The Internet of Things is emerging as an unprecedented business opportunity for many players in the communications, Information Technology (IT) and consumer electronics industries. Although today’s media focus is mainly on devices and applications, we need to understand that the network can “make or break” this next step in the evolution of the Internet. This paper discusses how to leverage machine-to-machine communications, big data analytics and the cloud to power a smarter world and monetize the Internet of Things.
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Introduction

The convergence of machine-to-machine (M2M) communications, big data analytics and the growth in connected devices is enabling a highly connected world known as the Internet of Things (IoT).

The coming decades will be characterized by billions of smart devices, trillions of dollars in economic growth and cost savings, and exabytes of sensor-generated data. In this environment, the IoT is emerging as an unprecedented business opportunity for many players in the communications, Information Technology (IT) and consumer electronics industries. Although today’s media focus is mainly on devices and applications, we need to understand that the network can “make or break” this next step in the evolution of the Internet.

From the WWW to the IoT

Over the past decades, the Internet has evolved from a static repository of interlinked hypertext documents to a dynamic universe of networked humans, machines and applications (see Figure 1).

Figure 1. The next step in internet evolution

The Internet of content

We could say that the real Internet, as we all use it today, started in the early 1990s with the definition of HTTP and the creation of the World Wide Web (WWW). Throughout this first phase, the web was static and used mainly to publish and share content.

The Internet of services

Then, user-created content, XML, web services, and a broad range of commerce, productivity and collaboration tools led us forever away from the static pages of the early websites. This is when we started talking about Web 2.0.
The Internet of people
With the availability of affordable mobile broadband access, the proliferation of smartphones and tablets, and the booming popularity of social network apps came a third phase in Internet evolution. That’s where we are today.

The Internet of things
Now we are at the beginning of the next revolution in the way we’re using the Internet — a revolution that is enabled by M2M communications and big data analytics.

Daily life changes when everyday objects connect and become part of information systems and end-user applications, and create an unlimited, ubiquitous and connected universe in which machines and humans interact to make our society safer, greener and healthier.

So, it’s not really a big surprise that the Internet of Things was at the top of the 2014 and 2015 editions of Gartner’s Hype Cycle for Emerging Technologies, with an anticipated 5 to 10 year period to reach full maturity.

An unprecedented opportunity
The Internet of Things is emerging as an unprecedented opportunity for many players, leveraging the convergence of consumer electronics, communications and IT technologies. (Only the last two are addressed in this paper.) Most analysts acknowledge this is the right time to create and commercialize new devices and applications — and to change the way we live and work through new and innovative services.

• IDC expects the global IoT market to triple from 1.9 trillion US dollars in 2013 to 7.1 trillion in 2020, with 28.1 billion “things” connected [1].

• Gartner forecasts that 4.9 billion connected things will be in use in 2015, up 30 percent from 2014, and that the number will reach 25 billion by 2020. They observe that “The Internet of Things has become a powerful force for business transformation, and its disruptive impact will be felt across all industries and all areas of society” [2].

Futurists have been talking about smart cars and intelligent buildings for many years, but M2M communications and data analytics are not as new as many believe. For more than 40 years supervisory control and data acquisition (SCADA) has helped transportation, utilities and industrial companies to manage applications, optimize processes and reduce the cost of operations [3]. And Henry Ford is said to have measured pacing of the Model-T assembly line more than a century ago. But it’s only very recently that the various technologies have come together to deliver affordable and scalable products and services.
M2M communications enable a world of connected services

M2M is a broad label, used to describe any technology that enables connected devices to exchange information over short-range and wide-range wireless and wired networks, and perform actions without the manual assistance of humans.

Decreasing hardware costs and ubiquitous mobile access are enabling smarter endpoints and seamless connectivity. Adding a few sensor chips or a wireless connectivity module to a new product or device is not going to raise its price dramatically. The average smartphone contains about a dozen sensors, and a modern car may have 100 on board.

The proliferation of these mobile devices and M2M endpoints is creating a whole range of opportunities for new applications. These endpoints constitute the foundation of sensor networks that enable monitoring and remote control of daily life objects at home, in the city, in your car, at the office, and so on.

Wireless and wired data networks are the backbone of the IoT. LTE networks complement short-range wireless technologies such as ZigBee, Z-Wave, Bluetooth® and Wi-Fi® to assure wide-area M2M connectivity. Further evolution of 3GPP standards, such as NB-IoT (narrowband IoT), eMTC (Enhanced Machine Type Communication) and EC-GSM (Extended Coverage GSM) will optimize today's mobile networks for IoT applications, and Cat-0 and Cat-M (low-speed, low-power) devices. Fixed broadband gateways and small cells also have a role to play in providing in-building coverage and accelerating the deployment of new applications in connected homes and offices.

The ever-growing number and variety of networked devices will require a scalable and more energy- and resource-efficient network. Sensor-generated data will be massive, M2M endpoints and applications may behave differently, and traffic patterns may be very application specific.

5G, the next-generation mobile network, will be designed to provide optimal performance and a superior customer experience for all services, supporting the broadest possible range, from video streaming to IoT applications. 5G is expected to be more spectrally efficient, support much higher device connection densities, prolong device battery life, widen network coverage and reduce signaling overhead.

Thriving on the 4 V's of big data

As sensors and devices spread across almost every industry, the Internet of Things is going to trigger a massive influx of big data. An abundance of generated data, combined with algorithms and tools to analyze this information, and a growing understanding of how collective data can be used, will add greater efficiency to our lives.

From an IT perspective, the IoT is thriving on the “4 V's” of big data: volume, velocity, variety and value.
Volume (data at rest)

The world’s data volume is set to grow 40% per year, up to 50x by 2020, of which 35% of stored data contains information that might be valuable if analyzed. Nearly 40% of this information will be “touched” by cloud providers [4].

Velocity (data in motion)

The average broadband speed is growing by a factor of 3 in the period 2012–2017, and the world may have exascale\(^1\) computers before 2020, with a 1000x performance improvement over machines of 2010 [5].

Variety (data in many forms)

100 TB of data is uploaded to Facebook daily as well as 48 hours of YouTube video every minute. In healthcare, electrocardiogram graphs can be generated based on 1,000 readings a second, while heart rate, respiration rate and blood oxygen are displayed each second, resulting in 86,400 readings per day [6]. At the same time, 92.1 million DVDs are “filled” daily with the information produced by all the new video surveillance cameras installed worldwide in 2013 [7].

Value (data enriching our daily lives)

Eighty-three percent of US government IT professionals say real-time data offers substantial savings. Eighty-seven percent say it can save a significant number of lives. Seventy-five percent say that big data can help improve the quality of citizens’ lives [8]. As storage and processor hardware further evolve, and the capabilities of data analytics and Artificial Intelligence software develop, consumers and businesses will get more and more value from big data (see Figure 2).

Figure 2. Big data’s incremental value for application users

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\(^1\) Exascale computers are capable of at least one exaFLOPS: a billion billion calculations per second.
The long tail of applications

The “long tail” model was introduced many years ago to describe the creation and distribution of video content, with a few Hollywood blockbusters on the left and a massive amount of user-generated YouTube-style movies in the long tail.

The same model is also valid for characterizing the apps that all of us have installed on our Apple iOS or Android tablets and smartphones today, and it looks like a good model to segment IoT applications, too (see Figure 3).

Figure 3. The IoT’s long tail of applications

In search of the killer app

It’s very likely that over time a few “killer” apps will emerge, potentially with hundreds of millions of devices connected. We could call them the Facebooks of the Internet of Things — though it may still be too early to predict which ones will be successful and which ones won’t.

Addressing the long tail

There will also be a very long tail of IoT devices and applications — consumer gadgets such as the smart toothbrush or the connected dog collar, or hobbyist developments on Arduino boards and the like.

Providing value to verticals

From a business perspective, however, the most interesting part of Figure 3 is “segment/industry/business specific.” In the short term, the most interesting opportunities will be in vertical industry segments, where M2M applications will contribute to productivity, cost savings and/or customer experience transformation.
The IoT will power a smarter world

To be successful in M2M business today, good segmentation and a clear understanding of each industry sector’s specific requirements as well as a compelling value proposition are important.

Figure 4. Map of IoT domains and verticals

A 2013 global survey conducted by TechRepublic and ZDnet [10] revealed that developing new business opportunities is a key decision driver for IoT implementation. Enhancing existing products/services and providing faster response times are also top priorities. Cost savings came in a distant fourth, with less than half of respondents rating this decision driver as important or very important.

Enabled by wireless and wireline data networks and IoT platforms, new and innovative IoT applications will contribute to lifestyle, safety, productivity and energy savings and also provide a better customer or user experience. Many devices and applications have already found their way to the public, either as prototypes or commercial products.

Smarter living (consumer and home segment)

IoT technology can help meet people’s basic needs for safety, security and food while enriching their home with digital lifestyle, comfort and entertainment applications. Gartner says that, by 2022, a typical family home could contain more than 500 smart devices [11].
• Home-energy equipment and safety and security systems will become popular first, leading the way to broader consumer adoption [12].

• In 2014, 13% of US households owned at least one smart home device, and 26% intended to acquire any device/system within 12 months [13].

• By 2020, the connected kitchen will contribute at least 15% savings in the food and beverage industry while leveraging big data analytics [13].

**Smarter vehicles (transportation segments)**

Gartner says that, by 2020, a quarter billion connected vehicles will enable new in-vehicle services and automated driving capabilities [14]. Messages exchanged by these cars and their environment will generate 30 TB of data each day, creating 14.5 billion US dollars in potential big data value worldwide [15].

• A high-end Lexus contains 67 microprocessors, and even the world’s cheapest car, the Tata Nano, has a dozen [16].

• From April 2018 onwards, all new cars in the European Union (EU) will be equipped with eCall technology. In the event of a serious accident, eCall automatically dials 112 — Europe’s single emergency number [17].

• According to the US Transportation Department, direct communication between cars may reduce accidents by up to 80% [18]. In the six years since its self-driving car project began, Google vehicles have been involved in 12 minor accidents during more than 1.8 million miles of autonomous and manual driving combined. Google says that “Not once was the self-driving car the cause of the accident [19].”

**Smarter cities (cross section of all segments)**

• By 2050, 66% of the world population will live in cities [20]. Broadband networks, connected things and open data will help drive competitiveness, sustainability and livability. According to BI Intelligence, urbanized land areas will generate 4.1 TB of data per day per km² by 2016 [21].

• In Amsterdam, the Netherlands, street lighting can be adjusted to improve security and save energy [22].

• San Jose, USA, aims to improve quality of life through real-time data tracking of air quality, traffic flow and more [23].

• The Chattanooga, USA smart grid avoided 58 million minutes of customer interruption [24].

• In Pisa, Italy, an intelligent guidance system lets drivers find a free parking space and pay for it using their smart phone [25].

• In the Spanish city of Santander, waste is collected only when garbage bins are at full capacity [26].

• In Sussex, in the UK, a device worn around the neck lets family and caregivers keep track of people with dementia [27].
Monetizing the IoT

Overall, M2M business is characterized by very small revenues per connection and even smaller margins. According to ABI Research, about 20% of the IoT value chain is in “connectivity” while 77% of revenues are characterized as “value-added services”, including platform revenues, device management, device connectivity, cloud services, application development, system integration, analytics and professional services [28].

One of the often underestimated challenges of building a sustainable M2M business is dealing with a complex and highly fragmented ecosystem in which sensor, SIM card, module and device vendors, network and platform suppliers, application developers, system integrators, and connectivity and service providers are contributing to the value chain.

Communications service providers (CSPs) may play different roles in this chain, complemented by partners (see Figure 5). Their M2M offering may range from connectivity and SIM card wholesale, over device and application onboarding, to solution integration and customization for specific segments or customers.

Figure 5. Possible roles of a communications service provider

<table>
<thead>
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<th>Network + transport</th>
<th>M2M platform</th>
<th>Development portal + storefront</th>
<th>Application hosting</th>
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<td>Partner(s)</td>
<td>Partner(s)</td>
<td>Partner(s)</td>
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<tr>
<td>Connectivity and SIM wholesale</td>
<td>M2M capabilities within intelligent network analytics, traffic optimization and device management</td>
<td>Partner(s)</td>
<td>Partner(s)</td>
</tr>
<tr>
<td>Fostering application to increase network utilization</td>
<td>Integrating “things” into applications</td>
<td>Partner(s)</td>
<td>Partner(s)</td>
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<tr>
<td>End-to-end solutions for vertical markets and consumers</td>
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In this developing business environment, M2M services and solutions are sold directly by service providers as well as indirectly through (or with) partners, such as application developers, vertical solution providers or system integrators [29, 30].

To be successful, service providers will need to conduct a thorough analysis of their strategic priorities and capabilities before determining their best route-to-market for every aspect of the supply chain — and look for innovative business models and partnerships to make the business case flow.
A challenging technology environment

Some processing may happen locally in IoT endpoints but, because of the devices’ small processing and memory footprint and the absence of a human operator, the more complex functions, such as analytics, data aggregation, device management and communication control, will likely be hosted in the network.

In a recent FutureScape report [31], IDC predicts that:

• Within the next five years, more than 90% of all IoT data will be hosted on cloud-based service provider platforms.

• Within three years, 50% of IT networks will transition from having excess capacity to handle the additional IoT devices to being network constrained, with nearly 10% of sites being overwhelmed.

• By 2018, 40% of IoT-created data will be stored, processed, analyzed and acted upon close to, or at the edge, of the network.

• Within two years, 90% of all IT networks will have an IoT-based security breach, although many will be considered “inconveniences.”

• By 2017, 90% of data center and enterprise systems management will rapidly adopt new business models to manage non-traditional [IoT] infrastructure and bring-your-own-device (BYOD) categories.

Current IoT users, service providers and industry analysts all emphasize the need to reduce complexity, to optimize the end-to-end architecture and to provide a better experience for all stakeholders.

Business Insider says, “The IoT lacks a common set of standards and technologies that would allow for compatibility and ease-of-use. There are currently few standards (or regulations) for what is needed to run an IoT device. Consortia that group together global industrial, tech, and electronics companies are involved in an effort to standardize the IoT and solve the most pressing security concerns.” [32]

According to Harbor Research, “Current IT and telecom technologists are operating with outdated models of data, networking and information management that were conceived in the mainframe and client-server eras and cannot serve the needs of a truly connected world. ‘Smart Systems’ should automatically be understood as ‘real-time networked information and computation’, but it isn’t.” [33]

ABI Research agrees:

“... a key challenge for the industry remains the complexity of developing, deploying, and managing M2M applications ... This is a challenge both for mobile network operators that are trying to offer profitable services tailored to the M2M market, as well as for application developers and service providers that are trying to reduce costs, speed time to market, and simplify robust application deployments.” [34]
The value of the network

It should be clear that the Internet of Things (r)evolution can only succeed when it’s supported by a network that allows scalable deployment, secure delivery, cost-effective operations and fast time-to-market of new applications.

Performance

Basically, in an IoT network there are two opposite-directional data flows:

• A device-outbound stream, through which sensor and device data are delivered to the network, the data center and the respective applications

• A device-inbound flow through which actuation, control and management information is delivered to M2M devices and gateways

In most cases, the device-to-application (upstream) data will far outweigh the application-to-device (downstream) traffic. But at times, there will be significant throughput in the latter direction, too. In the upstream direction, the traffic may be very application specific — sometimes the flow will be continuous and sometimes bursty (see Figure 6).

Traffic modeling by Bell Labs has revealed that M2M applications may consume up to 67% of computing resources in the radio network controller. Access channel capacity does not appear to pose a problem, nor does data volume.

Figure 6. Traffic modeling of different IoT applications

Scalability

The IoT growth figures cited are impressive. The time is now for anticipating massive up-take of devices, applications, traffic, and profile and usage data. This can be achieved only through a network and platform infrastructure that is scalable by design: this is a network that includes overload protection mechanisms at the radio access network (RAN) and in the core network combined with application-level control to enable more efficient use of network resources [35].
Because many of the capabilities will be implemented in the cloud, software-defined networks (SDNs) and network functions virtualization (NFV)-based networks will provide carriers and enterprises with the necessary means to cope with and manage the growing number of devices and applications, and the IP traffic they generate.

Manageability

Because some devices may be deeply embedded in third-party infrastructure (such as industrial equipment, transportation containers and cars) and may have no registered owner at all, remote management capabilities become extremely important.

The adoption of device management and service automation capabilities will also help the M2M service providers accelerate device and application onboarding while reducing operating costs.

These capabilities streamline tasks such as [36]:

- Remote device activation and bootstrapping
- Device configuration
- Troubleshooting
- Firmware upgrades
- Application lifecycle management

Horizontalization

The legacy M2M market has been fragmented by divergent protocols and custom applications. This fragmentation makes it difficult to communicate with all devices in a unique way and develop solutions that can apply to more than one vertical market.

M2M service providers need to stop deploying separate stovepipes for different applications and work towards an “any device, any app, any network” model. An end-to-end network architecture with a common set of service capabilities, standardized interfaces and open APIs should help them to reduce investments, facilitate partnerships, and speed time-to-market.

Deployment of a horizontal M2M control and management platform will allow service providers to abstract devices and applications from the underlying access networks and technologies, which will in turn result in reduced development effort, lower operational expenses and a better customer experience.

Support for flexible growth

Cloud technologies such as SDN, NFV and data center hosted services will facilitate initial deployment and enable smooth growth of IoT applications. SDN will help transmit and process the data generated by an explosive number of IoT endpoints without putting the network under further pressure, while capabilities such as service chaining, dynamic load management and bandwidth on demand will make service providers more agile.
Infrastructure virtualization is a means to de-risk IoT investments, support innovation and keep operational expenses low. Recent business modeling by Bell Labs has shown that virtualization of the enhanced packet core may lead to up to 40% savings in total cost of ownership (TCO) for M2M services [37].

**Security**

In a world where security and privacy are playing a more and more prominent role, functions such as authentication, authorization, encryption and data protection score high on the IoT checklist.

According to ABI Research, “Most M2M applications are lacking the basic security requirements that have been a de-facto standard for information and communication technologies elsewhere. If not addressed sooner, this weak link could throttle the successful adoption of M2M in healthcare, industrial installations, and consumer homes.” [38]

Security will need to be supported by the network cloud, and not only by the devices. Data centers will need to ensure that information is available at all times and that the big data as well as the connections over which it is transported are protected against loss and unauthorized access. Because CSPs are already seen as “trusted partners”, there is an opportunity for them to build on this relationship in the development and the commercialization of IoT services.

**Interoperability**

To achieve the “any device, any app, any network” objective mentioned earlier, devices and applications need to get abstraction from underlying access networks and technologies. This model can work only when there is maximal interoperability between devices, platforms, data formats, protocols and applications.

Furthermore, because many M2M devices are often characterized by very small power, memory and processor footprints, communication and management protocols need to be simple and lightweight.

The development and adoption of standards such as oneM2M [39] will harmonize device interactions, simplify integration and create economies of scale. Standardization will also make it easier for individual stakeholders to partner and interwork with each other’s components, networks and services.

**Cloud networking**

BI Intelligence forecasts that 40,000 EB of data will be generated globally by 2020 [40]. When M2M platforms open up their data, new applications can leverage intelligence in objects and in the cloud. Huge numbers of data points may be correlated and aggregated into analytics, making networks and applications smarter and giving users full control over different domains such as security, multi-modal transportation, retail, e-government, social statistics, environmental measurements, and senior or child assistance services.
The generation of these analytics and their exploitation needs big data-enabled IT infrastructure. And big data applications require a superior network: backhaul for all connected objects, open data center interconnections, a cloud SDN distributed architecture, and so on.

**Gateways and IoT hubs**

In today’s early IoT market, “things” may connect to the “internet” in different ways, using a broad variety of protocols. The Australian Communications Alliance’s IoT think tank counted like 130 different standards for connecting sensors to networks [41]. Many devices connect to, or even just loop back over, a home gateway or smartphone via short range wireless protocols such as Bluetooth, Zigbee or Z-wave, rather than using a cellular internet connection.

Many devices and applications are delivered as DIY kits (e.g. smart light bulbs and thermostats), while more sophisticated services (e.g. home security) can only be acquired as part of an integrated and managed end-to-end solution. At the same time, OTT players like Apple and Google are launching their (proprietary) frameworks for connecting and managing devices and applications.

Particularly for smart home applications, the residential gateway or home hub may play a key role in routing traffic from/to a wide variety of devices to/from the web.

**Bringing the IoT to life**

The IoT has emerged as an unprecedented business opportunity for many players in the communications, IT and consumer electronics industries — and also a means for service providers, enterprises and vertical markets to enhance productivity, achieve cost savings and/or transform their business.

Nokia is a leading IP networking, ultra-broadband access and cloud specialist. We have the right assets to partner with M2M service providers, enterprises, utility providers and public administrations in building the infrastructure for the Internet of Things, providing a better customer experience at a lower TCO while helping the various players move up the M2M value chain.

For more information about how Nokia can help you navigate the challenges of the Internet of Things, go to:


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