%, respectively), in our view semiconductor companies’ sales and marketing groups will need to dramatically adjust their market scope to address IoT customers. We believe investors looking for IoT themes should understand a semiconductor company’s market strategy.

Along with the changing customer base, we predict a basic change for selecting which semiconductors to use in an IoT product. In the past, the microprocessor was the first semiconductor component selected when developing a new product, and most other component choices followed. In our view, an IoT product may be designed with Internet connectivity as the first functional component selected and the microprocessor core as a secondary decision. We believe it may be the Internet connectivity’s speed, power dissipation, security, and some cases analytics capabilities that are end differentiators in an IoT product. Again, we believe IoT investors should evaluate which semiconductor companies’ products can allow for end product differentiation.

We see IoT as changing and expanding the semiconductor customer base. With design decisions moving from prioritizing processors to prioritizing input/output components, we expect processor companies to focus on building a portfolio of I/O options. In our view, the combination of a need for specialized components and the broadening customer base may expand the market for technology licensing. We expect a licensing strategy may become an important factor for a semiconductor company to capitalize on the IoT market.

We see that semiconductor companies will play a key role as the Internet broadens and each node in the network adds some intelligence or analytics to the information captured. Ultimately, IoT can drive increasing need for processing power and storage both centralized and at the network’s edge.

In summary, we view the IoT market as slowly changing the semiconductor market. With this change, we believe there will be opportunities for investors to find the new market leaders. Below we discuss how IoT may create opportunities for various companies under our coverage, beginning with our top three picks for IoT exposure, Microchip, Ambarella, and Broadcom.

**Microchip Technology Incorporated (MCHP, Buy, $44.99)**

We believe Microchip is well positioned to benefit from growth in the IoT market for multiple reasons.

First and foremost, we note MCHP has been enabling IoT-like products for over 20 years across a range of markets including automotive, consumer, wireless, industrial/medical, and computing. While some proposed IoT platforms such as wearables are conceptually new, many IoT proposals (e.g., the proverbial smart thermostat) represent variations of applications where Microchip already participates.

Second, we believe Microchip’s product portfolio is well suited for IoT applications. Although some IoT products may leverage innovative technologies such as advanced image processors or exotic sensors, we believe many IoT devices will be constructed primarily from systems-on-chip (SoCs) containing basic building blocks including microcontrollers, analog, and embedded memory, coupled with I/O and connectivity options such as Wi-Fi and Bluetooth, all of which are included in Microchip’s current portfolio. In particular, we believe Microchip’s acquisitions of SMSC, Roving Networks, and ZeroG significantly strengthened the company’s connectivity portfolio. We believe IoT applications will demand low cost and power, which aligns well with Microchip’s design and manufacturing capabilities. Furthermore, we expect growth in the IoT market may boost Microchip’s IP licensing revenues from embedded memories.
Third, we believe the IoT market will be addressed not only by major corporations such as Google and Apple, but also by many small companies and new startups. Given the expected rapid pace of innovation in the IoT market, we do not believe it is possible to pick winners and losers ahead of product introduction. We note Microchip’s proven low-cost support model currently enables tens of thousands of customers, ranging from small to large. In contrast, many established semiconductor companies focus primarily on large OEMs, and provide relatively weak design support for smaller customers. In addition, Microchip’s development platforms and software support enable customers to move very quickly from one processor to another, which we view as a critical advantage since customers do not always know at the time of initial design how powerful a processor is required.

Ambarella, Inc. (AMBA, Buy, $31.06)

We view Ambarella as a pioneer in IoT – in fact the company is making video-enabled IoT products possible today. For example, Dropcam’s home surveillance cameras leverage Wi-Fi, Ambarella’s video compression, and cloud-based services to provide functionality unattainable by a standalone camera. Furthermore, the popular GoPro sports cameras may be viewed as the most successful video-enabled wearable device yet introduced to the market.

Unlike other digital video companies who focused on un-differentiated decoding solutions, over nine years ago Ambarella focused on differentiated high-quality video encoding. Early products addressed video infrastructure applications, serving customers who would pay for high quality encoding. Next-generation products were targeted at emerging real-time encoding applications including sports, IP surveillance, and automotive cameras.

We believe Ambarella has developed impressive technical capabilities beyond IC design, including video compression, software, and the know-how required to achieve high-quality end-to-end video transmission over an Internet connection. In addition, the company has developed key signal processing capabilities, including for example fisheye lens correction for surveillance applications.

We believe Ambarella has a significant technical lead over competitors, which has earned the company a Tier 1 customer base in each of their targeted end camera markets. In addition, the company recently announced cooperation with Google on a reference platform for the emerging wearable market.

We also believe management has a compelling vision for high-quality video processing in IoT. The company believes analytics and other processing must be done in the camera to be practical in many cases, as there is not sufficient time to send data to centralized servers for processing. We believe the company is well positioned to differentiate and add value to their video processing solutions with the development of camera-based video analytics.

We note operating leverage is achieved by utilizing the same silicon platform across all non-infrastructure camera applications. In addition, the company is working on reducing the power consumption, size, and cost of their processing solutions, which we expect will enable a host of new IoT and wearable applications.

Broadcom Corporation (BRCM, Buy, $29.77)

With the industry’s broadest portfolio of connectivity solutions, it should come as no surprise we believe Broadcom will actively participate in the emerging IoT. There are multiple initiatives across the company in every business unit, as the company seeks to expand its connectivity markets.

Some initiatives may be viewed as extensions of existing strategies, such as development of streaming audio capabilities over Wi-Fi for consumer applications. We believe these efforts where the company emphasizes high performance and integration for leading OEMs will continue to be successful.

Similarly, we believe the company is well positioned to grow their Ethernet switching and PHY businesses as performance needs increase in data centers that support IoT devices. We also believe the company will gain traction in automotive connectivity applications, as performance and low power consumption are valued.
What is most intriguing to us, however, is the company’s announcement of two new Bluetooth and Wi-Fi SoCs targeted at low-cost low-power peripherals for SmartPhones and tablets. While acknowledging the IoT market is in its infancy, Broadcom intends to initially offer generalized connectivity capabilities, and offer customized components as the market gains momentum and as customer needs become clearer.

It is not clear to us, however, that the entire IoT market will evolve in a fashion that favors Broadcom’s *modus operandi* of leading-edge performance and customer-driven integration. Possibly the need for leading-edge performance will not be intense, and customers may place greater emphasis on time to market, low cost, and low power. Possibly many applications will be satisfied with “good enough” connectivity performance. In a hyper-rapidly changing environment, markets may change rapidly or remain sufficiently fragmented that creation of specialized SoCs for selected customers may not be a successful strategy.

In the uncertain emerging world of low-cost low-power IoT solutions, we believe Broadcom may need to reconsider their strategy and support a larger customer base for an extended period of time.

**Intel Corporation (INTC, Buy, $25.13)**

After finding itself in the position of playing catch-up in mobile markets, under new CEO Brian Krzanich the company is determined to not be late to new computing markets. No longer focused only on PCs, the company’s expanded view, according to CEO Krzanich, is now “if something computes and connects, it does it best with Intel inside.” Intel is already taking steps to address the nascent IoT market, and not surprisingly, is making moves on a variety of fronts.

Leveraging its McAfee and Wind River technologies, the company has introduced intelligent gateway systems intended to support cloud connectivity for both legacy and leading-edge infrastructure devices. We believe Intel will continue to seek to shape the IoT ecosystem, applying their broad portfolio of processors, software, and security capabilities.

In an effort to gain an early foothold in IoT devices, the company has also introduced the Quark CPU, which is designed for very low cost and low power applications. According to Intel, the Quark device is one-fifth the size and utilizes one-tenth the power of a current Atom CPU. The Quark device utilizes a 32-bit single-threaded Pentium, and includes integrated security and image processing capabilities. At this time, Intel envisions the product family is ideal for interactive kiosks, signage, intelligent vending, ATM machines, medical devices, and vehicle infotainment systems.

We believe Intel's Data Center business will continue to do well in the IoT environment. In our view, Intel is taking the competitive threat from ARM-based servers very seriously, and will continue to introduce new products aimed at emerging product niches. Intel is also now embracing selected use of accelerators for functions such as signal processing and security, and is not attempting to perform every function in x86 software. In addition, we believe Intel’s dominant share in the server market provides them with the key relationships and insights required to continue to develop customer-driven products.

We believe Intel will continue to succeed in Data Center products aimed at IoT applications, but the outcome of the “client” side of IoT is less certain.

We note that in current embedded products (e.g., thermostats, motor control, appliances, and so forth) the choice of CPU core is not particularly relevant since embedded products do not typically run customer-selected application programs. In PC and server markets, Intel’s dominance is based in no small part on the need to run legacy applications relying in varying degrees upon an underlying x86 instruction set. In mobile markets such as SmartPhones, reliance on an underlying instruction set is not as important as in a PC, but the ability to run popular operating systems such as Android is required to support common applications. In the emerging IoT space, there is as yet no clear standard or consensus on how devices will best be interconnected; this architectural battle remains to be fought. While some IoT devices may run customer-selected applications programs, in our view the majority of IoT devices are more likely to resemble special-purpose embedded devices supported by connectivity. As such, the
choice of which CPU to utilize is not particularly relevant; customer choices are more likely to be made based on a combination of low cost, low power, and inclusion of key mixed signal and analog functionality. In other words, we believe the IoT device space will be dominated by SoCs, particularly at the lower end of product functionality.

**Marvell Technology Group Ltd. (MRVL, Buy, $15.18)**

Marvell previewed its Kinoma open source software platform at the recent CES show in Las Vegas. While this software platform was touted in part as enabling the Internet of Things, we view this platform as an extension of Marvell’s Connected Lifestyle strategy, aimed primarily at higher performance home media applications, and do not believe this platform is particularly applicable to the plethora of lower-end devices generally envisioned as constituting the IoT.

We believe Marvell will eventually participate more actively in IoT, but is not yet certain how to leverage its skills in high-performance connectivity and integration. Given its extensive connectivity portfolio, we would not be surprised if the company unveils lower-cost low-power connectivity solutions similar to what Broadcom has announced. In our view, the IoT market will need to undergo a period of Darwinian experimentation and evolution before, if ever, highly-specialized high-volume SoCs can successfully be defined.

**Synaptics Incorporated (SYNA, Buy, $56.81)**

While we take note and approve of Synaptics management’s tight focus on existing notebook, smartphone, and large touchscreen tablet markets, we believe the company’s expanding portfolio of human interface solutions and low-cost implementations will lead to IoT market opportunities over time. For example, we envision IoT devices could benefit from innovative applications of Synaptics’ hover touchscreens or pressure-sensitive ForcePad capabilities.

In addition, we note that Synaptics is already well positioned with easy to use reference platforms, and is expanding their customer reach in the China market to address local design houses for smartphones and tablets. In our view, the company’s efforts to expand their customer support beyond only leading OEMs may prove helpful in addressing a growing variety of IoT platforms.
Enterprise Storage – Aaron C. Rakers, CFA

Internet of Things (IoT) = Big Data; Big Data = Architectural Change in Storage; HDDs Poised to Benefit from Data Explosion

Whether we use monikers such as the Internet of Things (IoT), ubiquitous computing, GE’s Industrial Internet, or Machine-to-Machine (M2M), we are referring to the phenomenon that relates to the forthcoming proliferation of Internet-connected devices, encompassing an expanding list of verticals and applications. While this is by no means a new concept (e.g., think about the promise of RFID tagging several years ago; in 2004 BusinessWeek published a report estimating M2M to be a $180 billion business by 2008), the costs of embedding sensors in all types of things / objects has today led a growing list of enterprises and investors to consider the long-term implications – GE viewing this revolution as an important driver of much needed long-term productivity growth. The scope, scale, and complexity of what is being discussed today looks to have meaningful impacts on data center architectures. While we believe the impact on our coverage universe of IT hardware has yet to be fully understood / defined, we believe the appetite (or need) for enterprises to extract real-time value out of the data being created will have meaningful implications in terms of the evolution of enterprise data centers. Internet-connected devices and objects must be able to sense their environments in order to add value, and they must be always connected to the Internet (4G, WiFi, and / or other emerging standards) to facilitate remote monitoring and control.
The number of Internet-connected objects is projected to grow to anywhere from 25 billion to 50 billion objects by the end of this decade. Gartner’s report titled *Forecast: The Internet of Things, Worldwide, 2013* projects 26 billion excluding PCs, tablets, and smartphones (estimated ~7-10 billion devices) in 2020 while Cisco projects there will be 50 billion Internet-connected devices. We believe estimates differ so widely because IoT is still a nascent market classified under a far-reaching umbrella; however, the implications of next-generation data center architectures are very significant and we believe important to be considered today. From smart grids (e.g., GE’s Grid IQ SaaS solutions) to the impact on the healthcare industry (wearable sensors, smart pills, etc.), transportation, and a growing list of manufacturing use cases, the one thing that underpins the value of IoT will be the ability to dynamically capture, analyze (big data analytics), and store a vast array of data objects – clearly leaving IoT to have meaningful implications for our coverage universe.

As we think about this explosion of connected things, and thus digital content and the need to store and analyze all of this data (and / or metadata), we offer up the following thoughts, or more notably questions at this point:

- **IoT/M2M = Big Data = Hyperscale / Clustered-based Public Cloud Adoption or Dedicated / Converged Big Data Appliances?** While the value of IoT will vary significantly depending on specific verticals and use cases, we believe many enterprises will be left to decide the different architectural requirements of being able to capture, analyze, and effectively utilize the data being created. We believe the size of investment and the compute scalability requirements of big data results in many enterprises looking at public cloud as an attractive deployment model. We believe some enterprises will turn to cloud-based big data solutions, which will likely leverage hyperscale compute clusters. In a survey published by Oracle in late 2012, it was noted that M2M projects and the leverage of cloud-based services was a “no brainer” given the ability for enterprises to minimize complexity and eliminate infrastructure costs. For example, privately held GoGrid, a noted competitor of Amazon Web Services (AWS), has introduced services such as Raw Disk Cloud Servers, which allows for the collection and analysis of big data in a hyperscale deployment leveraging Hadoop file system (see discussion below) and is noted to be offered at $0.60/hour using high-capacity HDDs.

Amazon, IBM’s Softlayer, Verizon Terremark, and CenturyLink’s Savvis cloud solutions also offer Cloudera Hadoop support. Microsoft offers its Azure HDInsight solution – a service for deploying Apache Hadoop clusters in the cloud, with integrated JavaScript and Hive management consoles. Google recently published a blog highlighting the ability for customers to store Hadoop-destined data directly into Google’s Colossus-based storage service, a move focused on bypassing the usage of Hadoop Distributed File System (HDFS).

Gartner characterizes big data as a “composite” market, meaning that big data solutions are currently in the additive stage (i.e., companies are deploying Hadoop clusters alongside their traditional enterprise data centers). Big data will likely quickly transition to a competitive stage in which enterprises will either refresh a traditional data center or replace it with a big data cluster architecture – from which we / investors will be focused on cloud as the long-term winning solution. In 2018, Gartner projects that big data will become destructive and traditional data center infrastructure will be ripped-and-replaced before its scheduled retirement with new architecture better suited for handling big data workloads. The difficulty tracking a composite market is that in the competitive phase, vendors can simply rename their traditional products as big data, thereby making it tougher to track big data’s building market share.

For enterprises that do not view public cloud as an option for their Big Data requirements, dedicated / converged appliances could be the alternative solution. We believe the dedicated appliance approach would look to capitalize on the lowest latency characteristics of converging compute and storage into a single deployed / dedicated solution. From Oracle’s *Exa-series* solutions to EMC’s Pivotal HD (Hadoop 2.0; Greenplum HAWQ-based) solutions, NetApp’s Open Solution for Hadoop, HP’s HAVEn (Hadoop/HDFS, Autonomy IDOL, Vertica, Enterprise Security,
Technology: The Internet of Things

Enterprise Storage Industry Analysis

- Enterprise Storage – Direct-Attached Storage (DAS), Networked (SAN and / or NAS), or the Drive (or Need) to Commoditization via Software-Defined? One problem with big data is that traditional enterprise data centers were not built to handle it. Specifically, transferring data between compute / memory and storage arrays takes too long in a traditional data center. Rather, processing big data requires parallel computing, or splitting up and distributing pieces of data across thousands of nodes that are working in parallel in order to finish the processing job more quickly. Big data requires in-memory processing (for interactive real-time processing), NoSQL databases (for unstructured data), modern Ethernet networking fabrics (to facilitate east/west server-to-server communication), and Apache’s open-source Hadoop / MapReduce. While Hadoop is open source, there are numerous versions or distributions (Cloudera, Hortonworks, Intel, Pivotal, MapR, etc.), many of which have been augmented with enterprise features and functionality.

We believe this will leave us / investors to increasingly think differently about the impact Big Data will have on the traditional storage market – supportive of our view that enterprise storage is in the early stages of the most meaningful change we have seen since the late-1990s/early-2000 timeframe. In terms of our coverage of the traditional storage solutions providers – from EMC (EMC, Buy, $26.22) and NetApp (NTAP, Hold, $45.85) to infrastructure vendors such as Brocade (BRCD, Hold, $9.58), Emulex (ELX, Hold, $7.69), and Qlogic (QLGC, Hold, $11.29) – we believe investors will increasingly question the long-term impact of cloud and / or dedicated Big Data focused solutions and architectures. One of the underpinning architectural attributes of Hadoop is MapReduce. MapReduce distributes compute task across multiple nodes, which in turn leaves us to think about the need for scale-out commoditized clusters with shared storage and / or the movement of compute to data versus the traditional movement of data to compute. This has left most to consider Big Data based on Hadoop as being a direct-attached storage (DAS) deployment rather than networked (SAN / NAS) based storage; no storage is shared across the individual clustered compute nodes. The clustered compute + DAS architectural approach spreads broken down data writes in parallel across the clustered nodes with three copies of the unstructured data (one local copy and two remote node copies).

Another shortcoming of traditional enterprise data centers is that data is stored in silos, often controlled by different business segments. Enterprise segments may still use Hadoop and big data analytics on their siloed data, but analytical insights derived from siloed data will be inferior to insights generated from an enterprise’s comprehensive data set. Data must be centrally accessible for Hadoop’s Map engine to distribute it across the various nodes in a cluster and for Hadoop’s Reduce engine to bring it back together and produce the insight. Gartner projects that even by 2017, 90% of all data will still be siloed and unproductive from a big data perspective. Furthermore, Gartner predicts that even in 2017, 25% of big data deployments will be unproductive due to insufficient network architecture. In order to generate maximum value from big data, enterprises must search for previously “dark” data and include it in a central repository. In fact, the value of big data benefits from the networking effect so much that Gartner projects that companies may cooperate to create a massive pool of shareable data. Companies would still compete to extract value from the common big data pool.

The debate around the optimal architecture for Hadoop deployments will likely continue to shift. While most big data workloads are relatively small today, they will undoubtedly grow over time. Offseting the growth of big data workloads (as more workloads grow in excess of 1TB) will likely be continually decreasing hardware costs. We believe that enterprises will be able to afford to add compute, memory, and storage to single scale-up servers in order to continue to process most big data workloads. Eventually, the debate may mean even less in the long run as most data centers will eventually comprise low-cost commodity off-the-shelf (COTS) hardware that is defined by software (software-defined data centers). VMware highlights that the trend in data center architecture will increasingly be toward converged storage and compute (moving compute closer to data). This will likely be driven
by new distributed file systems and emerging software architectures abstracting control/data plane capabilities into software (i.e., EMC’s ViPR and ScaleIO, VMware’s VSAN, Nutanix, SimpliVity, Nexenta, etc.), faster networks to enable data to be replicated across nodes, and SSDs. VMware highlights that converged server / storage will enable better scalability and will likely be most commonly deployed on virtual machines. Moreover, VMware predicts that virtual machines will consume storage from a converged pool of resources regardless of protocol (i.e., NFS/CIFS, block, object, or even HDFS).

Privately held Nutanix notes that bare metal Hadoop deployment on average runs at 10%-20% CPU utilization levels and thus represents a significant waste of resources. Virtualizing the physical resources into a software-defined pool allows for optimization of MapReduce performance requirements.

- **Data, Data, and More Data**: HDDs the Cleanest Way to Play IoT-driven Data Growth? While the velocity requirements associated with real-time analytics are likely to increase the importance of Flash (or next-generation memory technology), we believe sheer volume of data created by the billions of Internet-connected devices will drive the need for HDDs. Intel has estimated that each person will have seven connected devices by 2020. EMC’s 2012 report titled *The Digital Universe in 2020: Big Data, Bigger Digital Shadows, and Biggest Growth in the Far East* predicts that digital content will increase from 130 exabytes in 2005 (note: HDD industry shipped 450 exabytes on a trailing 12-month basis) to ~40 zettabytes (40,000 exabytes) by 2020, doubling every two years. Each of these connected devices is expected to not only access data from the cloud, but increasingly generate machine-to-machine data into the cloud, which in turn has become a key driver of the HDD industry. According to industry data and our own estimates, we see enterprise / cloud HDDs exiting 2013 at more than 20% of total HDD industry capacity shipped – a trend expected to continue to increase to upwards of 60% by 2020. Although we will be continually evaluating the merits / impact of next-generation memory technology as a replacement to HDDs (e.g., 3D V-NAND, Memristor, etc.), today we believe the $/GB advantage and overall capital intensity of HDDs makes this consolidated industry a key beneficiary of IoT proliferation.

Regarding incremental revenue from the Internet of Things, estimates vary dramatically. Gartner projects that providers of IoT products will generate an incremental $60 billion in revenue in 2020; IoT service providers are projected to generate an additional $250 billion in incremental revenue by the end of this decade. In addition to these new revenue streams, Gartner projects that the ability to monitor and remotely control IoT devices will add $1.9 trillion annually in total global value. Gartner defines added value as anything that either increases revenue or decreases costs. To put this in perspective, the size of the total U.S. economy is currently $15.5 trillion. IDC’s research estimates that the Big Data technology total addressable market (solutions and services) will grow from $16.1 billion in 2014 to $32.4 billion by 2017, growing at a 27% CAGR. We believe this value creation ties to GE’s view that IoT could represent the important (or needed) next wave of productivity growth.

While Gartner’s $1.9 trillion annual projection might seem high, it helps to consider examples of how IoT devices will add value. Wearable sensors for real-time health monitoring will, among other things, help people suffering from chronic diseases. For instance, diabetes can sometimes lead to the need to amputate limbs if a patient’s condition deteriorates and medical intervention is not provided quickly. Indeed, wearable sensors for healthcare are perhaps the most impactful example of value added via IoT objects, both monetarily and in terms of improving human lives. According to McKinsey Global Institute, the cost of treating chronically ill people globally could be more than $15 trillion in 2025. The U.S. currently spends roughly $2.8 trillion on healthcare per year, or 18% of GDP; two-thirds of this, or $1.8 trillion, is currently spent on caring for people with chronic diseases. Given McKinsey’s estimates of penetration and cost reductions, the impact from wearable sensors just in healthcare could eventually be more than $2 trillion per year. Other examples of IoT devices that can add significant value are sensors that ensure the integrity of transportation infrastructure assets or that ensure that factory equipment is operating at maximum efficiency. For instance, New York Air Brake now monitors real-time events (i.e., throttle position, braking effort, and fuel usage) on moving trains. While the volume of data is relatively small (each train produces less than 1MB of data per day), the
variety and value of the data is large; across 18,000 locomotives, a 1% decline in fuel consumption equates to $1 billion per year in cost savings. Other sources of big data, on the other hand, are massive, i.e., generating 1TB of data per hour. While sensors for healthcare and large infrastructure assets may add the most value, LED lights, smart meters, and security cameras will likely represent the vast majority of deployed IoT units.

Source: Gartner

While the Internet of Things will be important to our coverage universe, it is but one phenomenon driving the massive growth in unstructured data that is projected to take place over the next several years. As illustrated in HP's diagram below, additional big data drivers include mobile web data, social media data, click stream data, GPS data, video/photos and other user-generated content. Big data will be a more important focus point for companies in our coverage universe because it will impact how data centers ingest, process, traffic, and store data. In short, big data will change how data centers are architected.

Source: Hewlett-Packard
Big data is often defined as data that is high volume, high velocity, and high variety (i.e., the 3 V’s) or what we would describe as a vast, fast mix of data (some industry publications highlight big data as more appropriately being considered mixed data). Big data is also unstructured (i.e., doesn’t fit neatly into a traditional relational database schematic such as SQL), has low latency as well as “bursty” high bandwidth server-to-server traffic (i.e., east/west as opposed to north/south data center networking traffic). Roughly 75% of the world’s information is unstructured, and unstructured data is growing at 15x the rate of structured data according to IBM. Big data will be generated in massive volumes and companies will develop competitive advantages as they are able to ingest big data in real-time and make sense of it. The ultimate goal, in our judgment, will be to make better decisions with insights derived from big data. Yahoo! has projected that by 2017, 50% of enterprise data will be big data, i.e., stored or analyzed using Hadoop. By 2020, Gartner projects that essentially all data will be big data.

Hadoop Overview

Hadoop, created in 2005 by Doug Cutting and Mike Cararella, is an open-source framework that has become the standard “operating system” for processing big data. It was modeled after Google’s File System and Google’s MapReduce, which Google described in published reports in 2003 and 2004, respectively. Google had a need to index massive amounts of information, i.e., the global Internet, but as other companies began collecting massive amounts of data, they turned to Hadoop rather than designing their own distributed file system and compute paradigm. Hadoop is comprised of two main elements: the Hadoop Distributed File System (HDFS) and MapReduce. HDFS distributes data to the various compute nodes in a scale-out cluster. MapReduce orchestrates, or “maps”, the processing of data at the various nodes in parallel before “reducing” or combining the intermediate results into the final answer in other nodes.

While data mining previously was a pejorative term (in that scientists were expected to construct a theory first and test against empirical data second), the value of Hadoop lies in its ability to identify patterns and generate insights (without any theories) from vast amounts of raw big data. For instance, Hadoop excels at combining customer service call logs with Facebook posts as well as Tweets to identify which customers have the most social strength and pose the greatest risk if they remain unsatisfied. Analyzing this amount and type of data in a SQL relational database would be much more difficult. Extrapolating this use case into other potential value-added capabilities remains at the early stages, in our opinion.

One problem with the first iteration of Hadoop was that it did not support several features (i.e., backup/archive, snapshots, and high availability) that were necessary for enterprises to become comfortable with Hadoop deployments. Hadoop 1.0 was also somewhat limited in scalability, had relatively poor data security, and an inability to run multiple workloads on one cluster. Hadoop 2.0 was recently launched and offers more enterprise features. Hadoop 2.0 improves scalability as well as high availability by eliminating the single point of failure inherent in Hadoop 1.0’s name node. Hadoop 2.0 also enables enterprises to run multiple applications on a single cluster, supports integration with NFS (file-level storage), and offers the ability to take snapshots (point-in-time data copies). While Hadoop 1.0 did not offer several features, vendors such as Symantec and Red Hat offered their own file systems, i.e., Clustered File System and Gluster File System, respectively, that provided enterprise features such as high availability and snapshots.

Hadoop was originally designed to be run on low-cost commodity off-the-shelf (COTS) physical servers arranged in a scale-out cluster architecture with directly attached storage (DAS) as opposed to a network-attached storage systems such as NAS or SAN. It’s interesting that Hadoop is essentially the opposite of virtualization – as virtualization combines many workloads onto one physical server, Hadoop distributes one workload across many physical servers. Hadoop was designed with DAS in order to reduce the need to send data over the network (i.e., elimination of latency). Once data resided in local storage at a specific node, it stayed there. As new jobs
were run, server nodes processed their local data as necessary and sent the Map results to another server node for the Reduce step. While Hadoop is still most commonly associated with a scale-out cluster of physical servers each with their own directly attached storage, we discuss in the next several paragraphs why these requirements no longer hold.

First, while Hadoop was designed to run in a scale-out physical cluster, most big data analytic workloads do not require a scale-out architecture. While conventional wisdom among big data practitioners remains that Hadoop deployments require scale-out clusters of physical servers, Microsoft Research’s 2013 report Scale-up vs. Scale-out for Hadoop: Time to Rethink? highlights that the majority of big data analytic workloads are relatively small (i.e., <100GB) and therefore do not need a scale-out approach. For instance, the median job size of two representative analytic clusters at Microsoft and Yahoo! were less than 14GB, and 90% of big data analytic jobs on a sample Facebook cluster were less than 100GB. These relatively small (<1TB) big data analytic workloads are better served by running on a single scale-up server (increasingly powerful given next-generation multi-core processors). A single scale-up server would still need to be extremely capable (i.e., four 8-core processors for 32 cores on a quad socket board with 512GB of DRAM and an SSD along with HDDs to solve the I/O bottleneck). The advantage of running Hadoop on a single server is that it completely eliminates the need to send data across a network to various nodes. The 32-core single scale-up server in Microsoft’s tests outperformed an 8-node scale-out cluster in 9 out of 11 big data analytic workloads tested; the single scale-up server also only trailed by 11% for the remaining two workloads tested.

The main problem with scale-out clusters of physical nodes (especially for relatively small workloads that don’t need them) is that they result in unnecessarily high costs, power consumption, and data center footprint. For tera-scale and peta-scale (+1TB and +1PB, respectively) Hadoop workloads, however, scale-out physical clusters are still required to provide optimal performance. We would note that Microsoft Research had to tweak Hadoop in order to run big data workloads on a single scale-up server. For instance, Microsoft used file systems such as ZFS instead of HDFS to serve files. End users that wanted to run Hadoop on a single scale-up server would also need to make these tweaks, since Hadoop is inherently designed to run on a scale-out architecture.

Second, similar to how Hadoop does not necessarily require a scale-out architecture, solutions such as VMware’s Serengeti (which virtualizes Hadoop server nodes) eliminate the need to build clusters of physical servers. One benefit of virtualized Hadoop is that end users can run big data analytics workloads on existing infrastructure rather than upgrading to new hardware. Another benefit is that virtual Hadoop nodes eliminate the need to manage a cluster of hundreds or thousands of physical servers and replace HDDs at each node as they fail. In addition, Hadoop saves a total of three copies of a data set to protect against data loss in case nodes fail. This increases the cost of storage by a factor of three (even if a scale-out cluster uses inexpensive HDDs for local storage). We would note, too, that Hadoop’s method of maintaining three copies of data does not provide an enterprise with backup/archive or the ability to recover from snapshots. VMware’s Serengeti also provides high availability and better fault tolerance because virtual Hadoop nodes can be migrated more easily if they should fail. In addition, as networking technology continues to improve (i.e., InfiniBand or even 16Gbps ‘trunked’ FC; 32Gbps FC being a 2016 story) and SSDs are able to provide hundreds of thousands of IOPS, it will become easier for virtual server nodes to either access data on a SAN or NAS over the network or on PCIe Flash cards connected to the server. On the other hand, virtualized Hadoop deployments will not offer the same performance, especially with massive (tera-scale and peta-scale) data sets, as we mentioned before. In addition, it’s possible that the increased licensing costs from a virtual Hadoop deployment may more than offset the savings from building a physical scale-out cluster of commodity servers, given the relatively low cost of commodity servers.

Third, Hadoop no longer requires directly attached storage. Instead, when connecting an array to either a cluster of physical or virtual server nodes, there are multiple storage options. First, an array with its built-in enterprise features can be segmented into multiple volumes of directly attached storage and each server node can be attached to a
separate volume in a share-nothing architectural approach, i.e., NetApp’s Open Solution for Hadoop. Alternatively, Hadoop's primary data set could be stored on an array in a shared-nothing architecture while a SAN or NAS, i.e., EMC’s VMAX, could function as an additional level of data protection while also providing an enterprise feature set. Third, all data could be stored on the array in a shared environment, i.e., EMC’s Isilon. A downside with using a shared environment is that scalability is limited, but Isilon can also be used in a grid architecture to provide unlimited scale-out. In this case, Isilon can run HDFS as a protocol layer on top of its OneFS file system. The other advantage of using shared storage as opposed to directly attached storage is that as storage requirements grow and a physical cluster deployment expands to accommodate additional storage needs, server utilization may decline to inefficient levels, i.e., 10%. With a shared storage array, both compute and storage utilization can be tailored to maintain maximum utilization of both resources.

As we’ve discussed, private cloud deployments of big data workloads have changed since Hadoop’s introduction due to workload requirements and reduced hardware prices. In addition, due to the cost and complexity of building a scale-out physical cluster or managing a virtual Hadoop deployment, many enterprise customers are running big data analytic workloads in the public cloud. The advantage of using the public cloud, i.e., AWS, is zero capex requirements, big data in the public cloud can be shared with enterprise partners, and a private Hadoop deployment can still view data on AWS as available to the cluster, thereby providing backup functionality.

In the meantime, companies such as EMC and NetApp are continuing to help customers solve shortcomings of Hadoop and optimize big data workloads. One shortcoming of Hadoop is that it can be difficult to load data into and out of Hadoop. Companies such as EMC have addressed this by eliminating the need to migrate data. Isilon’s OneFS operating system / distributed file system can represent data either as NFS / CIFS or HDFS as necessary depending on the application. Isilon also supports all versions of Hadoop so that end users that begin on a Hortonworks Hadoop distribution can continue to use their Isilon storage system after switching to MapR or Pivotal. Another shortcoming of Hadoop is the difficulty of writing MapReduce code in Java. Instead of requiring users to be proficient in Java, EMC’s Pivotal enables end users to write SQL queries for Hadoop data sets. Pivotal's HAWQ translates those SQL queries into MapReduce code.
Enterprise Software – Brad R. Reback

So how does enterprise software fit in? In this section, we take a closer look at four enterprise software subsectors that stand to benefit: big data, middleware, analytics, and event processing.

- **Big Data** – Although data has been growing at a rapid pace over the past decade, we believe we are hitting an inflection point and anticipate data will grow even faster over the next several years. We highlight that many industry analysts have predicted that data will increase by 300 times by 2020 to roughly 40 zettabytes (equal to 43 trillion gigabytes) and unstructured data (e.g., video, email, files) will account for a large portion of this.

We also believe this unprecedented level of growth in data will be fueled by “big data,” which consists of multi-structured data such as web logs, sensor and social network data, Internet text and search indexing, call detail records, and large-scale eCommerce data, etc. We also think that big data can broadly be defined by the “four Vs”: volume, velocity, variety, and veracity. Big data is composed of huge volumes of data, being created at an extraordinary pace (e.g., think of sensors within a car system, which are constantly monitoring numerous items such as fuel level, tire pressure, oil level and sending data back the car’s computer) and in a variety of different forms (e.g., structured, unstructured, semi-structured). We also point out that the trustworthiness of the data will often be uncertain.

Over the next several years, we expect increased social interactions, rising levels of machine-to-machine communication (which should greatly benefit Splunk (SPLK, $81.82, Not Covered)), and 24/7 connectivity (from 4G wireless and increasing mobility trends) to further fuel this growth in data. Although we believe this explosion in data is good for the entire database market (we believe key players such as Oracle, IBM, Microsoft, and Teradata will benefit) as all of this data needs to be housed, managed, and set up for analytics to be run on, we think most legacy database software is ill equipped to handle many aspects of big data (especially the unstructured component).

We believe companies will be forced to rethink their architectures and approaches in order to develop offerings that can effectively turn the deluge of data into useful insights. We believe this trend has already begun, as several large tech vendors have already acquired new technology companies (e.g., HP acquired Vertica, EMC acquired Greenplum [now part of Pivotal], Teradata acquired Aster Data) to address the “big data” opportunity. We also think legacy vendors realize that several new technologies and frameworks, such as Hadoop and NoSQL, are better built to handle these new sources of data and have developed connectors and partnerships with leading providers of Hadoop and NoSQL to broaden their capabilities.

In regard to the IoT, we view this as just another component of big data and another reason why most database companies’ addressable market is likely to increase over the next decade. As we highlighted above, we think the explosion in data created from sensors will be beneficial to numerous players, including traditional database management software providers **Oracle (ORCL, Buy, $38.15)**, **SAP (SAP, Hold, $79.65)**, **Teradata (TDC, Buy, $45.00)**, **Microsoft (MSFT, Hold, $36.06)**, and **IBM, Buy, $182.73, covered by our colleague David Grossman**. We also expect it to help a new crop of technology players that cater to the unstructured component of big data, such as Cloudera, Hortonworks, Pivotal, Cassandra, and MongoDB.

- **Middleware** – We classify middleware into two general buckets: integration middleware and development middleware. We think both areas should benefit from the rise of IoT.

Integration middleware can be thought of as the plumbing used to connect disparate systems across an enterprise. This plumbing has become integral across most organizations as legacy applications (be it mainframe, client/server, or even SaaS) were/are not necessarily designed to talk to each other, or at the
minimum communicate with each other in the manner desired by the organization. Integration middleware helps to fill this void.

In many respects the IoT trend is just business as usual for integration middleware providers. Integration platforms, by definition, connect disparate data sources together and new sensor data represent just another data feed to be integrated. That said, the IoT movement should likely serve as a tailwind to integration middleware providers as companies look to bring in new data sources to the mix. We highlight TIBCO (TIBX, Buy, $21.95), Oracle, and IBM as having strong integration middleware portfolios.

Development middleware typically serves as the development platform for building apps. Much of the investment and advancement in this area in recent years is around building out a Platform-as-a-Service (PaaS) development environment. A PaaS often consists of an application development platform supporting several programming languages, libraries, and other services (e.g., scalability, fault tolerance, automating routine tasks), and also takes care of the raw underlying infrastructure (e.g., compute, memory, storage, etc.) provided by the underlying cloud Infrastructure-as-a-Service (IaaS). A major benefit of a PaaS is that the developer can just focus on coding applications instead of also worrying about the underlying enabling technologies.

We believe that the rise of IoT should benefit PaaS players as companies look to simplify development, management, and controllability of smart devices. While there are a number of startups looking to get into this space (e.g., Linkify, Carriots), we note that a number of companies in our coverage universe are building out PaaS offerings. We highlight Red Hat (RHT, Buy, $58.12), Pivotal (owned by EMC, VMware, and GE), Salesforce.com (CRM, Buy, $60.08, covered by our colleague Tom Roderick), Microsoft, and Google (GOOG, Hold, $1160.10, covered by our colleague Jordan Rohan).

- **Analytics** – One of the big challenges facing the industry is how to make sense of the enormous amount of data being generated from IoT sensors. In many respects the needle is getting much smaller while the haystack gets exponentially larger. Vendors are addressing the market from a number of unique perspectives (e.g., moving data into fast in-memory from slow hard disks, building out data grids, etc.), and we think data visualization will play an important role in an IoT world and will remain an area of growth for the foreseeable future.

Data visualization solutions are designed for business users to quickly input, manipulate, and analyze large data sets via an intuitive user interface. These products have grown in popularity in recent years as they provide a level of flexibility and simplicity that traditional business intelligence (BI) tools couldn’t offer, and in most cases with little to no ongoing IT involvement. As way of background, traditional BI tools often required a significant level of IT involvement and investment each time report changes needed to be made, often with delays ranging from days to weeks.

Regarding IoT specifically, we expect business users to mash up new streams of real-time, sensor-driven data with transactional or historical data to glean insights across industries (for example, combine customer foot traffic with actual purchase behavior to improve store layout/yield). Given this backdrop, we think vendors such as Qlik Technologies (QLIK, Hold, $28.12, covered by our colleague Tom Roderick), TIBCO, and Tableau (DATA, $78.53, Not Covered) should benefit from the upcoming data tidal wave.

- **Event processing** – Event processing is all about automating business processes and responding to stimuli in a real-time manner. Not surprisingly, the longer the time period between an “event” and a given response to the event, the less of an impact any response is likely to have. For example, the time to offer a promotion or address a customer complaint is while the customer is still shopping in the store and not months after the fact. We believe feeding new sources of relevant and timely IoT-related data into complex event processing (CEP) engines can help enterprises drive revenue, reduce costs, and/or mitigate risk across industries.
CEP solutions are often implemented in three broad swathes: monitoring (proactively looking for early indicators that assess system health or failure), compliance (ensuring events stay within predefined tolerance thresholds), and engagement (interacting with customers in real-time). The CEP engine then compares the activity against pre-determined rules and will kick off an automated response accordingly. CEP systems can be as simple as routing calls efficiently across call center representatives or as complicated as evaluating a diverse set of inputs (inclement weather, engine trouble, inventory/location of spare parts, available repair staff) to make sure one airplane malfunction/delay does not ripple through the network and cause widespread travel disruptions. CEP solutions are currently used across a wide variety of verticals including finance, manufacturing, energy, retail, transportation, and logistics, just to name a few.

The real benefits from an IoT world, in our opinion, will not come from simply identifying or capturing new streams of data. On the contrary, business value will likely be derived from the ability to analyze and ultimately make decisions based off of it in a timely manner (to capitalize on this opportunity, IBM recently announced a $1 billion investment to bolster its emerging Watson supercomputer and ecosystem). We think the following vendors should benefit given their solid CEP platforms: TIBCO, Oracle, IBM, Informatica (INFA, Buy, $42.90, covered by our colleague Tom Roderick), and SAP.
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Software: Applications & Communications – Tom M. Roderick

More End Points, More Information, More Marketing. IoT a Boon For Targeted Marketers

The term “Internet of Things” or “IoT” for short has been in existence since approximately 2009 as the concept of what the Internet was rapidly evolved. Historically, the Internet was seen as a network that enabled the exchange of data between traditional devices, namely PCs. However, with the rapid evolution in non-traditional connected devices, the concept of the Internet has dramatically changed, moving past traditional data exchange to command and control. Devices such as smartphones, tablets, and hybrid laptops coupled with the evolution of 3G and 4G LTE networks have, in a short while, altered the traditional mindset of what can be accomplished with connected devices. This concept is at its height of relevancy with the recent conclusion of CES as well as the recent sale of home automation startup Nest to Google for $3.2 billion. While we could discuss at length the rapid evolution of connected devices that make up the current IoT, including consumer devices such as Sonos, Nest, Philips Hue, connected home security, etc., we’ll do our best to whittle down the broad concept into how it affects our core research focus, Applications Software – particularly Cloud-Based Applications Software.

We view the relationship of cloud-based enterprise software with IoT as somewhat paradoxical – while the evolution of cloud/SaaS software has its foundation within the rapid proliferation of broadband connectivity (as these solutions are typically accessed via a web browser and require a steady connection), these solutions are not, in and of themselves, elements of IoT. However, cloud software is both dependent on the IoT and is also a key driver in the proliferation of devices that comprise IoT. More specifically, modern cloud solutions blur the lines between software on the traditional desktop and new devices such as smartphones and tablets. In fact, we believe the proliferation of connected devices such as smartphones and tablets has been instrumental in driving the continued adoption of cloud software. One of the inherent benefits of cloud-based software is that it is accessible on nearly any device with an Internet connection and, more recently, this experience is actually optimized for such devices. We note that companies such as salesforce.com (CRM, Buy, $60.08), Cvent (CVT, Buy, $36.64), Intralinks (IL, Hold, $11.82), and Brightcove (BCOV, Buy, $11.80), among others, leverage their optimized support for connected devices as a key differentiator versus competing solutions. More specifically, while Cvent offers a traditional SaaS event management solution that is managed via the browser, its recently released mobile offering provides improved engagement and an optimized experience for conference attendees once on-site. Furthermore, cloud software has pushed beyond the boundaries of simply leveraging an improved mobile experience as a means of differentiation to serving as the foundation for many technologies that ultimately drive the adoption of such devices.

Big Data, Big Marketing Opportunities. As noted earlier in the section by Brad Reback’s team, the proliferation of connected devices has magnified the amount of data capable of being collected by enterprises, marketers, and brands. The flip side of this equation is that the number of end-points capable of receiving individualized, targeted messages is also expanding at a very rapid clip. The confluence of data and end-points, in our view, is nirvana for marketers around the globe. Marry these elements with more refined analytic techniques across far broader arrays of data (made capable via Hadoop and other emerging Big Data technologies), and the combination suddenly becomes very powerful. This is where applications software comes into the mix, as the means of analyzing data, creating targeted campaigns, and adjusting such campaigns to differing mediums, such as mobile, social, email or end-device alerts, can provide a very powerful set of options to marketers.

For nearly 15 years, we have heard of the long-awaited promise of being sent a location-based notification for a discounted coffee when coming within a block of Starbucks. Indeed, that vision has become a reality. But now, envision the next step of sending notifications to all sorts of devices. A refrigerator whose lightbulb has gone out will have the ability to push Amazon or local merchant options for lightbulb re-orders. A Nest thermostat that is no longer communicating with the utility room furnace can offer a set of choices of local repair services and standard parts fixes. Even device-specific information can market to the individual on a 1:1 basis. For instance, the example of Philips’
connected toothbrush, oft-cited by salesforce.com CEO Marc Benioff, has the ability to share end-user data (How much have you brushed?  With what frequency?  Where?  How often do you replace toothbrush heads?) with manufacturer, partners, even dentists and can tailor a message as needed. Personal wearables like the Fitbit are yet another excellent example of this.

Thus, we look at Cloud-based marketing software vendors to be great beneficiaries of the Internet of Things movement. To this point, the top pick in our universe clearly becomes salesforce.com, which is in the process of cobbling together targeted marketing solutions like email, social, and mobile marketing (via the ExactTarget acquisition), social media monitoring (via the Radian6 acquisition) and even targeted Facebook and other social network-based marketing (via the BuddyMedia acquisition). We note there are other key beneficiaries in software, like Adobe (ADBE, $60.88, Not Covered), Marketo (MKTO, $43.52, Not Covered) and Oracle (ORCL, Buy, $38.15, covered by our colleague Brad Reback) (via the acquisitions of Eloqua and Responsys (MKTG, $26.98, Not Covered)). As recent as Wednesday, January 22, Responsys acquired PushIO, a push notification company capable of sending notifications to all sorts of different devices – entirely consistent with a rapidly evolving IoT strategy.

Next generation technologies for device interaction, content management also offer an intriguing angle. We also believe that investors need to pay attention to software-based technologies that allow consumers to interact in a different manner with their devices. For example, Nuance (NUAN, Hold, $15.79) provides cloud-based speech solutions that are instrumental in improving the user experience across smartphones and tablets by enabling speech as a method of data input and control. In addition, salesforce.com is proving itself an innovator in driving IoT, with the company’s software enabling more intelligent integration with historically non-connected devices ranging from cars (Toyota) to airplane engines (GE).

Ultimately we believe that cloud-based software is a key driver in enabling and improving the proliferation of connected devices. A prime example of this is Synchronoss’ (SNCR, Buy, $30.01) Personal Cloud offering, adopted as a white-label solution by carriers such as Verizon, Vodafone, and AT&T thus far. Synchronoss’ cloud-based platform enables and improves the delivery of connected devices including smartphones and, more recently, non-traditional connected devices such as cameras by intelligently bridging the connections between user, device, and network (in this case, the mobile carrier). In addition, the company’s cloud-based data management offering helps drive the adoption of connected devices by improving the transfer and management of key data such as pictures, contacts, and text messages.

In all, we’ve historically favored cloud-based technologies that have embraced the dramatic evolution driven by the advancement of the Internet, first with “Web 2.0”, or traditional cloud-based applications accessed via the browser and more recently with IoT. Companies like salesforce.com, Brightcove, Synchronoss, Cvent, and Veeva (VEEV, Hold, $31.62) have all leveraged the proliferation of connected devices, while also having helped enable the proliferation of such devices. We expect this virtuous circle to continue for years to come, with marketers waiting in the wings, waiting for prime opportunities to reach consumers.
Electronic Supply Chain – Matthew Sheerin

How does it impact us?

With the “tens of billion” of potential connected devices, we see a propagation of hardware components that are essential to the execution and implementation of wireless connectivity. The first and possibly the biggest beneficiary are sensors – the primary node, or data gatherers for the “neural network” – which are used to convert physical phenomena into electric signals, or vice versa. There is a long list of sensors in the market used to observe a varied set of physical phenomena, including piezoelectric, pressure, temperature, motion, level, flow, image and bio sensors.

At the first step in the Internet of Things (IoT), we believe it is important to note the value of such devices. In addition we see a broad array of passive components as beneficiaries of the electronification of devices, including connectors, capacitors, rectifiers, diodes, wireless-antennas and flex-PCBs. We also see opportunities for EMS (electronic manufacturing services) companies, which would have increased manufacturing of consumer electronics, including wearables such as Fitbit and Nike+FuelBand, medical devices and industrial equipment.

Areas of growth...

The potential growth opportunity for IoT seems to be infinite, with all home goods, logistics, and transportation becoming “smarter” and efficient. To simplify our analysis we segregate the market into six key growth areas: (1) home appliance and building construction, (2) connected healthcare, (3) process industries (such as petro-chemicals, manufacturing, food & beverage), (4) location-based retail, (5) automotive, and (6) consumer wearables.

- **Home appliance and building construction:** A key area of growth that is just starting to pick up is the appliance and building construction market. The first underlying theme is energy management, where appliances, fire detection, or lighting systems through the apartment or house are transmitting data to a central system and monitoring power load. The second is that the already connected systems can be monitored and manipulated remotely by owners. We have already seen some investment in these products, particularly given the recent purchase of Nest Labs (manufacturer or smart thermostats and smoke/CO alarms) by Google. BCC Research’s expectation of sensor growth in this market is at an 8% CAGR from 2014-2019, which we see led by consumer appliances and heating-ventilation-air-conditioning (HVAC) climate control systems.
Nest Labs Thermostat

Source: Nest Labs

<table>
<thead>
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<tr>
<td>Home Appliances</td>
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<tr>
<td>HVAC climate control</td>
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<tr>
<td>Fire detection</td>
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<tr>
<td>Lighting control</td>
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<tr>
<td>Elevator/escalator</td>
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<tr>
<td>Building access</td>
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<tr>
<td>Miscellaneous</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

Source: BCC Research

- **Connected healthcare:** In the goal of finding effective treatment at affordable costs, as well as improve the quality of healthcare, we have seen the adoption of technology to provide “intelligent” medical devices. The role of IoT has enabled medical practitioners to remotely get real-time, accurate information in order to provide better and faster services. In order to monitor individuals an array of sensors has developed, which include high precision pressure, temperature, chemical, flow, position, image, and biosensors. The overall healthcare sensor market is expected to growth from $9.0bn in 2014 to $13.9bn, a 9% CAGR, with point-of-care being the fastest growing sub-segment, according to BCC Research.

Source: Hewlett Packard
Technology: The Internet of Things

Electronic Supply Chain Industry Analysis

<table>
<thead>
<tr>
<th>Healthcare Sensor Growth By Application 2014-2019 (in $mn)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
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<tr>
<td>-------</td>
</tr>
<tr>
<td>Point-of-care</td>
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<tr>
<td>Home diagnostics</td>
</tr>
<tr>
<td>Patient monitoring</td>
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<tr>
<td>Drug delivery</td>
</tr>
<tr>
<td>Other medical</td>
</tr>
<tr>
<td><strong>Total</strong></td>
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</table>

Source: BCC Research

- **Process industries**: There are a variety of process-based industries spread across multiple market verticals. While each has its own set of growth characteristics, they all can benefit from synthesized data, in order to improve exploration, manufacturing automation, quality control, safety, and energy efficiency. **Oil & gas** is one such market sector in which we see tremendous growth – companies use sensors for monitoring crude or gas levels, manage flow by monitoring the pipelines, tankers and vehicular transportation, and pressure and temperature sensors to make production safer at refineries. Another industry is **food & beverage**, where real-time monitoring can improve quality control by providing a consistent product and improve yields by instantaneously notifying significant deviations in product. And since raw water is extensively used, its monitoring and treatment is critical to the function of the industry. This example can be extended to the **manufacturing** and **chemical** industries, where environmental issues are pervasive. In addition, it only makes intuitive sense to track all products to improve logistics and reduce supply chain bottlenecks. Since the sector is broad, it is difficult to put a precise number on the revenue opportunity, but we approximate the entire sector to present a $20 billion+ opportunity by 2019 (based on data from BCC Research).

- **Location-based retail**: Consumer behavior is often tracked in the retail sector, to better provide services and maximize sales based on collective patterns. And although retailers do have a sense of consumer choices, their behavior within the store is not really understood. Pressure and motion sensors attached to wireless chips have the ability to provide data on footfall and customer journey within the store, compare newer versus repeat customers, measure effective promotions and thus analyze missed sales opportunities. While there is still little concrete data on the potential opportunity for sensors, given the privacy concerns and the ability of retailers to adopt location-based analysis, we have seen a slew of tech companies, including **Cisco** (CSCO, Buy, $22.56, covered by our colleague Sanjiv Wadhwani), making a push into this sector.
Automotive – Automotive is considered to be the largest sensor market worldwide, which at an estimated $16.55bn makes up roughly 22% of worldwide sensor sales, according to industry trade group BCC Research. While automotive sensor sales in 2014 are expected to grow at a modest 5% y/y, BCC estimates a 7.5% 5-year CAGR from 2014-2019. While part of this growth rate is perpetuated by the need for tighter environmental regulations, greater fuel mileage, and increased safety features, we see passenger vehicles communicating important data to both Auto OEMs (which may then aggregate data to make automobiles more efficient and safer) and/or traffic systems (which can then automatically regulate signals and thus reduce congestion) or possibly even notify the appropriate services or repairs when needed (we have seen this with systems such as OnStar, and with Tesla vehicles, though it is not completely automated).
**Consumer wearables** – We have recently seen the promulgation of consumer wearable devices, given two trends – the health conscious nature of people today, and the need to be more information-connected. Indeed, devices such as Fitbit, Nike+FuelBand, Jawbone, and Armour39 (by Under Armour) continue to feed the health frenzy by consumers, providing them with a varied set of data such as calories burned, sleep schedules, etc., and integrating it with online information and apps for the user. And while the information upload is a newer phenomenon, we note that Google Glass and Samsung’s Galaxy Gear are pushing those limits. In terms of growth opportunity, MarketsandMarkets expects unit shipment of 134 million by 2018, a 30% CAGR.

![Nike+FuelBand](image1.jpg) ![Google Glass](image2.jpg) ![Samsung Galaxy Gear](image3.jpg)

Source: Nike, Google and Samsung

**Beneficiaries in our Coverage**

While all companies in the Electronic Supply Chain should benefit to one extent or another from the Internet of Things, we see the following five companies as the biggest and the most direct beneficiaries in our coverage.

**Amphenol (APH, Hold, $88.49)** – In late 2013, Amphenol entered the sensor-space with the purchase of GE’s Advanced Sensor Business. This division supplies sensors and related products to transportation, automotive, industrial, and medical industries, all markets where Amphenol has significant exposure. The importance of this transaction for Amphenol cannot be understated, which has seen a convergence of sensor and interconnect technologies in automotive and industrial applications, and has implemented sensors in sub-assemblies for customers for several years. Our sense is that Amphenol will most likely continue to look at M&A to gain momentum in this space. The other two ways that we believe Amphenol will be a beneficiary from the Internet of Things are through selling connectors and its RF antennas into the “connected devices.” Indeed, the company currently sells RF components into the Apple iPad, and it only makes sense for it to capture some of the exponential gain in wireless devices.

**TE Connectivity (TEL, Buy, $59.18)** – While TE Connectivity has a small (but growing) portfolio of sensors, as the largest connector maker in the world it stands to benefit tremendously from selling its connectors, wireless and circuit-protection solutions into the various IoT industries. We see Automotive as the biggest growth market for TE, which
makes up 40% of its sales and where it has long-standing industry relationships. The industrial, medical, and consumer wearable sectors also present themselves as growth areas for TE.

**Littelfuse (LFUS, Hold, $93.71)** – Littelfuse has roughly $100mn in annual sales from the sensor market, or about 13% of total revenues, by our estimate; making it the biggest direct beneficiary, in terms of exposure, within our coverage. Littelfuse entered and expanded into the segment through the acquisitions of Accel and Hamlin, and provides sensors for the automotive (such as brake fuel, crash and seat-belt sensing, etc.), consumer goods (exercise equipment, air conditioning, home-showers, etc.), and industrial applications (such as water meter, HVAC, and construction equipment). In addition, the company can sell its traditional circuit protection devices (thyristors, varistors, etc.) into circuitry involved around IoT devices. While still small in dollar terms, there is tremendous growth opportunity for Littelfuse both organically and M&A into adjacent markets, in our view.

**Vishay Intertechnology (VSH, Buy, $14.36)** – We see Vishay as another supplier that should see incremental top-line growth from more connected devices. But for the passive & active component supplier (which has no sensor sales), the benefit should come from selling its resistors and inductors into the automotive and industrial markets (where it has 20% and 30% of sales exposure), and from its diode and opto-electronics portfolio, which should see increased demand from the industrial, medical, and consumer markets.

**Flextronics (FLEX, Buy, $7.63)** – EMS provider Flextronics should be one of the larger beneficiaries with the increased adoption of wearable devices. The company has an existing relationship with Google through Motorola-related manufacturing and is also involved with Google Chromecast product. Management expects to leverage its existing relationship to manufacture products such as Google Glass in the future. In addition, the company also has a partnership with ICEdot to build crash sensors and is involved with the manufacturing of Nike+FuelBand. We note that smartwatches could present additional opportunity in the wearable space for the EMS company, and Flextronics management expects total revenue from wearable devices to exceed $1 billion over the next couple of years. But while that is a large dollar number, we note it will make up less than 5% of Flextronics projected sales.
Semi-conductors: Analog & Mixed Signal – Tore Svanberg

Internet of Things - Overview:

As the world becomes more digital, massive amounts of data are now being processed both by humans and machines. Digitization will significantly change the technology market through the Internet of Things (IoT) by combining technologies such as SoCs, Power, Connectivity, Software, Big data, powerful sensors and robotics; helping companies create efficiencies and intelligent automation by capturing information from any machine that can then be networked. While the traditional IT market spending environment is likely to only grow at a low single digit rate and has somewhat plateaued, the Internet of Things is creating new markets and is the next semiconductor growth opportunity with the potential for billions of connected devices. Analog, mixed-signal semiconductor technologies are also considered to be at the center of the IoT market, with the most important product categories being low-power microcontrollers, low-power connectivity ICs (Zigbee, Z-Wave, BLE), sensors, and power management ICs. From our perspective, we believe IoT can initially be divided into three large categories: consumer (including retail), enterprise, and government (especially cities). In this section of the report, we will be focusing on the consumer piece of IoT and the three areas where we see the most potential near-term: Home Automation/Connected Home, Wearables, and Automotive. Below we outline the analog, mixed-signal semiconductor opportunity within this segment, discuss the relative size of the market, and try to present some of the challenges that may impact the adoption of this technology. Additionally, we address the underlying technology key to each segment identified and finally highlight a few key players most levered for the IoT from an analog, mixed-signal semiconductor perspective.

I. Connected Home/Home Automation

The Opportunity

The connected home market continues to be a central theme that promises to change and improve the traditional model. Consumers have already taken to the IoT-enabled home with connected devices and appliances working in the background, with things like smart thermostats (Nest), smart meters, lighting control systems, music streaming, HVAC, white goods, and many other devices that are on the horizon. Technology companies have been talking about the connected home and the role of this technology, which has evolved dramatically over the past several years, and will likely continue to change. Once used entirely as a means for surfing the web and data transfer between computers, the connected/home network is now responsible for delivering triple play services throughout the home and will likely provide the foundation to connecting an ever-growing number of mobile devices, appliances, and systems to the Internet. Home automation now includes programming and remote control of systems and appliances, where these connected devices have a graphical user interface, which in turn can be accessed on multiple screens, and can include a variety of sensors and other logic capabilities for processing of real-time information.

There remains a lot of room for innovation in the home, even though the idea of an intelligent home has been around for a long time. Technology such as mesh networking allows users to save significant energy and money by installing new connected devices in the home (thermostat, lighting, smoke detectors, alarms) that can seamlessly connect with utility (electricity, water, gas, etc.). The connected home therefore must continually evolve and provide greater bandwidth to handle the requirements of consumers and their appetite for additional connected devices. Therefore, we believe the connected home/home automation market within the umbrella of the Internet of Things is poised for substantial growth over the next decade given the ever increasing demands placed on improving efficiency (energy savings through remote home management) and the need for security. As more consumer electronics with embedded capabilities will be widely available, we believe this market will only evolve and become more prominent with the advancement of semiconductor technology and the help of companies that view the connected home market as an integral part of their growth strategy in the coming years.
Sizing of the Market

The combination of an increasing number of Internet-connected devices throughout the home and the expanding need for Internet services beyond communication, information, and entertainment to newer areas such as home monitoring, security, and automation could create interesting (and new revenue) opportunities for service providers and ultimately those semiconductor companies that have capabilities such as embedded microcontrollers (MCUs), wireless devices, and sensors in this application area.

Typical Connected Devices Throughout Existing Home Area Networks

![Diagram of connected devices](image)

Source: Silicon Labs

As it relates to digital home automation for the “smart home”, there are a few notable devices and applications that will likely be a big trend in 2014 and beyond including lighting control, smart thermostats, and security systems with ZigBee, WiFi, and Bluetooth wireless connectivity to control any number of consumer electronic devices in a home environment. Big box stores, cable and phone companies, and home security companies have all been vying for position in this market and have been rolling out their own brands of “smart” home systems. Lowe’s has Iris, its own brand of smart home system, ADT Security has its Pulse system, AT&T launched its Digital Life home automation service, and Time Warner Cable launched its IntelligentHome system; and there is no shortage of companies looking to enter the market with their own service. According to research published by MarketsandMarkets, the value of the home automation and controls market was worth $19.5bn in 2012 and is expected to grow to $48.0bn by 2018, an estimated CAGR of 16.9% from 2013-2018. As companies take advantage of wireless technology’s increasing accessibility and affordability for home automation customers, we note that there is no one set standard for wireless technology or standard for home automation. In our research, we found that the ZigBee protocol (we discuss other standards in the technology segment of this report) is used in wireless mesh networks and is largely seen as ideal for applications like smart energy, connected homes, security, lighting, and other monitoring and control applications. The ultimate goal of all these connected devices and sensors is their ability to gather important data/information and the ability of these various devices to communicate without the need of our input to make decisions.
The smart meter, which started to gain momentum in 2010, was the first large opportunity using the ZigBee protocol, with the next wave now in Security, Monitoring, and Automation and the overall build out of the home area network. With 115mn households in the U.S. alone and an estimated 8-12 devices per home (and the list is growing to include various white goods, smart appliances, in home displays/remote control, HVAC and lighting control systems), the connected home is poised to be one of the fastest growing opportunities within the Internet of Things market and for levered semiconductor companies.

Challenges

In the coming years, an important challenge for companies that have their sights on Home Automation will be to apply advanced analytical tools to support the ever-growing amounts of data that will be generated from IoT devices and unlock the true value of these devices and trend. These companies will also be challenged to ensure that their networks have a high level of security embedded so that no one can take control or manipulate personal information or health records, seize control of machines on a factory floor, or disrupt supply chains. In fact, there are now reports highlighting IoT based cyber-attacks involving typical household smart appliances and devices, having significant security implications for device owners and enterprises alike. While the IoT holds great promise for enabling control and fostering in an era of smart/connected devices, these devices, however, are typically not protected by anti-spam and anti-virus software features, leaving those devices vulnerable to malicious attacks.

As there are predictions for 50bn connected devices by the year 2020, there are important aspects on how things are deployed, that will help in realizing those numbers. We believe the industry will only be able to achieve these lofty predictions if it can simplify how things connect and communicate with one another, and how it addresses the security features within IoT devices.

IoT – Proliferation of Connected Devices

Source: futurepredictions.com
II. Wearables

The Opportunity

Among the various sub-segments of IoT, the wearables market has tremendous potential, but is perhaps also the most uncertain category as it is still very difficult to determine which wearables will really take off vs. those that are more considered to just be “hype.” For instance, even the most popular wearables today, including Google glasses, Samsung smart watches (Galaxy Gear), and a whole magnitude of fitness/sports devices (Nike Fuelband, Jawbone, FitBit, Garmin, LG Lifeband, Sony Core, etc.) tend to have very mixed reviews. We believe the main reasons for this are that wearable devices today are somewhat “clumsy” and typically don’t have enough functionalities to be “must-have gadgets.” Price points are also extremely important where the “magic” number (varies by type of wearables) is likely in the $25-$50 range while most wearables today cost $100+ and those with slightly more functionality cost $200-$400 (prohibitive pricing for mass market adoption). Either way, it is clear that this is becoming a very popular IoT category and thousands of CE (and retail) companies are pouring millions of dollars into this market to find the “right” device.
Size of Market

Given all the uncertainties mentioned above, sizing the wearables market is like throwing a dart on a dartboard. While Home Automation and the Connected Car have meaningful and tangible benefits (and therefore also great opportunities for semiconductor companies over time), wearables are still by many considered to be unnecessary “gadgets.” Yes, athletes can collect important performance metrics and consumers can in general collect important information about their health, but most of the time the data just gets stored and not necessarily used for meaningful and tangible benefits. Therefore, independent research firms vary greatly in their total market size estimates. ABI
Research, for instance, predicts the wearables market will reach $6bn by 2018, yet Juniper Research estimates the market will reach $19bn by 2018 (yes, $13bn delta…). IMS falls somewhere in between, estimating the wearables market to reach $6bn by 2016 with the three largest sub-categories being Infotainment, Healthcare and Medical, and Fitness and Wellness.

![Image: World Market for Wearable Technology – Revenues by Application – Mid-range Forecast]

**Fig 1. Wearable Technology by Application. The size of the bubble indicates relative market size.**

*Source: IMS Research*

Regardless of its size, and as mentioned above, the wearables market is a great opportunity for analog and mixed-signal semiconductor companies as the types of ICs that go into a typical wearables device are predominantly analog. Take for instance a new wearable shirt by ClearBridge Vitalsigns, which monitors all sorts of health and fitness related metrics. It contains meaningful analog content, including amplifiers, data converters, power management, battery management, and wireless connectivity of a mixed-signal MCU.
Similarly, Freescale has provided the exhibit below, defining some of the key building blocks in a wearable device. By our estimate, 80%-90% of the semiconductor content is analog, mixed-signal, again underscoring that the wearables market, regardless of its size, is ultimately a great opportunity for analog, mixed-signal semiconductor companies.
Challenges – who will prevail?

The main challenge for analog, mixed-signal semiconductor companies will be to determine the types of wearables devices that will ultimately be successful. Not only that, but partnering with the right OEMs (or supply chain partners) is also a challenge as nobody really knows yet the OEMs that will dominate the market. There is a very high likelihood that the infotainment part of the wearables market will be dominated by traditional consumer electronics companies (Samsung, LG, Sony, Apple, etc.) while the health/fitness devices will ultimately be dominated by medical device companies (GE, Philips, Medtronic, etc.). Alternatively, it is even possible that larger platform companies could dominate the wearables market given their experience with more robust operating systems (Apple, Google, Amazon, Microsoft, etc.).
III. Connected Car

The Opportunity

The average American forks out $14,000 a year in car ownership and spends well over an hour a day in the car (101 minutes is the published estimate that we have seen), which rounds to approximately 6%-8% of a person’s waking hours, and that makes driving the number 4 activity in America behind sleep (#1), work (#2), and television (#3). Although modern automobiles have been around for over a century (since 1886), the explosion of in-vehicle electronics has been more of a recent phenomenon. In fact, using SIA/WSTS analog ASIC industry billings data by end market as a proxy, automotive semiconductor grew at a compounded annual growth rate (CAGR) of 16.0% y/y over the last five years, as compared with a CAGR of 8.6% y/y for the overall semiconductor industry. A coverage company of ours saw its automotive business achieved an even higher five-year CAGR of 19.0%. Even as the presence of electronics in conventional gas-driven automobile continues to expand, and even as alternative energy vehicles push semiconductor content to new heights, we believe the Internet of Things (IoT) trends present an enormous opportunity for technology innovators separate and beyond catalysts that drove automotive semis growth momentum in the past.

Automotive Electronics — An Overview

Source: Linear Technology Corporation

The incorporation of the IoT concept into car is really evolutionary, given what has already transpired in the consumer electronics (CE) space. Smartphones and tablets, which are in essence efficient and effective platforms for the delivery of infotainment—communications (cell phone, email, SMS/IM), social networking (Facebook, Linked-In,
Google+, photo/video sharing (YouTube, Instagram), casual gaming, black box (accident) recorder, and other mobile apps—have been fully accepted by consumers and incorporated into their daily activities. Need more proof? Global shipments of smartphones have just overtaken that of basic phones and conventional form factor notebooks, and the installed base of smartphones will soon challenge that of laptop computers. Technological advances in hardware, coupled with innovations in software, are putting us on a path toward a level of global connectedness never before experienced by the human race. In our current state, we have only realized a very small fraction of the vast potential and benefits a wholly connected world could provide.

Connected Car

To comprehend the value consumers place on interconnectedness and mobility, look no further than the amount of time people spend with their devices. Generations of storage and datacom technology have come and gone within one lifetime: from floppy disks to CDs to DVDs to, now, the Cloud. The last semblance of ownership—a DVD holding licensed software—is now a thing of the past. Software is simply downloaded, whenever, on demand. The interconnectedness has moved the productivity push beyond the workplace into people’s personal lives! Search engines have made finding answers easy. Social networks have made friending “efficient.” Video/content servers have made entertainment available on demand. While the U.S., the most advanced country in the world today, has already arrived at being a fast-nation, we are now well on our way toward being in a state of induced ADHD. By stating this thesis, we are not making a social statement on our development. Rather, it indicates to us the rationale behind the connected car—why more connectedness would be tolerated, no, even welcomed. Putting a more positive spin on the trend, one can say consumers are becoming more efficient in their consumption of leisure.

Market Size of Connected Car

Bringing connectivity to the car is a straightforward extension of what has already been happening with consumer electronic devices. The much talked about automotive infotainment is a platform for delivering content to passengers and for interfacing with the driver on useful information such as traffic, navigation, weather, date, time, calendar, and audio entertainment. With continuous advancements in software and natural language processing, infotainment could someday take on the persona of an intelligent assistant. Along the way, there will be plenty of opportunities for innovative technology companies. In that effort, we believe analog mixed-signal ICs will play a significant role as enablers of many of the new functionalities.
The car can also be a generator of useful data, sending real-time traffic data to the Cloud to be consumed by others, creating a collaborative and distributed traffic control / congestion avoidance system. Similarly, vehicles can also survey road conditions, collect weather conditions, and perform other similar activities, and essentially form part of a network of sensors to feed to a big data system for the benefit of all. Last but not least, cars can become intelligent and perform self-monitoring for added safety and accident prevention. Via the Cloud, data on same model vehicles can be collected for early identification of design flaws or premature component failures.

Most believe the size of the connected car market is in the billions of USD once adoption is well under way. Some market watchers have pegged 2020, which is only six years away, as the year when connectivity could become standard on even volume models. To size up the opportunity, we estimate current in-car entertainment equipment market as proxy for the connected car TAM.

According to the U.S. Department of Transportation, world motor vehicle production totaled 55.2 million vehicles in 2012. Based on this data, we make reasonable assumptions on the average in-car infotainment package value of $300-$500 per vehicle and total bill of materials (BOM) that is 60%-80% of the package value (leaving OEMs 20%-40% gross margin). As a proportion of the total material and labor costs, we estimate semiconductor content to represent ~40%-60% of the BOM and assume that the 14% analog mixed-signal semiconductor annual billings as a percentage of total semiconductor sales applies here as well. As a result, we assess the potential served addressable market (SAM) for connected car (automotive Internet of Things) to be just over $1 billion ($1.01bn) by the year 2020.

### Connected Car Analog Mixed-Signal Semis SAM Estimation

<table>
<thead>
<tr>
<th></th>
<th>Worldwide Vehicle Unit Sales* (mn units)</th>
<th>Infotainment Package Value/Price</th>
<th>Bill of Materials (BOM) (% of Price)</th>
<th>Semis Content (% of BOM)</th>
<th>Analog semis (% of Total Semis Content)</th>
<th>Estimate of SAM ($mn)</th>
</tr>
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<tbody>
<tr>
<td><strong>Best Case</strong></td>
<td>55.2</td>
<td>$500.0</td>
<td>80%</td>
<td>60%</td>
<td>14%</td>
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<td><strong>Medium</strong></td>
<td>55.2</td>
<td>$400.0</td>
<td>70%</td>
<td>50%</td>
<td>14%</td>
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<tr>
<td><strong>Floor</strong></td>
<td>55.2</td>
<td>$300.0</td>
<td>60%</td>
<td>40%</td>
<td>14%</td>
<td>$556.4</td>
</tr>
</tbody>
</table>

Source: U.S. Department of Transportation (*), Stifel estimates

This estimate appears reasonable when compared with 2013 annual billings in automotive analog ASIC of $5.92bn, which covers all analog mixed-signal ICs used in cars. In addition to the pre-installed connected car equipment, there are also aftermarket opportunities that we assess could be $50mn-$80mn, based on 2012 $1.15bn aftermarket car audio/video/navigation industry sales assessed by industry watcher CEOOutlook.com.

Our estimated $1bn SAM for connected car electronics can be broken down further as follows: processors, 15%-20%; RFICs, 15%-20%; Power Management, 3%-5%; Connectivity, 5%-10%; Interface/Sensors, 5%-10%; and Display/Cameras, 30%-35%. These are, admittedly, very rough estimates based on existing systems, but they appear reasonable at first glance.
Challenges in Connected Car

As with all technological advances, there will be challenges both technical and human in nature. From the car makers’ perspective, electronics must operate reliably under the harshest operating conditions. Temperature in parts of the car can easily rise to 130-140 degrees Fahrenheit and at times be as high as 160° in the summer and also be as low as below freezing during winter seasons. When vehicle subsystems fail on a regular basis, a recall could be mandated and the cost to the manufacturer is usually quite prohibitive.

There will also be challenges from the perspective of consumer adoption. As with any new product category, there is always the risk of consumers resisting change, causing the adoption speed to slow and sometimes preventing the emerging technology from taking root. While supporters of the connected car concept point to the widespread adoption of smartphones and the general rise in connectedness as evidence that the technology will be embraced by consumers, the same facts can be used for the counter argument that there could be overlaps between some features in the connected car and what consumers already enjoy on their mobile devices—WiFi hotspot and content feed come readily to mind as examples.

Advocates for traffic safety may also raise the issue of the connectivity inside cars becoming serious distractions to drivers. The National Safety Council estimates that cell phone use and texting are responsible for 1.3mn-1.6mn crashes a year (approximately 23% of all crashes on updated 2011 figures). These are facts hard to refute, but a well thought out connected car may offer features that prevent accidents from happening and the potential for a positive impact by new technologies should not be ignored.

Lastly, we raise the general concerns that connected car could add significant cost to total cost of ownership. Beyond the initial equipment purchase, there will be subscription fees for ongoing services. Even at the low end of what a cell phone monthly service fee is today, which is approximately $30-$50 a month, it may slow the momentum of adoption.

In summary, there are many challenges to the connected car becoming standard features in passenger vehicles. However, we believe a well thought out system has the potential to add valuable services and desirable features. In addition, improved safety would be a benefit to the public that would be compelling and hard to argue against. If there is to be any truth to the connected car concept, we should see it pick up momentum within the next few years. Should it gain enough adoption speed to reach “escape velocity,” it should be a trend that benefits many of our analog mixed-signal companies.

IV. Technology

A. Sensors

The digital home/home automation products for today’s smart home include a wide number of devices and applications, encompassing networks of low-cost sensor nodes and actuators for data collection, monitoring, decision making, and process optimization. These functions can be implemented with an embedded microcontroller (whether it is an 8-bit or 32-bit ARM MCU) that focuses on data collection, processing, and wireless connectivity. In the IoT, each sensor node will be autonomous, consisting of a transducer, analog signal conditioning, radio, embedded processor, power management, and energy source. Wireless sensor nodes attached to the IoT will depend on low-power analog semiconductors to ensure longer operating times, or being able to operate without battery power or an external power supply. According to research firm Gartner, ICs that boost extremely low power levels and/or sensor levels will drive a TAM of $455mn by 2017 and that as many as 30bn sensor nodes will be installed and operating by the year 2020. With more objects becoming embedded with sensors and gaining the ability to communicate, this should result in networks that promise to create new business models, improve business process, and reduce costs.
Sensors, actuators, and other means of connecting things in the physical world to a complex network are expanding at very rapid rates. This rapid adoption of IoT is driven in part by a decline in the cost of sensors and actuators and the ability to connect to these sensors as well as the ability to analyze the tremendous amounts of data being generated. When objects can both sense the environment and communicate, they become better tools for understanding complexity and responding to it. Widespread adoption of the Internet of Things will evolve as a function of improvements in the underlying technologies. Advances in wireless networking and the move toward greater standardization of communications protocols allow for better interaction and data collection from the various sensors deployed. Low power wireless technology is enabling substantial cost reductions for traditional wired sensing systems as well as opening up new possibilities for sensor networking that could not have otherwise been done with a wired solution.

Mixed-signal intelligent sensors are generally characterized by their reliability, compact size, high levels of integration, and ease of use across a number of applications. Sensors have been deployed for a wide variety of applications, whether it is sensors to monitor traffic conditions allowing for real-time optimization of traffic flow, sensors that broadcast the position of buses, trains, and trams and make this data available to the public, or sensors within the home for lighting control systems, smart thermostats, and home security systems. Various innovative apps now give commuters real-time updates on the position and likely arrival time of their next bus or train. Each of these systems can then be further upgraded and extended, where in the case of a security system, it can also include a low-cost humidity sensor that adds additional functionality and interaction between different systems. Once restricted to very high-end homes, integrated home automation systems are now hitting the mainstream consumer/home owner, as the implementation of low-cost wireless networking solutions are implemented. One example of a product that has achieved relative success is the Nest Learning Thermostat. This device enables homeowners to remotely program temperature controls from any Internet-connected device, such as a smartphone, tablet, or PC. In sum, the latest security and home automation systems are leveraging innovation in sensing, connectivity, and embedded computing, driving smaller form factors, more affordable systems, and lower power systems that should increase adoption in the coming years.

B. IoT Communications

Machine-to-machine communications is the most complex element of the IoT universe, given the almost limitless interface possibilities and multiple standards that have been developed to accommodate factors such as bandwidth, distance, and other network considerations. The Personal Area Network or PAN is currently most prevalent, as IoT applications today are primarily found in the home (home automation devices). As the IoT infrastructure becomes more prevalent and robust, other networking technologies enter the picture, including LAN-based WiFi, Ethernet, and Bluetooth (both PAN and LAN), and WAN-based 3G, 4G (and eventually 5G), Ethernet, fiber optics, etc. Specialized broadband technologies are also important, including MoCA and HomePlug, to name a few. While LAN and WAN technologies have existed for decades and have reached critical mass, PAN technologies are relatively new (there are also older ones) and constantly evolving. For the purposes of this report we will discuss the PAN IoT standards that have reached the greatest critical mass to-date. These include ZigBee (also sometimes considered a LAN technology), Z-Wave, and Bluetooth Low Energy (BLE).
Types of PAN Networks

Source: Electronicdesign

ZigBee

The most popular PAN (or sometimes considered LAN) IoT standard today — at least based on number of members and support — is ZigBee. The ZigBee PAN radio standard was established in the late 1990s as an alternative to more power-hungry technologies like Bluetooth and WiFi. ZigBee is defined by the IEEE 802.15.4 standard (completed in 2003), which provides both Layer 1 (PHY) and Layer 2 (MAC) of the network. ZigBee software stacks are also used for network and applications layers. ZigBee is a low-power, wireless mesh networking technology that allows multiple nodes to communicate with one-another. According to the ZigBee Alliance (established in 2002), ZigBee can support up to 65,000 different nodes in theory and in practice, up to 500. ZigBee operates in the unlicensed industrial, scientific and medical (ISM) band, primarily in 2.4GHz, which has raised concerns about interference with Bluetooth or WiFi (which also operate in the 2.4GHz band). Maximum data rate is 250kbits/s with power of 1mW or 0dBm limits.

The ZigBee standard is overseen by the ZigBee Alliance, comprised of nearly 600 member companies, including end-product companies like Emerson, Kroger, Itron, Legrand, Landys & Gyr, Reliant, Schneider Electric, Tendril, and Philips; module companies like Atmel, CEL, Digi, Jennie, Lemos, and RFM; and semiconductor companies like Freescale, Microchip, Silicon Labs, and Texas Instruments. The ZigBee Alliance has grown dramatically the last 10 years (from 25 members in 2004) and has even developed many sub-standards, including ZigBee Building Automation, ZigBee Remote Control, ZigBee Smart Energy, ZigBee Health Care, ZigBee Home Automation, ZigBee Input Devices, ZigBee Light Ink, ZigBee Retail Services, and ZigBee Telecom Services.
The ZigBee Alliance and Sub-standards

Z-Wave

While ZigBee gets more press as an open standard with a substantial foundation in the ZigBee Alliance, the Z-Wave standard is also very popular among device makers. Z-Wave is used in multiple applications in home automation (especially lighting), home security, and sensor networks. Initially developed by Zensys (acquired by Sigma Designs in 2008), Z-Wave is a proprietary standard that actually offers considerable flexibility in its end-products due to its high interoperability characteristics. Also, in January 2012, the ITU included the Z-Wave PHY and MAC layers as an option in its new G.9959 standard. As opposed to ZigBee and Bluetooth, which primarily operate in the 2.4GHz band, Z-Wave operates in the ISM 908.42 MHz band (in the U.S. and Canada) and its modulation is based on frequency shift keying (FSK). According to Z-Wave, a network can have up to 232 nodes (in theory), but in practice up to 30. In open areas, Z-Wave has a range of up to 30 meters with available data rates extending from 9Kbits/s to 100Kbits/s.

Since Z-Wave is a proprietary standard, only one semiconductor company offers silicon on the standard: Sigma Designs. Sigma sells directly to OEMs and ODMs, which in turn pay the company a royalty. As opposed to ZigBee end products, which will often include proprietary software (and are therefore less interoperable with one another), Z-Wave end devices are interoperable, as Z-Wave does not allow custom or proprietary profiles.
Most Common Z-Wave Applications Today

![Z-Wave Diagram]

Source: Z-Wave

Bluetooth Low Energy (BLE)

Also called Bluetooth Smart, BLE was developed in 2006 by Nokia (called WiBree) and merged into the Bluetooth standard in 2010 (becoming a subset of the Bluetooth 4.0 standard). It was developed for the same reason as other “personal area network” standards: to develop a wireless networking technology for lower data-rate and lower power applications. BLE offers wireless networking capability using button cell batteries and is today primarily associated with the wearables market (health, sports, fitness). It operates in the same ISM band as regular Bluetooth (2.4GHz band), but uses different channels. The maximum data rate is 1Mbps and with 1mW of power.

BLE’s most obvious advantage is its vast member support. The Bluetooth Special Interest Group (Bluetooth SIG) consists of more than 20,000 members — significantly higher than both the ZigBee Alliance and the Z-Wave Alliance. Established in 2010, the BLE standard is relatively new and will have to catch up with the other two, which seem to have more critical mass, especially in areas like security, home automation, and smart sensors. From our perspective, it appears that Bluetooth BLE is getting more traction in the wearables market, especially as the technology gets more of a “push” from the smartphone market (and these are increasingly connecting). It also seems to get more attention internationally, in large part due to its vast global membership.

With three competing standards, the great debate continues over which will eventually prevail. ZigBee currently appears to have reached critical mass, given its wide adoption and development of numerous sub-standards. ZigBee is more prevalent in media and appears to market its standard more aggressively than the other two (at least in the U.S.). That said, we have also heard that the Z-Wave is very well-liked in the industry because of its interoperability features. Bluetooth LE, the younger of the three standards, has great support from its massive ecosystem. Realistically, it is too early to make the call on which standard will prevail, which is probably why most semiconductor companies are supporting many different standards (though not Z-Wave in this case). We note that in addition to ZigBee, Z-Wave, and BLE, there are numerous other wireless PAN (or LAN) standards, including 6LoWPAN, ANT, and Dash7, among others.
Key Comparisons Between BLE, ZigBee and Z-Wave

<table>
<thead>
<tr>
<th></th>
<th>Bluetooth LE</th>
<th>ZigBee</th>
<th>Z-Wave</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developed</td>
<td>2006 (Wibree)</td>
<td>2002</td>
<td>2006</td>
</tr>
<tr>
<td>Members (approx.)</td>
<td>20,000</td>
<td>600</td>
<td>160</td>
</tr>
<tr>
<td>Alliance</td>
<td>Bluetooth SIG</td>
<td>ZigBee Alliance</td>
<td>Z-Wave Alliance</td>
</tr>
<tr>
<td>Frequency</td>
<td>2.4GHz</td>
<td>2.4GHz</td>
<td>908.42MHz</td>
</tr>
<tr>
<td>Standard</td>
<td>Bluetooth 4.0</td>
<td>IEEE 802.13.4</td>
<td>Proprietary/ITU</td>
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<tr>
<td>Radio modulation</td>
<td>GFSK</td>
<td>DSSS</td>
<td>FSK</td>
</tr>
<tr>
<td>Data rate</td>
<td>1Mbps</td>
<td>250Kbps</td>
<td>40-100Kbps</td>
</tr>
<tr>
<td>Scale # of nodes</td>
<td>N/A</td>
<td>500</td>
<td>30</td>
</tr>
<tr>
<td>Security</td>
<td>AES128</td>
<td>AES256, ECC, RSA</td>
<td>AES128</td>
</tr>
<tr>
<td>Flash</td>
<td>Varies up to 256K</td>
<td>Varies, up to 512K</td>
<td>32KB to 64KB</td>
</tr>
<tr>
<td>RAM</td>
<td>8KB</td>
<td>16KB to 32KB</td>
<td>2KB to 16KB</td>
</tr>
<tr>
<td>Software</td>
<td>Royalty-free</td>
<td>Royalty-free</td>
<td>Proprietary</td>
</tr>
<tr>
<td>Power</td>
<td>1mW</td>
<td>1mW</td>
<td>1mW</td>
</tr>
<tr>
<td>Range</td>
<td>50 meters</td>
<td>10 meters</td>
<td>30 meters</td>
</tr>
<tr>
<td>Pro (1)</td>
<td>Vast members</td>
<td>Open standard*</td>
<td>No interference</td>
</tr>
<tr>
<td>Pro (2)</td>
<td>Low power</td>
<td>Low power</td>
<td>Low power</td>
</tr>
<tr>
<td>Pro (3)</td>
<td>Sub-standards</td>
<td>Interference</td>
<td>Proprietary**</td>
</tr>
<tr>
<td>Con (1)</td>
<td>Interference</td>
<td>Proprietary</td>
<td>Smaller ecosystem</td>
</tr>
<tr>
<td>Con (2)</td>
<td>Complex</td>
<td>Complex</td>
<td>One chip supplier</td>
</tr>
<tr>
<td>Con (3)</td>
<td>Incompatible</td>
<td>Range</td>
<td>Lighting, security</td>
</tr>
<tr>
<td>Main applications</td>
<td>Wearables</td>
<td>Thermostat, meters</td>
<td>Lighting, security</td>
</tr>
</tbody>
</table>

Source: Stifel

* ZigBee is an "open standard", but many end products are proprietary
** Z-Wave is a proprietary, but end products have high flexibility due to interoperability

C. Low Power Technology

Low power is a critical piece of the puzzle to enabling Internet of Things. Lower power consumption extends battery life, improves user experience, and in some instances allows for alternative/green energy sources that otherwise would not be sufficient in powering the devices.

Semiconductor design advances and low power process technologies have equally contributed to our ability to significantly lower power consumption in modern electronic systems. Circuit design techniques that turn off idling functional units, prevent switching in unneeded logic blocks, lower operating voltages to reduce voltage swing, are a few examples of modern circuit design techniques that are pushing the envelope on low power ICs. As to advances in process technology, that is beyond the scope of our work here and it suffices to know that a significant portion of improvements in IC performance is the result of improved processes. We will underscore, however, that analog companies that either operate internal fabs or maintain proprietary process technologies are more likely to hold a competitive edge over those that use foundry processes, as the latter would be widely available to all analog companies.
V. Selective List of Internet of Things IC Players

Atmel (ATML, $8.43, Not Covered)

Atmel's position in the IoT market derives primarily from its solid presence in the overall microcontroller market (mainly ARM-based 8-bit and 32-bit MCUs). We also believe the company will be a very important IoT player given its leadership in sensors and the concept of “sensor hub.” Atmel also possesses key IP in memory, security, and analog technologies. Recent acquisitions (which appeared to be part of the company’s IoT strategy) include Advanced Digital Design (power line communications, in 2011), Ozmo Devices (WiFi Direct, in 2012), and the smart metering business from IDTI (smart meters, in 2013). The company generates approximately $1.4bn in revenues. We do not know at this time how much relative exposure the company has to the IoT market (60% of revenues come from MCUs).

Freescale Semiconductor (FSL, $15.89, Not Covered)

Freescale is a leading IC supplier in MCUs and digital networking processors and has an extensive portfolio and list of customer engagements targeting the IoT. The company has a scalable, low-power mixed-signal MCU offering based on ARM architecture and has ARM-based QoriQ communications processors, aimed at a broad range of power-sensitive networking applications and other product categories such as the IoT. Its five core product groups (MCUs, digital networking, Automotive MCUs, Analog and Sensors and RF) are targeting four primary markets (Automotive, Networking, Industrial, and Consumer). A few specific capabilities and applications within IoT include: Building Automation, Smart City, Smart Lighting, Smart Grid, Smart Health, and Industrial Automation. In fact, Freescale already works with a variety of customers in the health area, as both Fitbit and OmniPod insulin pumps use its chips.

The company’s ARM Cortex cores not only power a number of smartphones and other mobile devices, but has also extended to the network with new devices. Its chips enable IoT gateways to communicate with appliances, security systems and monitors, and smart thermostats across a number of communication protocols including 802.11, Bluetooth, and ZigBee. Freescale has stated that it will be more active in the next-gen of networking and industrial applications. With a number of IoT related announcements coming out of CES 2014, we believe Freescale continues to emerge as a leader in IoT as this technology evolves.

Maxim (MXIM, Buy, $28.88)

Maxim participates in the Internet of Things in a variety of ways. The company has at the center of its strategy analog integration, which is very fitting for IoT applications where small footprint, low component count, reliability, and energy efficiency are critical. Its integrated power management system-on-chip (SoC) solutions have successfully penetrated the smartphone market and are gaining traction in adjacent tablets and e-readers, and could potentially be adapted for IoT devices such as wearables, connected home appliances, and connected car equipment. Moreover, Maxim is pursuing the “sensor hub” concept, which integrates the control of sensors and the processing of sensory data. Efficient and effective management of sensors would be critical for IoT devices, in our view. For the connected home, Maxim is a leading supplier of components to small-cell/femto-cell stations. Also, Maxim has pathway into connected car with its infotainment power management ICs and automotive Wi-Fi PHY chips. The company’s automotive business has grown from 1% of revenue seven years ago to high single digits today.

Microchip (MCHP, Buy, $44.99, covered by our colleague Kevin Cassidy)

Among analog and MCU semiconductor companies, we believe Microchip is among those with much to gain. The company has been a leader in microcontroller units (MCU) with a full lineup from 8-bit to 16-bit to 32-bit, and is well-entrenched in many of the areas IoT is expected to impact. The company has a comprehensive portfolio of analog blocks, including sensors and wireless communications IPs, which are easily integrated with its MCUs to form
intelligent controllers. Such controllers — MCU + analog + sensors — would be perfect, in our view, for simple IoT devices such as consumer wearables; connected home security, monitoring, control, and appliances; and various functions (lighting, safety, security, diagnostic, to name a few) in connected car. Already, we note Microchip’s MCUs are widely used in home appliances. It is also a supplier of CAN transceivers and offers its own automotive Wi-Fi solutions. (CAN, short for controller area network, is the incumbent connectivity standard for in-vehicle networking.) We believe Microchip is competitively positioned to be a significant player in the Internet of Things.

**NXP Semiconductors (NXPI, $47.85, Not Covered)**

NXP has been a very active participant in the IoT market evolving its technology roadmap over the years from its start with simple RFID tags to NFC to advanced wireless microcontrollers and modules. As a leader in NFC technology, which is now incorporated in mobile phones, tablets, tags, and readers, the company has far reaching capabilities to address IoT. The company also has advanced 32-bit MCUs equipped with high performance wireless connectivity, peripherals, and software development tools for IoT applications. Its real push, however, came just a few years ago with its introduction of IP-based light bulbs. The company has been successful in combining its wireless IP connectivity solutions with energy efficient lighting technology. The underlying technology for NXP includes its low-power RF and mesh networking solutions (assets acquired from Jennic), enabling IPv6 connectivity to all smart devices in the home and office. The company previously had targeted ZigBee capabilities, but has also embraced IP-based protocol – 6LoWPAN, through its JenNet-IP wireless networking solution for the IoT. Potential applications for its low-power RF and mesh-network solutions are broad and include things such as smart metering, tele-healthcare, security cameras, home appliances, and smart home automation. Overall, we believe NXP has a solid portfolio targeting the IoT, developing low-power technologies and continued research for the eventual integration of things like temperature, humidity, light, and pressure sensing onto a single chip. By having solutions in areas such as smart lighting, building control and home automation, and connected healthcare, we believe positions the company to be a key player in the IoT market for the long term.

**Qualcomm (QCOM, Buy, $75.87, covered by our colleague Sanjiv Wadhwani)**

Best known as a leading mobile chipmaker, Qualcomm has been working on the connectivity and interoperability issues central to the realization of Internet of Things. For Qualcomm, Internet of Things means the opportunity to sell more chips, and the company aimed to create an ecosystem with itself at the center of the community. Recently (December 2013), the company announced it is spinning out its AllJoyn code, developed by its Interactive Platforms Division, to an open-source community — AllSeen Alliance (ASA), established by the Linux Foundation — for cooperative development. On the product front, Qualcomm has released an SoC that marries communications, including Wi-Fi, with significant computing/processing capability. The chip has its genesis in the company’s Qualcomm Atheros unit (which grew from Qualcomm’s acquisition of Atheros Communications in 2011) and will target home gateways, routers, and media servers and control home lighting, climate, and security. Qualcomm is not new to the home, as the company’s products are already embedded in networking products sold into the home.

**Silicon Labs (SLAB, Buy, $44.61)**

IoT is now targeted to be one of the fastest growing opportunities for the company over the next several years as new products and markets begin to develop. The company has a fairly comprehensive portfolio targeting the IoT, with its core capability in mixed-signal technology driving the basic building blocks for this emerging opportunity. The company has embarked on new products designed and built to draw lower power and support the demand for high performance, high bandwidth networks. Silicon Labs products include energy efficient microcontrollers and wireless
MCUs, low-power RF ICs, and MEMS and CMOS-based sensing devices to detect pressure, motion, temperature, humidity, and gases.

The company is targeting areas such as Home Automation, wearables/consumer, and industrial (factory automation and infrastructure) and continues to cite increases in design activity and a growing number of deployments. With assets acquired through Ember Corporation (May 2012), the company has made significant progress in expanding its leading low-power wireless technology (ZigBee), we believe the company is now gaining traction in this market with a number of products (highly integrated sensors, low-power wireless MCUs and power products) and applications (home security and automation, smart energy and metering and medical). Additionally, with the acquisition of Energy Micro (June 2013), management believes it can further expand its MCU portfolio (32-bit MCUs and is also developing multi-protocol wireless RF solutions including Bluetooth Low Energy (BLE), 6LoWPAN, ZigBee, RF4CE, 802.15.4(g), KNX, ANT+, as well as other additional protocols) into new areas such as home automation, T&M, metering, and generally the IoT. The company generated approximately 10% of revenue (or ~$55mn) in a broad category of connected devices for the IoT in 2012, and we believe that percentage was larger in 2013. In sum, the company now has an end-to-end solution and believes it can capitalize on solid growth over the next three to five years as this market expands. Silicon Labs now has all the pieces (connectivity, software, and sensors) to be a strategic supplier for the IoT and remains our favorite way to play IoT.

**Texas Instruments (TXN, Hold, $44.09)**

Texas Instruments offers an extensive portfolio of products targeting multiple applications for the IoT market. Its broad product portfolio includes all the building blocks for the IoT: Nodes, Gateway/Bridge/Router, and the Cloud and encompasses products such as MCUs, wired and wireless connectivity, analog signal chain, processors (including multi-core), sensors, power management. With the amount of data generated and shared, TI has also created build-in hardware security technology, to prevent, detect, and respond to malicious behavior.

TI’s portfolio also includes Connectivity solutions, targeting thousands of customers (leveraging analog and EP customer base) and can support 14 different wireless standards (ZigBee, LBE, WiFi, ANT+, 6LoWPAN, NFC, to name a few) across in-building, automotive, and portable applications/devices. We believe this creates a competitive advantage as TI has an optimal solution for its customers, covering numerous wireless standards and network topologies. In relation to MCUs, products include Hercules line of MCUs targeting safety applications and dual-core ARM and signal processing, targeting a broad range of applications including smart-grid. In Digital Signal Processing, (DSP) TI has been able to gain share over the years, expanding into areas such as real-time processing with products targeting: automotive (data processing/accident avoidance systems, navigation, Bluetooth and WiFi, keyless entry, sensors), industrial automation (identification of defects in a product line, wirelessly connected LED lighting and energy management), home automation (Security and Safety system, sensors, smart home energy gateways, thermostats), fitness/health (activity and performance measurement), and security cameras (facial recognition for real-time processing). While IoT is just a small piece of TI’s overall electronics roadmap, the total opportunity could be much more substantial, in our view, given the company’s broad IoT portfolio.

**Other Players**

Micrel, Inc. (automotive; MCRL, Buy, $10.17), Linear Technology Corporation (automotive; LLTC, Hold, $45.79), Monolithic Power Systems, Inc. (various; MPWR, Buy, $34.68), Skyworks Solutions Inc. (connectivity; SWKS, $31.43, Not Covered), Sigma Designs Inc. (Z-Wave ICs; SIGM, $4.90, Not Covered), CSR plc (BLE ICs; CSRE, $46.21, Not Covered), Intel (processors; INTC, Buy, $25.13, covered by our colleague Kevin Cassidy), Broadcom Corporation (connectivity; BRCM, Buy, $29.77, covered by our colleague Kevin Cassidy), and STMicroelectronics (various; STM, $7.87, Not Covered), to name a few.
Communications Equipment & Mobility – Sanjiv R. Wadhwani, CFA

In this report, we discuss the subject of Internet of Things (IoT) – or as it is sometimes called, Internet of Everything (IoE) – including the various markets and implications for Qualcomm (QCOM, Buy, $75.87) and Cisco (CSCO, Buy, $22.56), two companies in our coverage universe that have been most active in the IoT/IoE space.

Gartner defines IoT as “the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment”. The Internet of Things (IoT) is considered to be a robust area of growth for the foreseeable future and several verticals are considered ripe for implementation of connected devices / machine-to-machine (M2M).

There are numerous examples and use cases of IoT / IoE, such as:

- Wearables, including personal healthcare applications,
- Connected Car,
- Connected Home,
- Smart City (e.g., energy / grid, & parking),
- Retail and Supply Chain Management,
- Industrial,
- and others.

At the recently concluded CES 2014 conference in Las Vegas, several vendors showed off their products and solutions addressing various market segments.

There are several enablers of IoT/IoE – areas where companies trying to service the space are focusing their business efforts. Listed below are some examples of what companies are working on in the IoT/IoE space:

- Ultra-low-power wireless connectivity (e.g., cellular 2G, 3G, LTE, Wi-Fi, ZigBee, NFC, Bluetooth, etc.)
- Sensors (e.g., temperature, motion, location, etc.), microcontrollers, batteries, and other components
- Software that allows autonomic computing and helps a networked device interpret data and make decisions
- Communication standards / protocols (similar to HTTP for Internet protocol)
- Security
- Applications
- Network infrastructure

Research firms such as Gartner and ABI Research as well as corporations such as Cisco have put forth growth projections for the Internet of Things. Cisco, for example, expects there will be up to 50 billion connected devices by 2020 vs. approximately 10 billion today. ABI Research predicts there will be approximately 30 billion devices by 2020 vs. 10 billion today. Gartner (December 2013) predicts there will be 26 billion, non-smartphone/tablet devices connected to the Internet by 2020.

We discuss the implications of IoT in this report with particular emphasis for large cap companies in our coverage universe – Cisco and Qualcomm – that have been most vocal thus far and have discussed product offerings that address various examples of IoT. We do note, however, that we do not believe the IoT will lead to meaningful revenue for companies in our coverage universe in 2014. Rather, 2014 will likely be a year of early adoption, while 2015 and beyond should be when we would expect meaningful contribution from the IoT.
Examples of Internet of Things

Wearables

According to Gartner (July 2013), the consumer wearable electronics market for fitness and personal health will become a $5 billion opportunity for devices, apps, and services by 2016 as the expectant growth expands beyond basic applications currently available. Further expansion is expected in fitness applications and personal health monitoring, such as activity monitoring, pedometers, sleep trackers, and heart-rate monitors, which are the most widely adopted applications and are often tracked currently by fobs, wristbands, or, in some cases, smartphones.

Other important wearable technologies such as smart watches have recently been released by startups such as Pebble as well as large, established companies such as Samsung and Sony. Qualcomm has also entered the space with the introduction of Toq, which uses the company’s Mirasol display technology as well as WiPower, wireless charging. However, Toq is expected to be a limited release where Qualcomm’s primary goal is to develop interest from partner companies to commercialize the display and wireless charging technologies. Fitbit is another startup that offers various fitness / wellness monitors. Google continues its Google Glass development and has several early adopters in its Explorer Program that are testing various applications and use cases.

Connected Car

Connected car was a major theme of CES 2014 with both Audi and Chevrolet announcing plans implementing 4G telematics in vehicles in 2014. Within the decade it is expected that all automakers will offer connected car and premium infotainment systems. Connected cars would be Internet-equipped and may also include a wireless LAN, thus allowing Internet access to devices both inside and outside of the vehicle. Vehicles could also be equipped with additional sensors that would enable enhancements such as crash prevention, remote diagnostics, and other benefits.

Several companies from multiple verticals are developing products and services for connected car and infotainment systems (e.g., AT&T, Google, Microsoft, Apple (AAPL, Buy, $556.18), Broadcom, Qualcomm, and others).

Connected Home

Similar to connected car, connected home was a notable theme at CES 2014. There are several use cases in this broad category such as security, thermostat control, connected appliances, and media. Many applications can be controlled remotely using a smartphone or a tablet. At this time, it’s unclear if the benefits of many connected home applications will outweigh the costs. For example, most existing thermostats are already “smart”. There are many incumbent, traditional suppliers of home security and it remains to be seen if consumers will pay a premium for "smart" appliances.

Similar to connected car applications, companies from several verticals are offering products and services for connected home applications. For example, Comcast offers home security when bundled with cable, phone, and Internet, and AT&T has rolled out remote door control that lets homeowners remotely open their doors for trusted users while the homeowner is away. Appliance makers such as Haier have made product announcements at CES. Qualcomm has introduced AllPlay, a platform that allows for wireless streaming of media across different brands of equipment. Dropcam is a company that provides wireless video monitoring and cloud recording that can also be accessed / controlled by a smartphone or tablet. Finally, Google has recently acquired Nest, an early smart thermostat provider.
Smart City (e.g., energy / grid, parking, others)

Smart City use cases cover a broad area of governmental-focused initiatives with aims of saving money (e.g., energy, grid, lighting, manpower, etc.) or generating revenue (e.g., parking). Examples of smart city IoT initiatives include monitoring the available parking spaces in a city and communicating open spaces to motorists attempting to park to minimize the time a driver spends searching for free spaces and reduce energy wasted by vehicles as the driver circles around looking for parking. Cities can also generate revenues through smart parking meters by pricing parking so that the rate is higher at peak periods. Another smart city device is smart lighting, which adjusts the intensity of light emitted from public street lamps based on the time of day and weather conditions to minimize waste. Smarter water control is another example where IoT can play a role. In essence, when leaks are detected by sensors, an intelligent system can automatically divert water away from pipes that are leaking. Smart utility meters that track utility usage such as electricity, gas, and water also save manpower since connecting the meters online will eliminate the need for workers to manually check utility meters for billing purposes. Real-time utility reading can also send useful alerts instantly when abnormal usage is detected. Although the design and implementation of smart city features has fallen to “big data” IT services companies such as IBM, hardware companies like Cisco have increasingly sought to expand into the smart city IT services space to expand their potential addressable market.

Industrial

Industrial usage originated from RFID tagging, which enabled assets or products to be tracked in real-time. Current examples of industrial uses for sensors include placing sensors on a multitude of industrial assets to track their designed thresholds and to send out alerts for maintenance before the industrial asset fails. Other uses include the use of networked sensors, cameras, and lasers to analyze manufacturing processes to determine if a part is good or bad based on its physical characteristics along with trends, variations, and relationships in the manufacturing system over time. Industrial safety is also another area with examples such as electronic fire extinguisher systems that send alerts out when the extinguisher is blocked or missing from its designated area.

Retail and Supply Chain Management

IoT examples for retail include shelves with weight sensors that communicate with the inventory system whenever the weight measured on the shelf is too light – indicating products should be restocked and reordered. Other supply chain examples include fleet management. By embedding sensors onto retail fleet vehicles, data such as location, temperature, speed, maintenance alerts, etc. can be tracked to optimize fuel, time, and repair costs. Other supply chain examples include the monitoring of temperature storage conditions in cold storage units moving frozen foods and creating alerts if temperature control systems fail. Another area of retail involves the use of online payment systems using near-field communications to wirelessly pay for goods. Airports have also benefited from sensors with airport luggage systems that tag a piece of luggage which moves through a conveyor belt. The luggage is then directed automatically by the next conveyor belt by reading the tag on the luggage. Finally, one of the biggest retail initiatives is the use of location-based services, which essentially track a user’s location (usually through their personal smartphone) and deliver ads or discounts for products or services based on the user’s current location or locations he or she has previously visited. Apple, through iBeacon that is available on iPhones, and Qualcomm, with its Gimbal product offering, are both addressing location-based context-aware retail opportunities.
Enablers of the Internet of Things

For IoT to become a reality broadly, improvements / enhancements in a number of areas are required. There still remains a lack of common standards or protocols between devices to communicate with one another. There are also a number of connectivity options such as cellular (2G / 3G / LTE), Wi-Fi, ZigBee, Bluetooth, etc. A non-exhaustive list of enabling technologies for the Internet of Things is listed below:

- Ultra-low-power wireless connectivity (e.g., cellular (2G/3G/LTE), Wi-Fi, Zig-Bee, NFC, Bluetooth, etc.)
- Sensors (e.g., temperature, motion, location, etc.), microcontrollers, batteries, and other components
- Software that allows autonomic computing and helps a networked device interpret data and make decisions
- Communication standards / protocols (similar to HTTP for Internet protocol)
- Security
- Applications
- Network infrastructure

Companies in our coverage universe are working on various enablers, most notably and not surprisingly wireless connectivity, communication standards, and network infrastructure, which we discuss in more detail below.

Ultra-low power wireless connectivity

There are multiple means for devices to communicate with others with pros and cons for each solution. Long battery life is a must for IoT applications and ultra-low power is a common requirement for any communication means. Depending on the application, one technology may be more advantageous to employ than others. Typical wireless connectivity technologies include cellular (2G, 3G, LTE), Wi-Fi, Bluetooth (including low-energy BT), Zig-Bee, and NFC (near field communication). The advantage of using one technology over another depends on the use case as each technology offers unique range and data rate characteristics (see Wireless Landscape exhibit below).

For example, NFC works well for in-store payments or locking / unlocking doors. Qualcomm’s Gimbal proximity and context aware technology uses low-energy Bluetooth and is suited for customized retail experiences. There are several examples of connected homes and connected cars that use cellular and/or Wi-Fi technology. ZigBee, which is based on IEEE 802.15.4 standard (low-rate wireless personal area networks (LR-WPANs)), is intended for low-cost, low-power applications. There are ZigBee use cases in connected home (lighting / thermostat), industrial, building automation, and others. Naturally, vendors with strengths in the various technologies are promoting IoT-focused products (Broadcom and Qualcomm Atheros for Wi-Fi, Qualcomm for cellular, etc.).
Communications Standards

Communication protocols for IoT applications go hand-in-hand with wireless connectivity. There are numerous competing standards, and lack of common standards is often cited as a hurdle for broad IoT adoption. Many industrial networks still use legacy or proprietary protocols such as Modbus RTU, RP-570, Profbus, etc. that are incompatible with TCP/IP. However, as the convergence of networks toward one common protocol IP occurs, legacy industrial equipment using proprietary protocols are likely to be eventually transitioned to IP-based industrial equipment. The possibility of adding tens of billions of devices in the next decade will also stretch the limits of IPv4, which only supported 4.3b IP addresses. However, the adoption of IPv6 solves this issue with an extremely large 340.3 undecillion (2^128) available IP addresses.

Qualcomm, through its open source AllJoyn framework, looks to solve issues of connecting different devices, allowing such devices to recognize one another and share information, even across brands, networks, and operating systems. Qualcomm is the lead backer behind the AllSeen Alliance consortium which, according to its website, is “dedicated to enabling and driving the widespread adoption of products, systems and services that support the Internet of Everything with an open, universal development framework supported by a vibrant ecosystem and thriving technical community. It is the broadest cross-industry consortium to date to advance adoption and innovation in the “Internet of Everything” in homes and industry”. In essence, Qualcomm, the AllSeen Alliance, and other organizations are trying to solve incompatibility issues that can arise with multiple protocols and communication standards.
Network infrastructure

IoT will require an incredible amount of storage and processing capacity to analyze the potentially trillions of message data flowing across billions of devices. While existing networking infrastructure equipment such as routers, switches, access points, and controllers can already handle the short and frequent nature of machine data being transmitted, enhancements to allow programmability and scalability will be key to automating the turn up and turn down of services that an intelligent network making decisions off of real-time/near real-time data demands. This programmability and scalability of network infrastructure on demand is the key to delivering the full promise of IoT – a world where real-world data can be collected, processed, and ultimately used by intelligent systems to automatically turn on (or off) useful services. To support this vision, access via open APIs to the underlying hardware will be necessary to deliver this programmable and scalable network. Also, the continuation of falling costs for storage and wireless coverage will enable enterprises and cities to store the vast amounts of collected data and provide the ubiquitous wireless coverage needed to track the ever-increasing number of online devices.

Qualcomm

Qualcomm’s Internet of Everything (IoE) Product / Platform Overview

Qualcomm has several product offerings and initiatives that address the Internet of Things market. Qualcomm’s AllJoyn platform is an open source software platform that enables connectivity and, from Qualcomm’s perspective, looks to enable developers to design IoE solutions around Qualcomm’s products. The platform lets compatible smart “things” recognize each other and “share resources and information across brands, networks, and operating systems,” according to the original AllJoyn press release. Qualcomm Atheros (QCA) division also announced a chip family to address low-power Wi-Fi solutions. The QCA4xxx family of chips includes processors and memory and targets applications such as home appliances, consumer electronics, and sensors. Qualcomm has also recently launched cellular and Wi-Fi chipsets that focus on connected home and connected car applications. The company has teamed up with software companies and is also working on open source platforms to address specific IoT initiatives such as healthcare. AllPlay is a practical use case that allows for wireless media streaming between different branded devices. Finally, Qualcomm has directly entered the wearables space with its Toq offering, though the product is designed to be a proof of concept and generate partner interest in Qualcomm’s display (Mirasol) and wireless charging technologies. We discuss Qualcomm’s various products / platform initiatives below.

Wearables

In September 2013, Qualcomm introduced the Toq smartwatch and has sold the smartwatch in limited quantities over the holiday timeframe. Qualcomm will not likely commercialize the technology, but rather, the company is looking to develop partner interest in Qualcomm’s captive Mirasol display technology and wireless charging technologies.

Healthcare

Through its Qualcomm Life subsidiary, the company is addressing the health monitoring space with its 2net Mobile offering. 2net Mobile is a software module designed to enable aggregation of clinical data from medical device sensors and then stream them through mobile devices securely to medical care providers. Currently the 2net Mobile platform works on Android devices. In addition, Qualcomm chipsets (cellular and Wi-Fi) enable applications such as Personal Emergency Response Systems (PERS) as part of mobile health.

Connected Home

Qualcomm has several initiatives in the connected home space addressing energy management and home automation to name a few. At the core, Qualcomm is offering Wi-Fi and cellular chipsets that address smart home applications. For example, Qualcomm’s Internet Processor (IPQ) and 802.11ac Wi-Fi products support connected
devices allowing for an enhanced consumer experience in the home. Additionally, smart metering is enabled by cellular connectivity (3G / LTE). The exhibit below shows a view of connected home envisioned by Qualcomm.

**Qualcomm View of Intelligent Home**

![Intelligent Home Diagram](image)

*Source: Qualcomm*

Haier, a home appliance maker, announced that a Qualcomm Atheros product has been incorporated into a washer/dryer combo and air conditioner.

Another connected home use case supported by Qualcomm is through AllPlay, which is built on the AllJoyn platform. AllPlay allows for wireless music stream across device types that can be controlled by smartphones or tablets.

**Connected Car / Infotainment**

Qualcomm has several products and programs addressing connected car and infotainment applications. The company is developing Wi-Fi and cellular products for telematics and working with automobile OEMs, suppliers, service providers, and applications developers. Qualcomm products are already used in electric vehicles and electric vehicle charging stations.

At CES 2014, Qualcomm introduced a chipset called Snapdragon 602A specifically for automobile infotainment system applications.

The following exhibit shows a view of connected car envisioned by Qualcomm.
Qualcomm view on Connected Car

Qualcomm, through its Qualcomm Retail Solutions subsidiary, has developed Gimbal, a context and location aware platform that allows for geofencing and customized consumer engagements. Qualcomm proximity beacons have also been certified to meet Apple performance standards and, thus, iBeacon-enabled apps on Apple phones and tablets can be developed.

Conclusion

Though Qualcomm has multiple activities in the IoT / IoE domain, we view 2014 as a year of early adoption and technology shakeout where there will be many initial winners and losers. We do not expect meaningful revenue contribution in 2014, but do believe several of Qualcomm’s product and platform initiatives should bear fruit over time. Qualcomm has clear strengths in cellular technology and, to a lesser extent, Wi-Fi connectivity technologies. Qualcomm has less strength in areas such as sensors and, thus, would be likely to partner with sensor companies in order to offer comprehensive solutions.
Cisco
The Internet of Everything (IoE)

Cisco defines IoE as IoT with actionable network intelligence added in to better allow convergence, orchestration, and visibility across previously disparate systems. Given the large expansion predicted in connected devices (from 12.5b in 2010 to 25b by 2015E and 50b by 2020E) and the expected expansion in network infrastructure required to support IoE, Cisco has set the goal of being the connecting platform for an IoE world that extends from networking to security to embedded technology. Cisco has projected the IoE market to be a $19 trillion opportunity and positively impact corporate profits by 21% by 2022. While Cisco estimates that IoT was only “born” sometime around 2008-2009, the company has already created initiatives such as Cisco’s Planetary Skin (a global array of environmental sensors), smart grid, and intelligent vehicles.

Conceptually, Cisco sees IoE as a network of networks that is made up of a loose collection of disparate, purpose-built networks such as the multiple networks that control engine functions, safety features, communication systems, etc. within a car. Buildings systems also have various systems for heating, venting, and air conditioning that can be connected with added security, analytics, and management features – allowing IoE to deliver more usefulness to humanity.

Cisco has heavily emphasized IoE because the company considers IoE to be the next definable era of the Internet. Historically, Cisco sees the Internet as having four previous stages. Stage 1 was the creation of the Advanced Research Projects Agency Network (ARPANET) which was the precursor network to the Internet, stage 2 was the domain name “gold rush” characterized by almost every company desiring a web presence, stage 3 involved the evolution of ecommerce sites such as eBay and Amazon, and stage 4 was the rise of social media sites such as Facebook and Twitter. Now, Cisco believes we have entered the next major stage of the Internet with the eventual connection of billions of devices and improved data analytics that defines an IoE world. The company sees IoE as a critical market to tackle as the size of the market opportunity is quite large and also from a humanistic view as IoE will help combat global resource constraints that are increasingly being encountered as the world population continues to grow while global resources remain limited or begin to deplete. An IoE world with smart cities would help conserve electricity, fuel, and material resources as a better understanding of how devices are used in real-time allows the world’s resources and productive assets to be used more efficiently. Even live animals such as livestock (or people) can benefit from sensors that can track their health to best ensure their healthy growth and survival.

Challenges to IoE Adoption

Cisco argues that challenges to the adoption of IoE include the limited amount of IP addresses available under IPv4, but the adoption of IPv6 will eventually overcome this issue. Power for sensors, however, remains a key challenge as the human resources required to manually replace or recharge billions of sensors would be unfathomably costly. The need for self-sustaining sensors is critical to truly bringing the estimated 50 billion or so devices Cisco anticipates will be online by 2020. Innovations in batteries that generate electricity from environmental elements such as vibrations, light, and airflow could potentially solve the power issue. Finally, having a common communications standard will be vital to ensuring the billions of connected devices can securely and seamlessly communicate with each other and to the network intelligence.

Cisco’s IoE Strategy and Products

The company’s functional focus for IoE will be on sensors, security, real-time analytics, and applications in the verticals of manufacturing, oil and gas, mining, defense, transportation, smart cities, and energy. Also, the company is pushing manufacturers to transition proprietary industrial networks into a single IP-based network – similar to the convergence of formerly disparate voice, video, and data networks into one IP-based network.
An IoE world is one with potentially billions of sensors, which leads to a staggering amount of data that is transmitted and stored. Eventually, intelligent systems will likely be designed that can automatically take actions based on analyzing the data collected. This world vision would require networks that are capable of programmatically turning up or turning down services, and Cisco’s IoE strategy revolves around delivering this scalable, programmable network.

Cisco’s role in an IoE world, in our view, will be delivering networking products through its pre-existing wired and wireless network infrastructure products such as access points, wireless LAN controllers, switches, and IP phones. Given the IP-centric nature of Cisco’s networking products, IoE will result in evolutionary changes to existing products rather than revolutionary ones. For instance, the biggest platform/technology change Cisco has introduced to date to address IoE include its nPower X1 network processor, an ultra-scalable and programmable network processor that powers the Network Convergence System (NCS) line of integrated packet and transport systems and Carrier Routing System (CRS) line of routers.

Cisco’s NCS is a network fabric targeted at service providers specifically to prepare networks for an IoE world with more machine-to-machine messages. The system will be the central nervous system of IoE and features programmability and virtualization capabilities that greatly improve service deployment speeds and lower costs.

Speed of deployment for new services and the ability to automate deployment of services are critical in an IoE world where real-world information captured by sensors can be processed and intelligence can be used to automatically turn up services. NCS plays a role in this type of network architecture because it is designed to scale Cisco’s Carrier Routing System (CRS) core routers and ASR 900 Edge routers from centralized systems to distributed architectures to facilitate the growth of Internet-connected devices like cars, homes, and machines. As a central nervous system NCS is designed to shift and redirect data center, core, edge, and optical networking resources in real-time to speed up delivery of services and reduce operational costs. NCS can also harness distributed network functions and other Cisco virtualization features to enable cross-domain function orchestration and service placement. A key technology enabling programmability is the nPower X1 processor, which allows NCS to automate the turn up (or turn down) of new services. The nPower X1 process is the first chip ever built with a multi-terabit silicon architecture and powers the NCS 600 and CRS-X. Current NCS customers include BSkyB, KDDI, and Telstra.

Currently, the NCS family of products includes the NCS 6000, NCS 4000, and NCS 2000 as a part of the Evolved Programmable Network portfolio. The NCS 6000, available now, features 5Tbps per slot, 1.2Pbps per system speeds, supports IP/MPLS routing, and single, back-to-back, and multi-chassis configurations. The NCS 4000, which ships in 1H14, supports 400Gbps per slot and 6.4Tbps per system, and single, back-to-back, and multi-chassis configurations. Also, it supports optical transport network, WDM, SONET, and Ethernet applications. The NCS 2000, also shipping now, connects DWDM transport networks at speeds of 100+Gbps and supports dynamic network configurability with 96 channel ROADM features.

Conclusion

Having dominant market share in enterprise IT networks places Cisco in prime position to capitalize on the expected proliferation of devices employing wireless sensors in an IoE world. The basic networking infrastructure and technologies (routers, switches, access points, etc.) are already in place and the introduction of programmable and scalable networking equipment should only serve to enhance automation and more efficient use of resources within the real world. Arguably, the key drivers going forward for enabling IoE is the invention of new use cases for sensor-enabled devices and the continuation of falling costs for sensors and networking equipment, which would open up even more business processes to benefit from the IoE.
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