



# Roadmap for **The Emerging “Internet of Things”**

Mark Fell, Managing Director, Carré & Strauss  
with a foreword by  
Hanne Melin, Director Global Public Policy, eBay Inc.





## About the Author

Mark Fell is the Managing Director of Carré & Strauss, a firm that specialises in decision support systems. During the course of a career in strategy, governance and technology he has advised a wide range of organisations, including Arup, BSkyB, Chiquita, Diageo, eBay, Estée Lauder, Europe's blank recording-media industry, the European Cancer Organisation, the European Cooperative Movement, Hydro, Knauf Insulation, LVMH Group, Mastercard, Nutricia, PayPal, Richemont Group, Shecco, UPS and Vodafone. Other relevant publications by the author include a "Manifesto for Smarter Intervention in Complex Systems". Mark Fell holds a Masters Degree in European Politics and Administration from the College of Europe, Bruges, a First Class Honours Degree in Politics from Edinburgh University and has studied at the Institut d'Etudes Politiques, Strasbourg. Married to a Dane, Mark is currently learning Danish and also enjoys endurance running, having completed races at the North Pole, in Antarctica, Greenland, the Sahara, Amazon, Himalaya and Alps, as well as an Ironman Triathlon.

## Acknowledgements

This roadmap emanates from my interaction over the years with clients and colleagues from a wide array of sectors and geographies. In particular, it is the result of my close collaboration with Hanne Melin, Director Global Public Policy, eBay Inc. The roadmap also builds on the work of many thought leaders, including Marco Annunziata, Gary Atkinson, Jarrett Bellini, Jeanne M. Brett, Jonathan Cagan, Hakim Cassimally, Jim Chase, Noel Crawford, Adam Dunkels, Dave Evans, Peter C. Evans, Hugo Fiennes, Neil Gershenfeld, Stephen B. Goldberg, Raghunath Govindachari, Wesley Newcomb Hohfeld, Eric Hunsader, Neil Johnson, Nicholas Johnson, Kaivan Karimi, Eugene Kaspersky, Natalia Kaspersky, Stuart Keeping, Daniel Kellmeriet, Stephen Ferber, Didier Levy, Adrian McEwen, Jing Meng, Daniel Obodovski, Marc O'Neil, Tim O'Reilly, Marc Rogers, Gregory Pankert, Hong Qi, Ansgar Schlautmann, John G. Sprankling, Karl Steinbuch, Ronak Sutaria, Brian Tivnan, William L. Ury, Jean-Philippe Vasseur, Craig M. Vogel, David Weinberger, Alan Winfield, and Guannan Zhao. Nevertheless this roadmap is my responsibility and mine alone, as are any errors and omissions.

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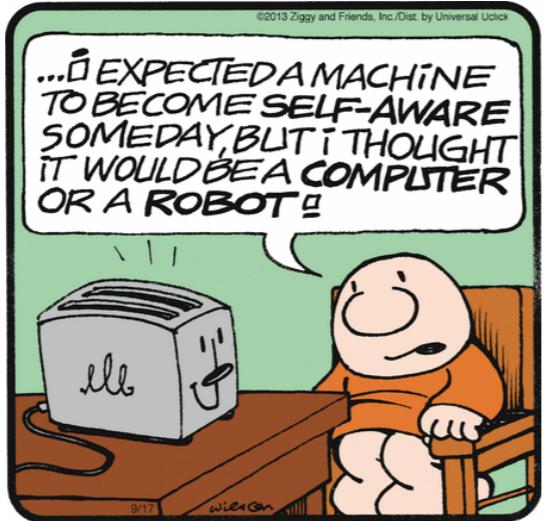
# Executive Summary

"In a few decades' time, computers will be interwoven into almost every industrial product", wrote computer scientist Karl Steinbuch in 1966. Coupled with connectivity, this prediction is finally coming to fruition. It is called the 'Internet of Things' (IoT) and it has the potential to change every aspect of the economy, society, politics and the environment.

This roadmap therefore takes the reader on a journey, starting with an examination of the IoT's principal characteristics, massive scale and impact. To bring things to life it provides concrete examples and demonstrates how the IoT is heading towards a world of 'Everything-as-a-Service' (XaaS).

The roadmap then examines the technology that makes the IoT possible - a world of sensors, actuators, microcontrollers, connectivity and the cloud. From here it explores how a complex and scattered value chain is bringing this technology architecture to market.

This leads the roadmap to address the future governance of the IoT. For if the IoT is to deliver on its promise of a better world then it is going to need to successfully address a whole series of powers, rights and interests. These include power over network standards, power over products and their



distribution, power over network traffic, as well as power over services and their distribution. Rights, such as property and privacy, are going to need to be safeguarded. Security is going to have to be guaranteed, as is competition in the marketplace. With a plethora of IoT stakeholder interests dispersed across a highly fluid value chain this is not a trivial task.

To assist with developing good governance in the IoT this roadmap proposes a three step process. This process is grounded in the 'Smarter Intervention in Complex Systems' methodology. It dovetails the IoT's value chain with a regulatory framework for balancing power, rights and interests.

If the IoT can be nudged in the right direction then there is no limit on its potential to enhance our lives.

## Foreword by Hanne Melin

One of the great promises of the Internet of Things (IoT) is as a technology that will “make our lives much easier and safer”.<sup>1</sup> The Everything-as-a-Service (XaaS) world described in this Roadmap can be an Everything-at-your-Service world.

This is a world where connected things serve as our personal concierges, able to anticipate our preferences and trigger a chain of experiences without prompting.<sup>2</sup> This is a world where technology helps you to set and achieve goals, take charge of your life and habits, and optimize your decisions and choices.

We should, however, not take for granted that the IoT will automatically evolve to the benefit of citizens. You find described in this Roadmap how companies wrestle to strategically position themselves across the IoT value chain with significant power – and money – at play.

Now is the time to nudge developments in a direction where also citizens, sitting at the far end of the value chain, are winners.

And commerce is the natural place to start. In the EU, consumer expenditure accounts for about 56% of GDP. Through the power of (informed) choice and active market participation, the consumer is an important player in driving and shaping the European economy. These consumer actions will gradually be carried out in the context of the IoT.

Indeed, commerce is a key area where the impact of a XaaS world will play out. Here, we could see power firmly tilted towards certain stakeholders. Or we could see empowered consumers reward competition and promote Smart Commerce.

For sure, there are architectural pieces missing before a Smart Commerce landscape is a reality. Bill Ready, CEO of Braintree, recently pointed out three of these missing pieces: an open and developer-friendly platform, security, and an agnostic payments OS.<sup>3</sup>

But there are also important policy considerations missing: Are consumers equipped with the requisite power to assert their position in the IoT

value chain? Do consumers enjoy the necessary rights to drive inclusive and sustainable growth in an IoT world? Perhaps most importantly, how do consumer interests look when XaaS meets commerce?

We need a policy debate addressing the intersection of XaaS and commerce because an Everything-at-your-Service world is not one of market segmentation, watered-down ownership, and locked-in services. Some may say these are concerns of an IoT future. But that future is rapidly approaching, and so we are wise to deal with them now.

In 2012, the European Commission took several steps to explore governance of the IoT. But the expert group it convened could not agree and the public consultation it launched provided disparate views.

We need to cut through arguments about for or against specifically regulating the IoT, more or less multi-stakeholder approaches, and what should be the right level of prescriptiveness of IoT governance.

And so, instead of arguments, this Roadmap proposes a framework and a process. It is a framework for policy assessments structured around the IoT technology backbone and the relationships across its value chain. And it is a process for policy interventions directed at the effectiveness of specific systems in reconciling interests, rights and powers among stakeholders in the IoT value chain.

Let's now apply this Roadmap to EU consumer policy and begin ticking off the missing policy considerations!

*Hanne Melin is Director Global Public Policy at eBay Inc. and formerly associate in the EU competition law practice of Sidley Austin LLP based in Brussels*

1) Kaivan Karimi and Gary Atkinson, cited below, see footnote 9

2) See discussion by Gerald Santucci (Head of Unit Knowledge Sharing at the European Commission) about objects as our subjects in the text “The Internet of Things: A Window to Our Future”, available: <http://www.theinternetofthings.eu/content/g%C3%A9rald-santucci-internet-things-window-our-future>

3) Fortune Magazine, 31 July 2014

# Introducing the “Internet of Things” (IoT)

## Scale of the IoT

In 2003, there were 6.3 billion people living on the planet and 500 million devices connected to the Internet. By 2020 there will be 7.6 billion people on the planet and 50 billion devices connected to the Internet.<sup>1</sup> Some estimates put these figures at one trillion Internet connected devices by 2025.<sup>2</sup> Whatever the numbers transpire to be, this rapidly emerging ‘Internet of Things’ (IoT) is set to have a profound impact on our society. According to Kellmereit and Obodovski three factors are driving the meteoric rise of the IoT:<sup>3</sup>

**1. Miniaturization.** Electronic devices have become smaller, more powerful and energy efficient.

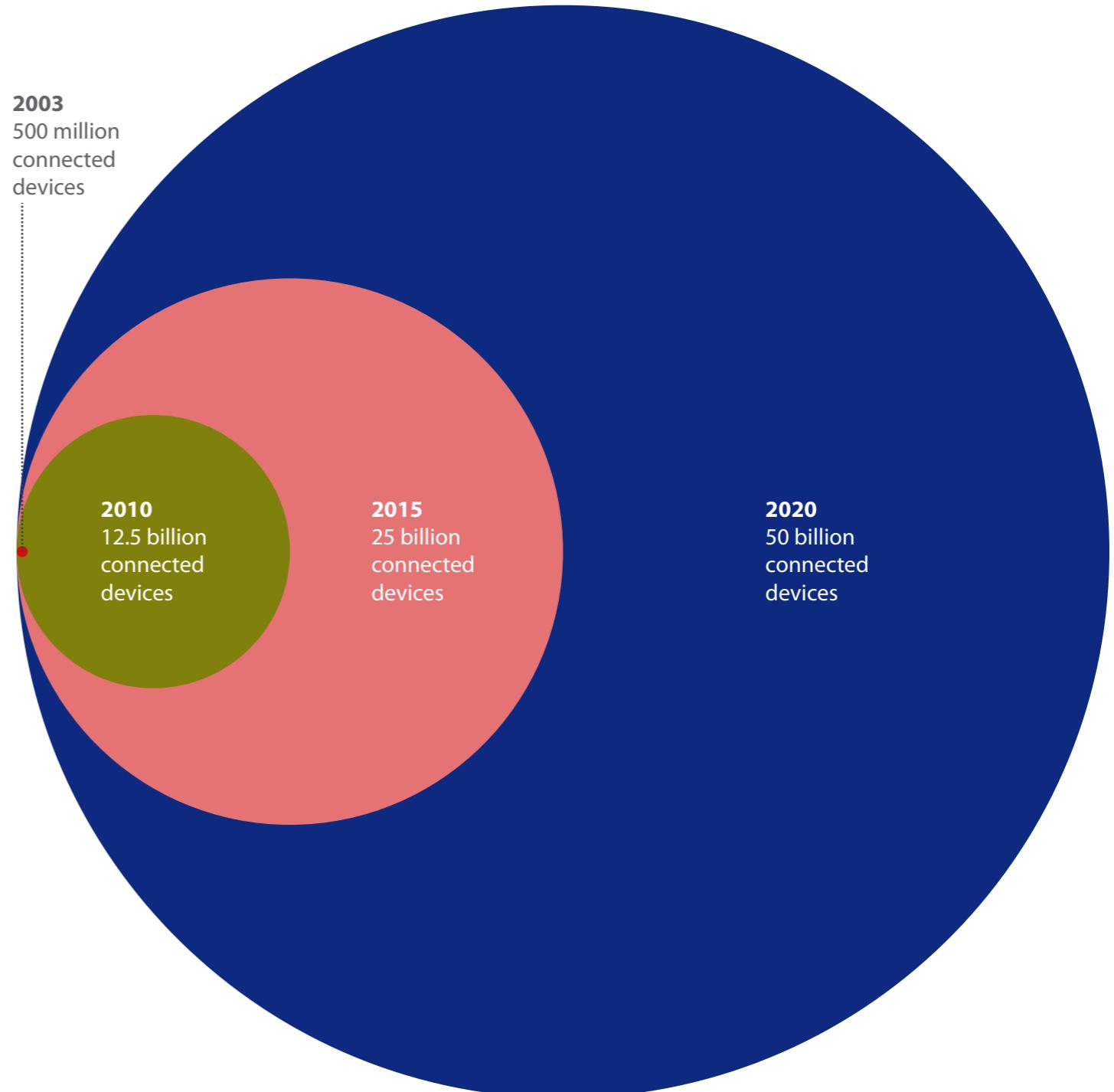
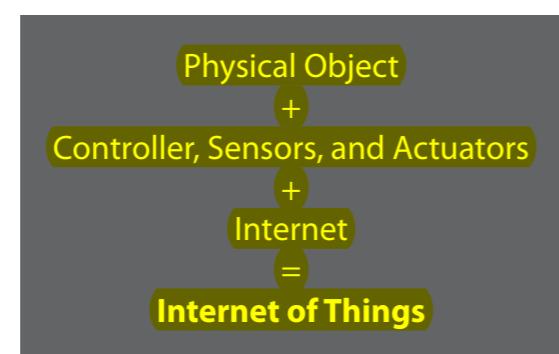
**2. Affordability.** Costs of electronic components and networks have been consistently going down.

**3. De-wireization.** More and more things are becoming wireless – the last wire to disappear will be the power cable.

## Definition of the IoT

The IoT is the result of technological progress in many parallel and often overlapping fields, including those of embedded systems, ubiquitous and pervasive computing, mobile telephony, telemetry and machine-to-machine communication, wireless sensor networks, mobile computing, and computer networking. Therefore the ‘IoT’ means different things to different people.

McEwen and Cassimally have sought to condense the components of the IoT into one simple equation.<sup>4</sup>



1) Estimates made by the authors of, “The Internet of Things - How the Next Evolution of the Internet is Changing Everything”, Dave Evans, Cisco, April 2011, p3

2) A point noted by the authors of, “What the Internet of Things (IoT) Needs to Become a Reality”, Kaivan Karimi of Freescale Semiconductor and Gary Atkinson of ARM, p2

3) “The Silent Intelligence - The Internet of Things”, Daniel Kellmereit and Daniel Obodovski, p14

4) “Designing the Internet of Things”, Adrian McEwen and Hakim Cassimally, p11

**Figure 1**  
Scale of the IoT explosion

Source: Carré & Strauss visualization based on Cisco figures

Similarly, Jim Chase of Texas Instruments offers the following definition of the IoT:<sup>5</sup>

*"The IoT creates an intelligent, invisible network fabric that can be sensed, controlled and programmed. IoT-enabled products employ embedded technology that allow them to communicate, directly or indirectly, with each other or the Internet."*

Adopting a more holistic perspective, Cisco see the IoT as evolving into the networked connection of people, process, data and things. They call this phenomenon the 'Internet of Everything' (IoE).<sup>6</sup>

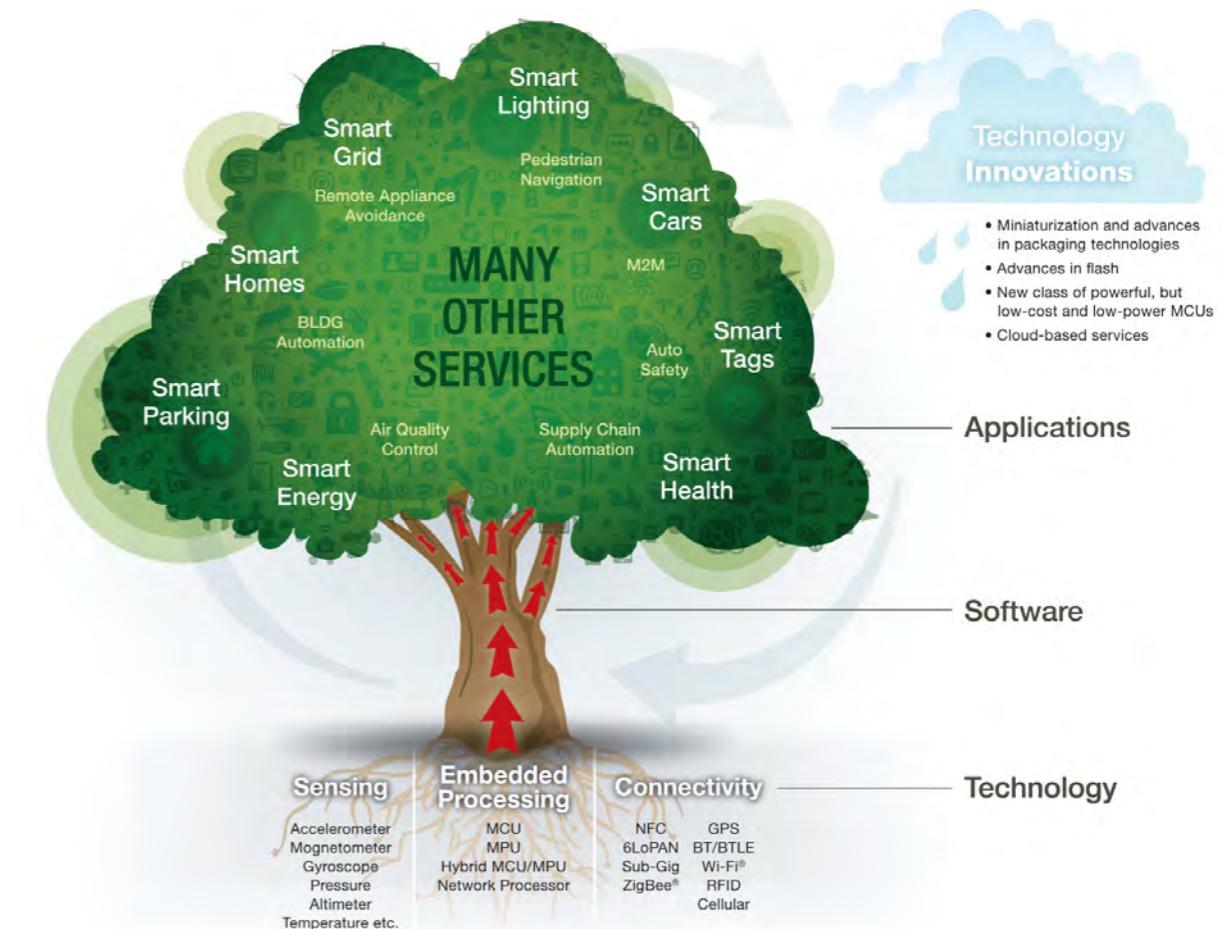
- **People.** Connecting people in more relevant ways.
  - **Process.** Delivering the right information to the right person (or machine) at the right time.
  - **Data.** Leveraging data into more useful information for decision making.
  - **Things.** Physical devices and objects connected to the Internet and each other for intelligent decision making.
- IBM talk of a 'Smarter Planet' by which they mean organisations and societies becoming instrumented, interconnected and intelligent.<sup>8</sup> They enthuse about 'Smarter Commerce', 'Smarter Products', 'Smarter Cities', etc.
- Others speak of 'Machine to Machine', 'Machine to Infrastructure', 'Machine to Environment', 'Intelligent Systems', 'Embedded Internet', 'RFID'. The list goes on.

5)"The Evolution of the Internet of Things", Jim Chase, Texas Instruments, September 2013, p1

6)"The Internet of Everything (IoE) Value Index", Cisco 2013, p3

GE have coined the term 'Industrial Internet' and view this as embracing intelligent machines, advanced analytics and people at work.<sup>7</sup>

- **Intelligent machines.** Connect the world's machines, facilities, fleets and networks with advanced sensors, controls and software applications.
- **Advanced analytics.** Combines the power of physics based analytics, predictive algorithms, automation and deep domain expertise.
- **People at work.** Connecting people at work or on the move, any time to support more intelligent design, operations, maintenance and higher service quality and safety.



**Figure 2**

**The IoT: different services, technologies, meanings for everyone**

Source: "What the Internet of Things (IoT) Needs to Become a Reality", Kaivan Karimi of Freescale Semiconductor and Gary Atkinson of ARM

Seeking to cut through all of the different terminology, Kaivan Karimi of Freescale and Gary Atkinson of ARM conclude that one can:<sup>9</sup>

*... call it what you want, but it's happening, and its potential is huge. We see the IoT as billions of smart, connected 'things' (a sort of 'universal global neural network' in the cloud) that will encompass every aspect of our lives and its foundation is the intelligence that embedded processing provides. The IoT is comprised of smart machines interacting and communicating with other machines, objects, environments and infrastructures. As a result huge volumes of data are being generated, and that data is being processed into useful actions that can 'command and control' things to make our lives much easier and safer - and to reduce our impact on the environment."*

This Roadmap uses this explanation of the IoT as its point of departure.

## Impact of the IoT

In the same way as there are many different definitions for the IoT, there are also a wide range of impact assessments for this technological development. What these assessments all have in common is that the projected impact is major and far reaching.

McKinsey Global Institute gauge that the IoT has the potential to create an economic impact of \$2.7 trillion to \$6.2 trillion annually by 2025.<sup>10</sup>

GE project that the Industrial Internet opportunity is worth \$32.3 trillion, or put differently, a sum that accounts for 46% of the global economy today (see Figure 3).<sup>11</sup>

Cisco estimate that over the next decade the value at stake (net profit) for the IoE economy is \$14.4 trillion. Their research indicates that there are five main drivers of this value at stake.<sup>12</sup>

- **Asset utilization (\$2.5 trillion).**

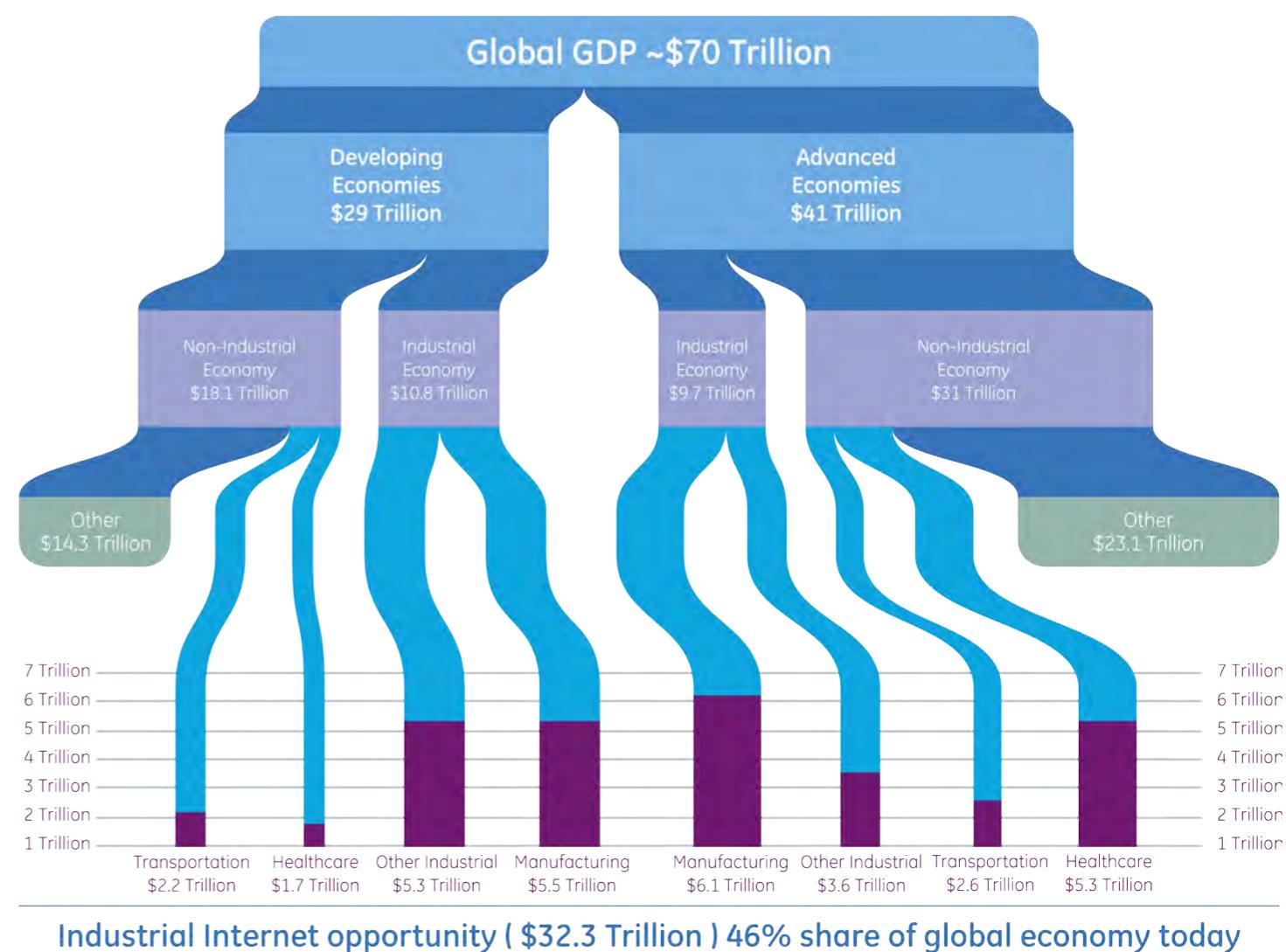
IoE reduces selling, general, and administrative (SG&A) expenses and cost of goods sold (CoGS) by improving business process execution and capital efficiency.

9) "What the Internet of Things (IoT) Needs to Become a Reality", Kaivan Karimi of Freescale Semiconductor and Gary Atkinson of ARM, p1

10) "Disruptive technologies: Advances that will transform life, business, and the global economy", McKinsey Global Institute, 2013, p51

11) "Industrial Internet: Pushing the Boundaries of Minds and Machines", Peter C. Evans and Marco Annunziata, GE, November 26, 2012, p13

12) "Embracing the Internet of Everything To Capture Your Share of \$14.4 Trillion", Cisco 2013, p4



Industrial Internet opportunity ( \$32.3 Trillion ) 46% share of global economy today

Figure 3

Industrial Internet potential GDP share

Source: "Industrial Internet: Pushing the Boundaries of Minds and Machines", Peter C. Evans and Marco Annunziata of GE, citing World Bank and General Electric research

- **Employee productivity (\$2.5 trillion).** IoE creates labour efficiencies that result in fewer or more productive man-hours.

- **Supply chain and logistics (\$2.7 trillion).** IoE eliminates waste and improves process efficiencies.

- **Customer experience (\$3.7 trillion).** IoE increases the customer lifetime value and grows market share by adding more customers.

- **Innovation, including reducing time to market (\$3.0 trillion).** IoE increases the return on R&D investments, reduces time to market, and creates additional revenue streams from new business models and opportunities.

Cisco's research also finds that four out of 18 industries will account for over half the total IoE Value at Stake. These four industries are manufacturing at 27 percent, retail trade at 11 percent, information services at 9 percent, and finance and insurance, also at 9 percent.<sup>13</sup>

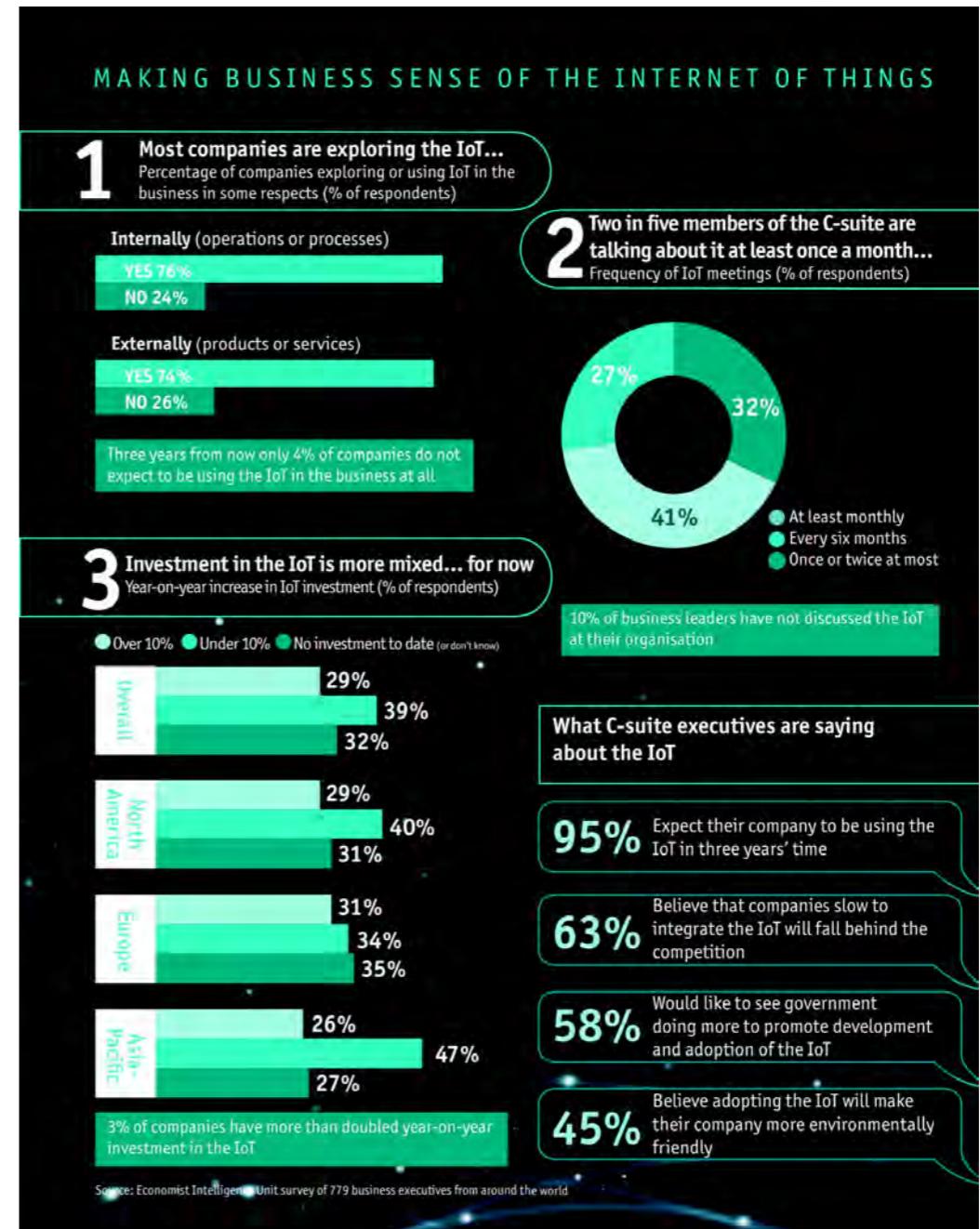
In addition, Cisco believe that this Value at Stake is well distributed across geographies, albeit that the IoE will impact regions differently. These differences will be driven by each region's economic growth rate, as well as by the relative size of each industry sector in each region.<sup>14</sup>

Given the magnitude of all these figures the Economist Intelligence Unit reports that:<sup>15</sup>

*"Only 9% of senior managers believe that the IoT will not change the way their company conducts its business in a meaningful way."*

For instance, Stephen Ferber, Director of Communities and Partner Networks for the Internet of Things and Services at Bosch Software Innovations observes that:<sup>16</sup>

*"These [IoT] products become platforms for new business services, and with these additional services you can also generate new revenue streams. Either you do this yourself or somebody else will do it."*



**Figure 4**

IoT survey of 779 business executives from around the world

Source: "The Internet of Things business index: A quiet revolution gathers pace", The Economist Intelligence Unit, 2013

13) Ibid. p6

14) Ibid. p5-6

15) "The Internet of Things business index: A quiet revolution gathers pace", The Economist Intelligence Unit, 2013, p13

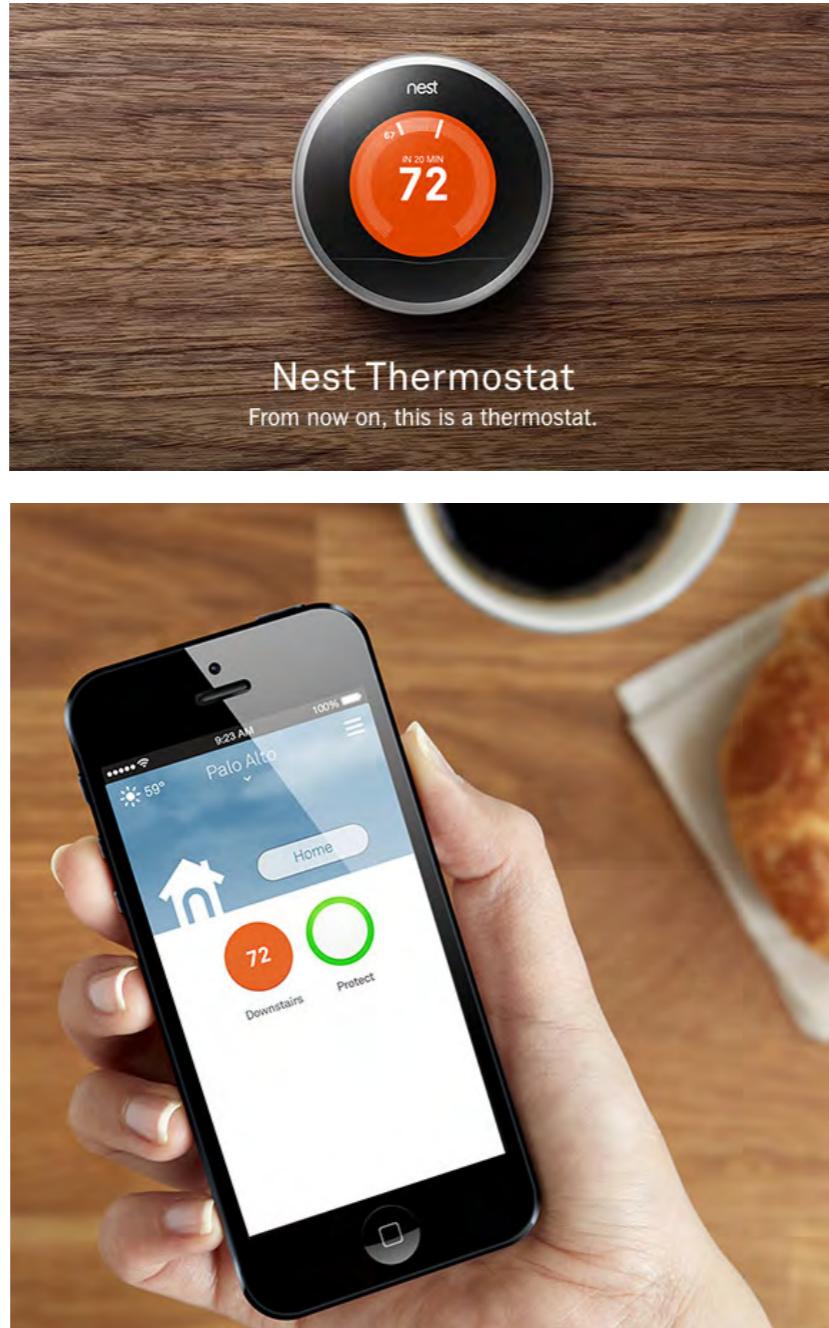
16) Ibid. p9

## Examples of the IoT

### Nest - Smart Thermostats

Recently acquired by Google, NEST is a home device company that is responsible for the Nest Learning Thermostat. Most people leave the house at one temperature and forget to change it. So the Nest Learning Thermostat learns your schedule, programs itself and can be controlled from your phone, tablet or PC. Teach it well and it is claimed that the Nest Thermostat can lower your heating and cooling bills by up to 20%.<sup>1</sup>

1) <https://nest.com/thermostat/life-with-nest-thermostat/>



**Figures 5-6 (Opposite Page)**

Nest's Smart Thermostat - the company was acquired by Google for \$3.2 billion in February 2014

Source: Nest

**Figure 7 (Above)**

IoT-enabled home with connected devices and appliances working invisibly for consumers

Source: "The Evolution of the Internet of Things", Jim Chase, Texas Instruments, September 2013



**Figure 8**

No product recall needed - Tesla sent a software update to its Model S vehicles to fix an overheating issue

Source: Tesla

### Tesla - Smart Cars

During a recent 'recall', Tesla's cars did not have to return to the original dealer's service departments. The recall involved the Universal Mobile Connector (UMC) used to charge Tesla's Model S vehicles. The resistance in the electrical connections was causing excess heat in the adapter.

Tesla addressed the issue by sending a software update which reduced the charging current by 25 per cent if it detected fluctuations to the power coming into the vehicle. Owners of the cars which had received the update, simply had to tap the touch screen on the dashboard to acknowledge that their software was 5.8.4 or newer.<sup>1</sup>

1) <http://guardianlv.com/2014/02/tesla-motors-on-an-electric-high/>

## Anki DRIVE - Smart Toys

Introduced by Tim Cook at Apple's 2013 developer conference, Anki DRIVE uses Artificial Intelligence (AI) and robotics to deliver what they are calling, the first video game in the real world. **Each toy car has been engineered to think:** It knows where it is, makes decisions, and drives itself. Using your iPhone, iPad or iPod you can take control of a car to play against friends or AI cars.<sup>1</sup> According to the Verge,<sup>2</sup> at the beginning of 2014 Anki issued a software update with new special abilities for players. One lets your car spin around 180 degrees and begin driving in the opposite direction - helpful for dodging attacks from other cars. Another brings your car to a screeching halt, which can also be an effective defensive tool.

1) <http://store.apple.com/us/product/HD003VC/A/anki-drive-starter-kit>

2) <http://www.theverge.com/2014/1/6/5280494/anki-drive-update-gives-your-robot-cars-new-ways-to-brawl>



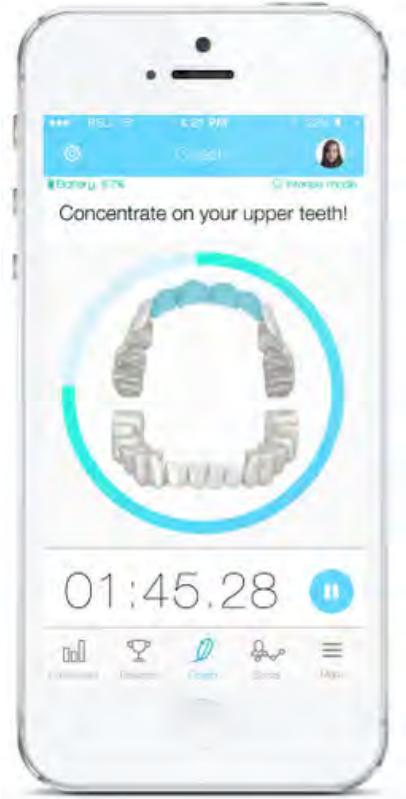
**Figures 9-12**

Anki's racing car game is the first video game in the real world

Sources: *Anki* and *Devolutions Blog*

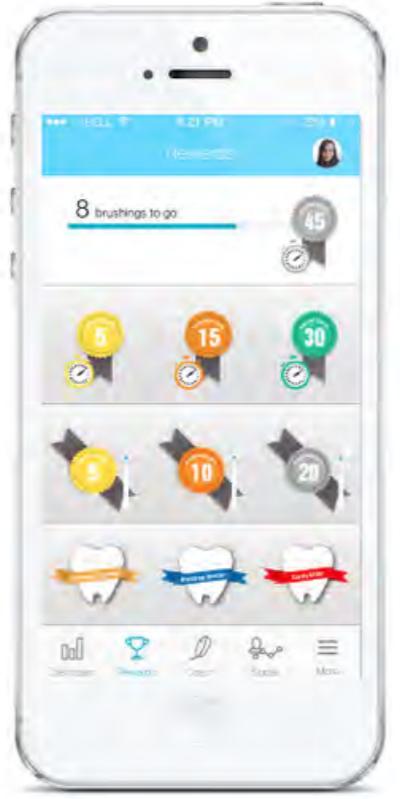
For Tim Cook's introduction of Anki Drive at Apple's 2013 developer conference visit:

<http://www.youtube.com/watch?v=QnsR-kZUx6o>



#### REAL-TIME REPORTING

Brush smarter thanks to real time data you can view on your smart phone anytime, anywhere.



#### PLAY AND PROGRESS

Improve your score as you progress and brush smarter every day. Better brushing habits over time leads to a higher score which is a great way to compare how you're doing with a family member.



#### SHARE AND COMPARE

Because Kolibree allows you to have multiple users on one profile, you can compare your scores with other family members. Built in incentives will help you improve your score over time.



### Kolibree - Smart Toothbrushes

The Kolibree toothbrush collects data on your brushing habits including duration, frequency, and neglected zones in your mouth and then communicates with your iOS or Android smartphone using Bluetooth technology.<sup>1</sup>

Kolibree claim that their app takes your brushing to an entirely new level by providing real time feedback and long-term reporting to see how well you've done each time and how you have improved over time.

Kolibree state that there's no need to wait until your next bi-annual check-up; you can share your reports with your dentist directly through the application. Follow your dentist's advice and download recommended brushing programs providing you with even better oral care.

1) <http://www.kolibree.com/>

**Figure 13**

Dental hygiene reinvented by a smart toothbrush

Source: Kolibree

## Lechal - Smart Shoes

Initially developed to help people with visual impairments navigate the world, Ducere Technologies has launched LECHAL interactive haptic based footwear.<sup>1</sup>

LECHAL footwear creates a hands-free navigation system through your feet, guiding the wearer towards their destination through simple vibrations in their shoes or insoles.

Imagine exploring New York City... Instead of pulling out your phone and looking like a tourist as you try to find a popular restaurant or theater, you can comfortably walk to your destination while your shoes will vibrate to signal which way to walk and when you've reached your destination.

Using Bluetooth to pair with a smartphone, LECHAL footwear can also be used to track fitness information like number of steps walked and calories burned.

The LECHAL application can be downloaded on a smartphone (Android/IOS/Windows compatible).

<sup>1)</sup> <http://the-gadgeteer.com/2014/02/28/lechal-launches-haptic-based-footwear/>

## Interactive haptic footwear



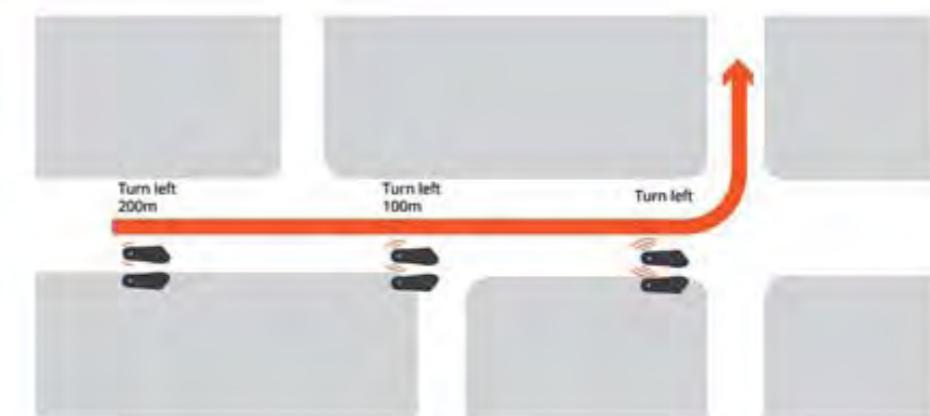
Endless possibilities...

Compatible with \*

**Figures 14-15**

Shoes that navigate

Source: Lechal





## Ambient Devices - Smart Umbrellas

An umbrella that can forecast rain has been developed by Ambient Devices.<sup>1</sup>

The umbrella features a built-in radio receiver in its handle that receives weather data for 150 US locations from a weather forecasting site, Accuweather.com, via a proprietary wireless network.

The forecast result will be indicated to the owner via the umbrella's handle. The umbrella's handle will light up if the forecast result is for rain in the next 12 hours. The light also tells you the type of rain. For instance, soft and intermittent pulses mean light rain while a very rapid and intense pattern signal thunderstorms ahead.

The smart umbrella is battery operated and requires activation via a customer service phone line.

<sup>1</sup>) <http://www.mydigitallife.info/smart-umbrella-that-forecasts-rain/>

### Figures 16-17

An umbrella that alerts you to local weather conditions

Source: <http://alstrupnext.com/tag/cloud-computing/>

## 'Everything-as-a-Service' (XaaS)

All of the examples cited above are a fusion of both product and service: thermostats that continually look for innovative ways to reduce your energy bill; cars that service and fix themselves whenever there is a problem; shoes that direct you around town; toothbrushes that team up with your dentist to improve your oral hygiene; and, umbrellas that check the local weather to ensure that you never get wet. The IoT is beginning to usher in a world of "Everything-as-a-Service" (XaaS).

Johathan Cagan and Craig M.Vogel expand upon on this trend in their book, "Creating Breakthrough Products":

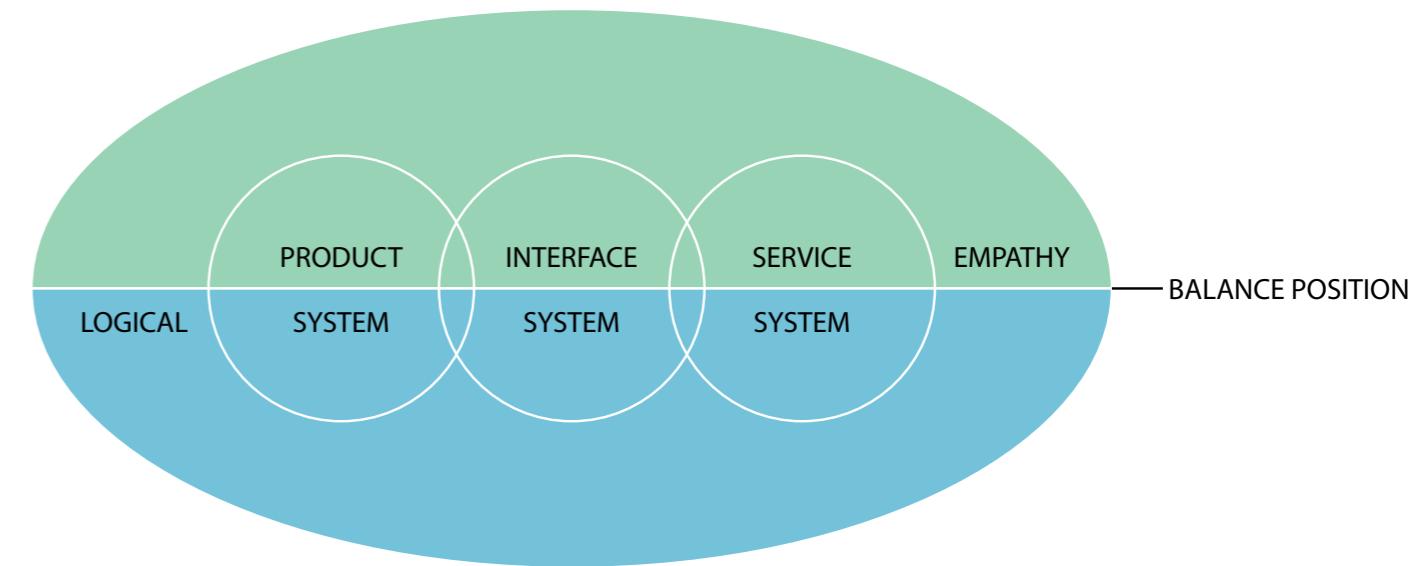
*"Product systems and service systems can no longer be discussed as separate. The opportunity for innovation is in creating new businesses where products, services, and interfaces are seen as interconnected parts of the value and profit in any new idea. Every product is connected to a service system, and every system relies on products that deliver value to consumers. Every product and service has an interface or touch points. The interface touch points can be tangible product controls, digital, human, or any combination of the three. The interface defines the way people interact with the services and physical products."*

For instance, Kolibree's product, a toothbrush, leverages Apple's iPhone as an interface to provide a service system that scores your brushing, compares your performance with other users, recommends that you "concentrate on your upper teeth", and even interacts with your dentist.

According to Cagan and Vogel:

*"Two aspects must be balanced to deliver a brand experience through the product, service, and interface system. The logical aspect accounts for the quantitative and analytical aspects of the system. This includes cost and price analysis, technology, durability and safety, benchmarking of competition, and cost cutting. The empathetic aspect accounts for the qualitative and human side of the system. This includes emotion, aspiration, fantasy, personality, style and connection between people. In practice, all good companies balance the logical and the empathetic aspects of their system."*

As companies seek to provide richer brand experiences they are likely to weave together their product and service systems with an increasingly diverse set of interfaces. Many of these interface systems will be third party platforms, such as Google Glass, Facebook's Oculus Rift, Sony's PlayStation Move or Jaguar's car windscreens concept (see Figures 19-30).



**Figure 18**

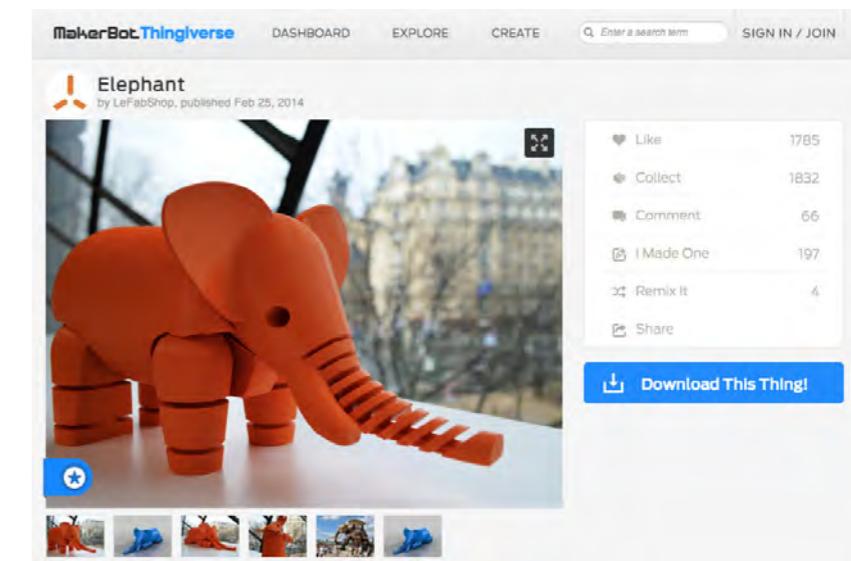
The era of interconnected ecosystems: product, interface and service - a world of "Everything-as-a-Service" (XaaS)

Source: Adapted from "Creating Breakthrough Products", Jonathan Cagan and Craig M. Vogel

Taken to its logical conclusion, XaaS brings one to technologies such as 3D Printing. In this world products morph into on demand services.

For example, MakerBot's Thingiverse (pictured right) is a online community for discovering, making, and sharing 3D printable things.

The extent to which 3D printing substitutes and/or complements traditional supply chains remains to be seen.

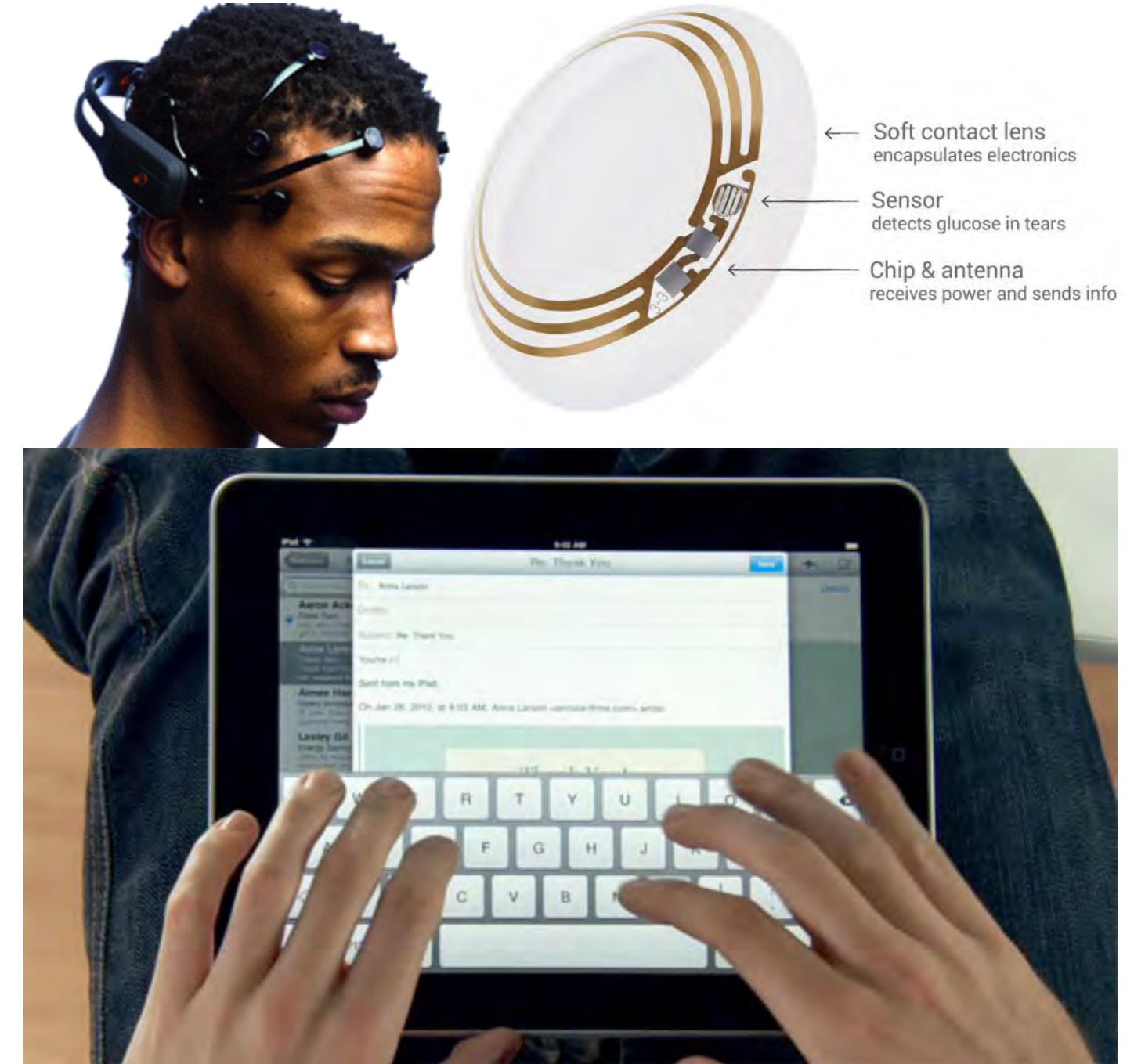


1)"Creating Breakthrough Products", Jonathan Cagan and Craig M. Vogel, p258-261

### Figures 19-29

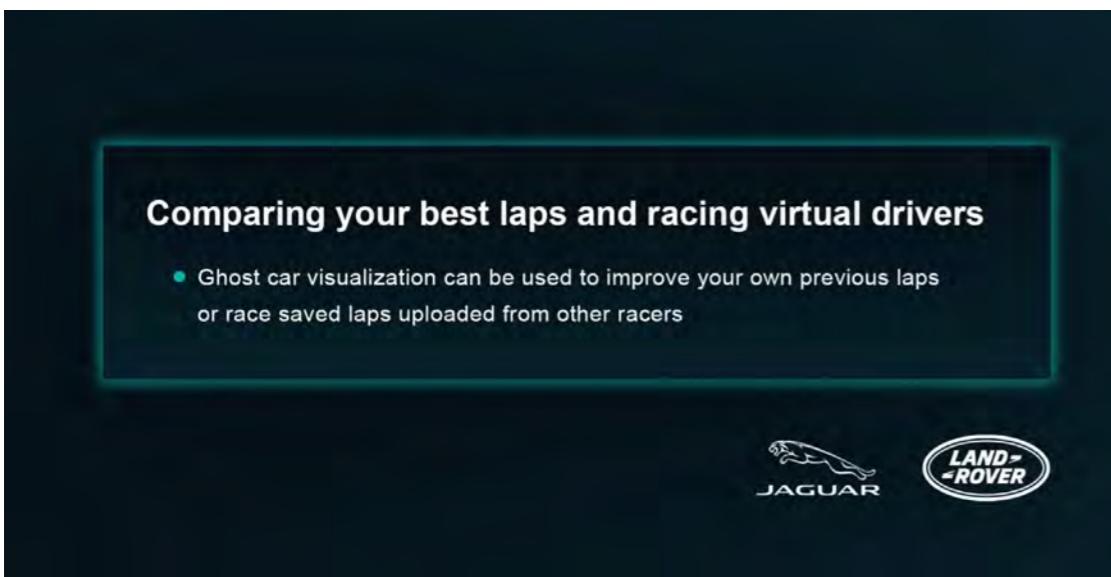
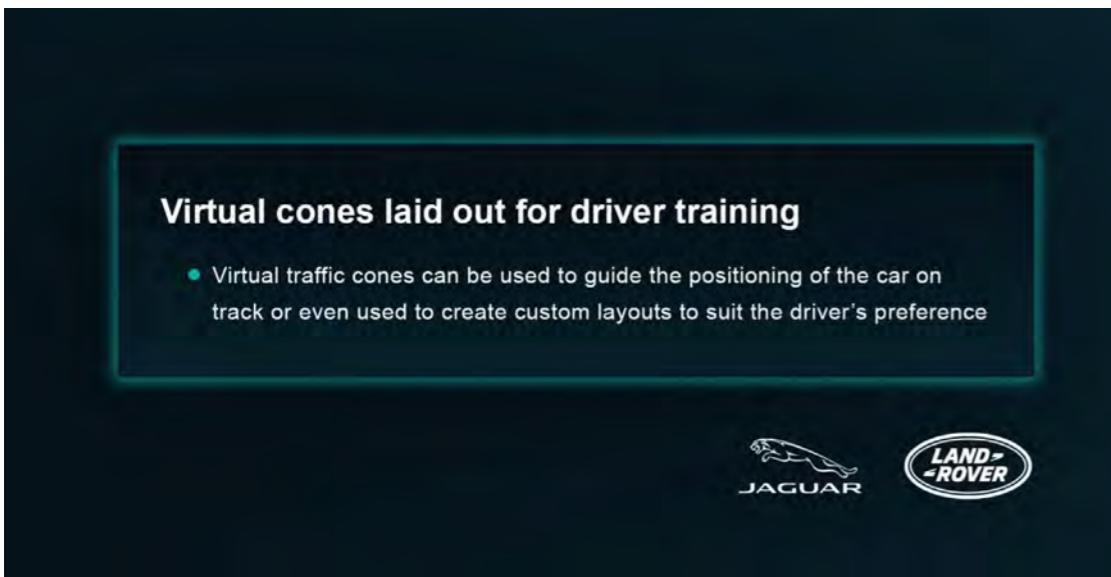
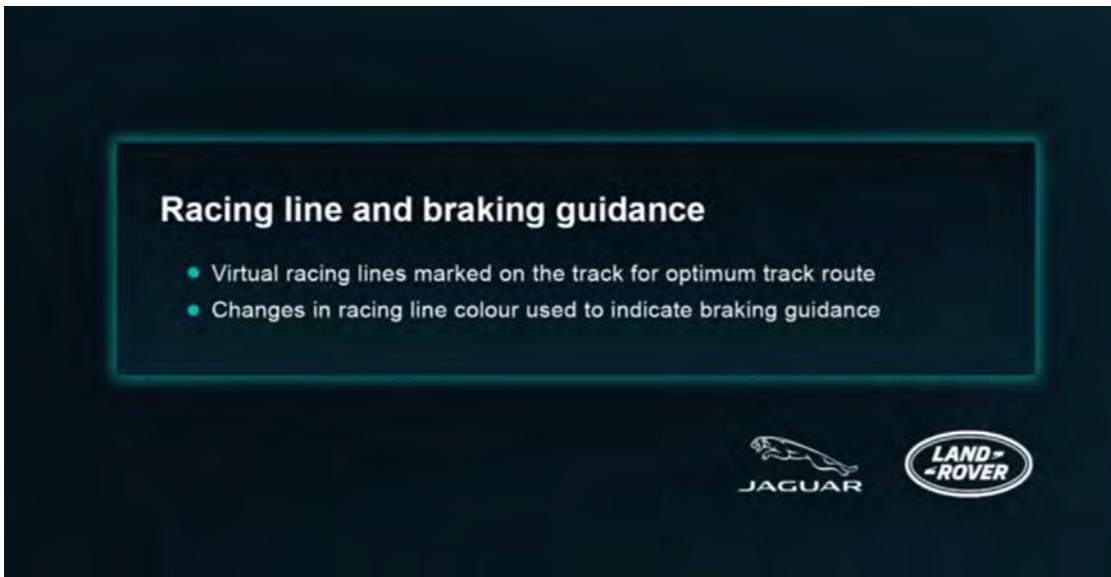
Examples of third party interfaces that smart products will increasingly dovetail with to deliver their services

*Google Glass, Oculus Rift, Sony PlayStation Move, Leap Motion, Digital Taste Slate Interface, BearTek Gloves, Apple's Siri, LG G Watch, Samsung Gear Live, Emotiv Headset, Google's Smart Contact Lense and Apple's iPad (see below for sources)*



#### Sources:

- <http://gvu.gatech.edu/glass>
- <http://www.forbes.com/sites/erikkain/2014/03/25/microsoft-should-have-acquired-oculus-rift-not-facebook/>
- <http://www.dualshockers.com/2010/08/28/move-is-no-better-than-kinect/>
- <http://blogues.radio-canada.ca/triplex/2013/08/05/leap-motion-amusant-mais-plus-ou-moins-utile-pour-l-instant/>
- <http://www.eteknix.com/get-ready-lick-tv-electronic-taste-may-coming-living-room/>
- <http://www.beartekgloves.com/>
- <http://www.forbes.com/sites/briansolomon/2014/06/17/siri-is-for-sale-will-apple-samsung-fight-over-nuance/>
- <http://www.wired.com/2014/07/android-wear/>
- <http://www.emotiv.com/apps/epoc/299/>
- <http://www.igyaan.in/71090/google-reveals-smart-contact-lens-prototype-tracks-glucose-diabetics/>
- <http://blog.tmcnet.com/blog/rich-tehrani/apple/ipod-iphone-ipad---will-it-be-a-hit-too.html>



**Figure 30**  
XaaS in action - Jaguar's concept of the car windscreen as an interface for services  
Watch: [http://www.youtube.com/watch?v=FeK9IkSD\\_nI](http://www.youtube.com/watch?v=FeK9IkSD_nI)

# Architecture of the IoT

## Technology Backbone of the IoT

Three core building blocks form the technology backbone of the IoT and enable XaaS (see Figures 31 and 32). These are:

- Sensors and actuators
- Embedded processing
- Connectivity and the cloud

Each of these building blocks are examined below.

## Sensors and Actuators

Smart objects use sensors and actuators to interact with their physical environments. Sensors are used to measure the state of the environment and actuators are employed to change or affect the environment.



For example, an iPhone 5 uses a small rotational motor with a counterweight (pictured bottom left)<sup>1</sup> to vibrate when it receives a phone call - i.e. an actuator. It then uses a microphone to take the call - i.e. a sensor.

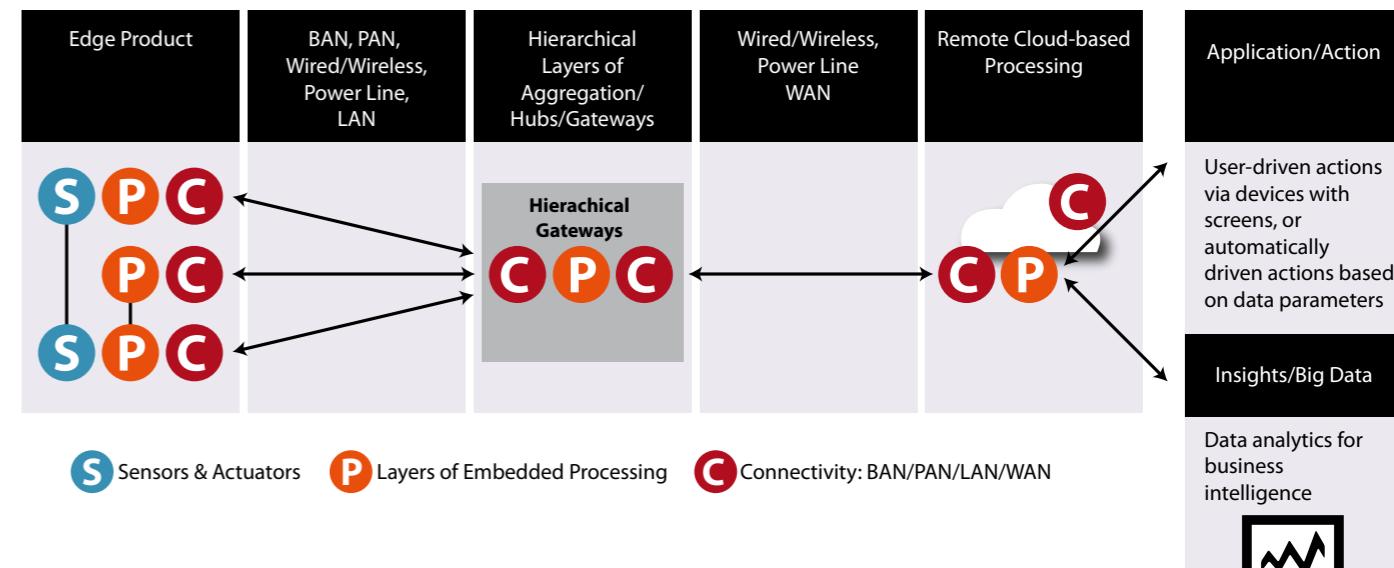
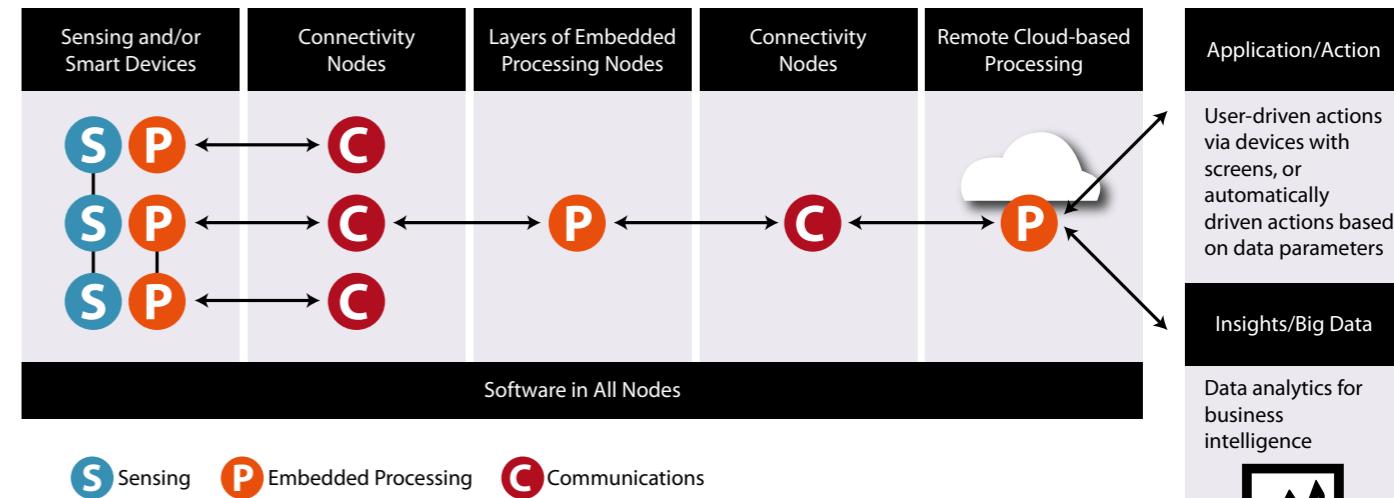
Essentially, sensors take a mechanical, optical, magnetic or thermal signal and convert this into voltage and current. This data (e.g. whether the voltage is high or low) can then be processed. Actuators follow this same process, but in reverse (see Figure 33). Voltage and current induce a mechanical, optical, magnetic or thermal change or affect in the physical environment.

Figure 34 gives an idea of the types of sensor that are being deployed in the IoT. These range from the very simple to the very complex. They may be employed as stand-alone sensors or as a constellation of sensors.

Aside from their cost and power consumption requirements, sensors are selected based on their precision, accuracy and resolution, as well as the degree to which they need to be calibrated.

It is this plethora of sensors that is ushering in the world of 'Big Data'. In this world most of the data is not user-generated, but instead machine-generated - an important change.

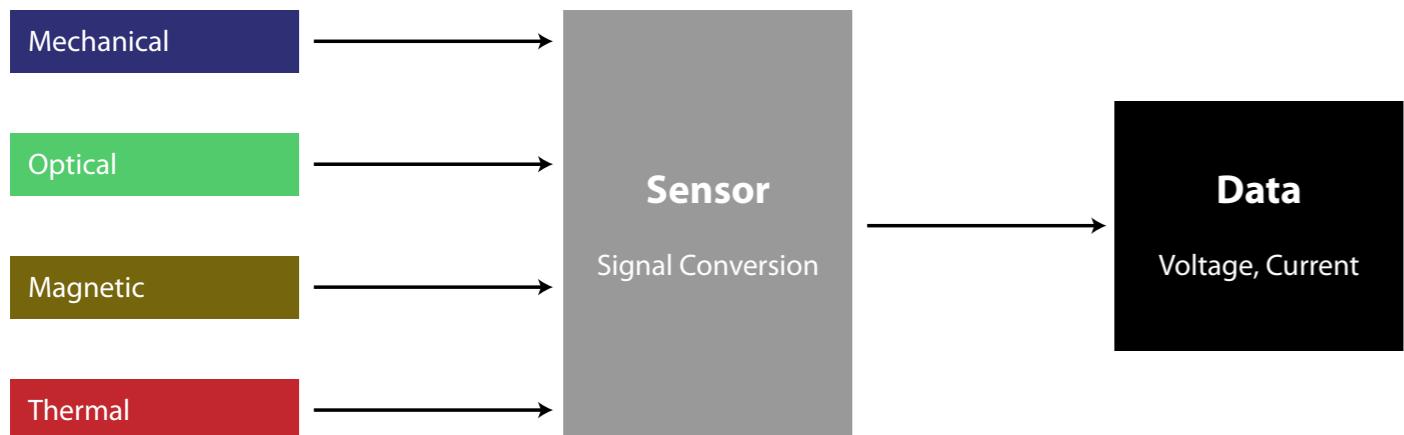
<sup>1)</sup><http://www.ifixit.com/Teardown/iPhone+5+Teardown/10525>



**Figures 31-32**

Functional (above) and product (below) views of the emerging architecture of the IoT

Source: Reproduced from "What the Internet of Things (IoT) Needs to Become a Reality", Kaivan Karimi of Freescale Semiconductor and Gary Atkinson of ARM



**Figure 33**

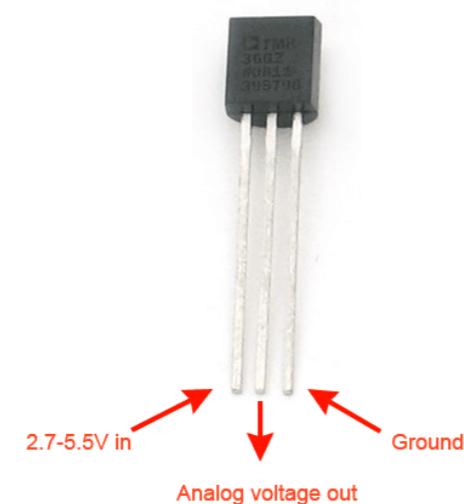
Reading this diagram from left to right demonstrates how a sensor works. Whereas reading it from right to left illustrates how an actuator works - some electrical input produces an action

Source: Carré & Strauss

Jean-Philippe Vasseur and Adam Dunkels demonstrate just how much data one temperature sensor (pictured bottom right) can generate with a simple example:<sup>2</sup>

*"Consider a smart object network that samples the temperature inside a building. Temperature is generally a slow-moving phenomenon, so the nodes do not need to sample very often. Still, people in the building may forget to close a window or leave the outer door halfway open, and the system should be prepared to detect this within a reasonable time frame. Considering these requirements, the building manager instructs the system to sample the temperature twice every*

*minute. With a sampling rate of two readings per minute, 2880 readings are taken each day, or 737,280 readings per year. Because the system is designed to work for ten years, there will be over seven million readings, from each node, during the lifetime of the system."*



<sup>2)</sup>"Interconnecting Smart Objects With IP", Jean-Philippe Vasseur and Adam Dunkels, 2010, p16

TYPES OF SENSORS			
Category of Sensor	What It Does		Example Devices
Position Measuring Devices		Designed to detect and respond to changes in angular position or in linear position of the device	Potentiometer Linear Position Sensor Hall Effect Position Sensor Magnetoresistive Angular  Econoders: - Quadrature - Incremental Rotary - Absolute Rotary - Optical
Proximity, Motion Sensors		Designed to detect and respond to movement outside of the component but within the range of the sensor	Ultrasonic Proximity Optical Reflective Optical Slotted PIR (Passive Infrared)  Inductive Proximity Capacitive Proximity Reed Switch Tactile Switch
Inertial Devices		Inertia Devices designed to detect and respond to changes in the physical movement of the sensor	Accelerometer Potentiometer Inclinometer Gyroscope Vibration Sensor/Switch  Tilt Sensor Piezo Shock Sensor LVDT/RVDT
Pressure/Force		Pressure Devices designed to detect a force being exerted against it	IC Barometer Strain Gauge Pressure potentiometer LVDT Silicon transducer  Piezoresistive sensor Capacitive transducer
Optical Devices		Optical Devices designed to detect the presence of light or a change in the amount of light on the sensor	LDR Photodiodes Phototransistors Photo interrupters Reflective Sensors  IrDA Transceiver Solar Cells  LTV (Light Voltage) Sensors
Image, Camera Devices		Image, Camera Devices designed to detect and change a viewable image into a digital signal	CMOS Image Sensor
Magnetic Devices		Magnetic Devices designed to detect and respond to the presence of a magnetic field	Hall Effect Sensor Magnetic Switch Linear Compass IC Reed Sensor  Fluid Flow
Media Devices		Media Devices designed to detect and respond to the presence or the amount of a physical substance on the sensor	Gas Smoke Humidity, Moisture Dust Float Level
Current and Voltage Devices		Current Devices designed to detect and respond to changes in the flow of electricity in a wire or circuit	Hall Effect current sensor DC current sensor AC current sensor Voltage Transducer  Digital IC Analog IC
Temperature		Temperature Devices designed to detect the amount of heat using different techniques and in different mediums	Thermistor NTC Thermistor PTC Resistance Temp Detectors (RTD) Thermocouple Thermopile  Infrared Thermometer/Pyrometer
Specialized		Specialized Devices designed to provide detection, measurement, or response in specialized situations, which also may include multiple functions	Audio Microphone Geiger-Müller Tube Chemical

**Figure 34**

A wide range of sensors are deployed in the IoT

Source: Reproduced from "Practical Electronics for Inventors", Paul Scherz and Simon Monk



**Figure 35**

An "Arduino Uno" microcontroller

Source: Arduino Arts, <http://arduinoarts.com/2011/08/the-arduino-uno-anatomy/>

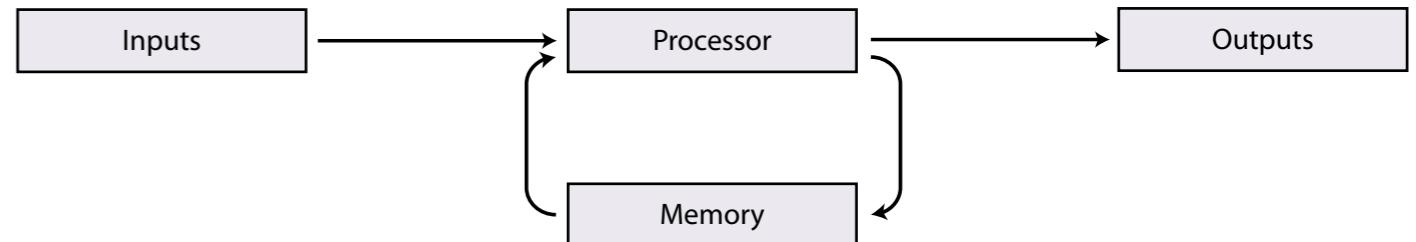
Name	Manufacturer	RAM (kB)	ROM (kB)	Current consumption (active/sleep), mA
MSP430xF168	Texas Instruments	10	48	2/0.001
AVR ATmega128	Atmel	8	128	8/0.02
8051	Intel	0.5	32	30/0.005
PIC18	Microchip	4	128	2.2/001

*Note: Each manufacturer has several models of each device. This table lists only one example from each manufacturer.*

**Figure 36**

Examples of microcontrollers used in smart objects

Source: Adapted from "Interconnecting Smart Objects With IP", Jean-Philippe Vasseur and Adam Dunkels, 2010



**Figure 37**

The basic architecture of a microcontroller - essentially it is a small low powered computer on a chip

Source: Carré & Strauss

## Embedded Processing

Embedded processing is what gives smart objects their intelligence. This function is usually provided by a 'microcontroller'. These run the software of the smart object and are responsible for connecting its sensors and actuators with a radio transceiver.

Basically, a microcontroller is a small low powered computer on a chip minus the monitor, keyboard and mouse.

Figure 35 presents the popular Arduino Uno microcontroller.

The microcontroller chosen for a smart object is a function of three considerations: its performance, price and power consumption. For instance, it makes no sense to select a high performance, expensive and power hungry microcontroller if all one wants to do is periodically measure the temperature. Figure 36 provides some examples of the various microcontrollers used in smart objects.

Note that when one couples sensors with actuators and a microcontroller the result is what has traditionally been termed a 'robot'. Alan Winfield provides one definition of a robot as:<sup>3</sup>

- An artificial device that can sense its environment and purposefully act on or in that environment
- An embodied artificial intelligence; or
- A machine that can autonomously carry out useful work

In other words, today's smart objects are robots, albeit connected ones. It is therefore no surprise that Google recently purchased nine robotics companies, Amazon is following suit, and the Editor in Chief of Wired has left to found a robotics company.

<sup>3)</sup>"Robotics - A Very Short Introduction", Alan Winfield, 2012, p8

## Connectivity and the Cloud

Connectivity for smart objects comes in many different shapes and forms. First, smart objects can leverage a number of different network topologies (see Figure 38). Second, smart objects can employ a plethora of different communication technologies to create these networks topologies (see Figure 39).

For instance, a Local Area Network (LAN) with a star topology can be achieved through any one of the following technologies: proprietary Sub-GHz and 2.4 GHz technology, WiFi, ZigBee (see image top right),<sup>4</sup> KNX, Wireless HART or 6LoWPAN.

Importantly using the Internet to link smart objects has not been the norm to date. Neil Gershenfeld and Jean-Philippe Vasseur believe that this has been due to three reasons:<sup>5</sup>

**1. Control.** Manufacturers have sought to establish proprietary control. The Internet has no tollbooths, but if a manufacturer can control the communication standards used by smart objects then they can charge consumers to use them.



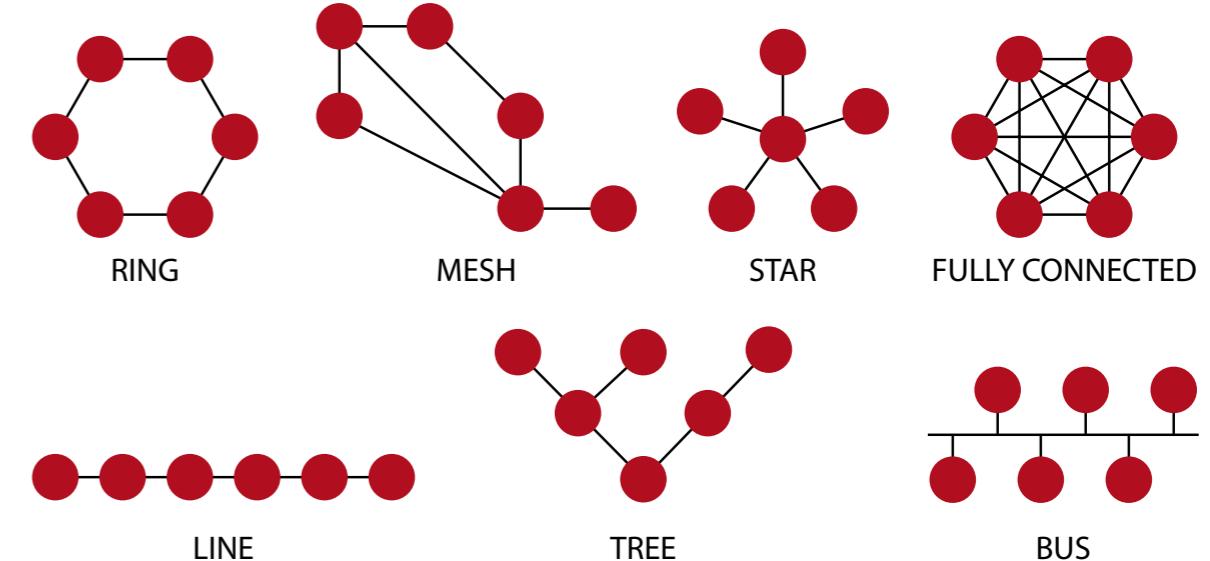
**2. Performance.** There has been a misguided belief that custom-built solutions would outperform the general-purpose Internet. In fact, these alternatives have been less developed and lacked the Internet's economies of scale, reliability and security.

**3. Cost.** For a long time the economics of the Internet was far removed from the economics of light bulbs. First, it revolved around large computers that cost hundreds of thousands of dollars. Later it centred on \$1,000 PC's. However, with the advent of microcontrollers this is no longer the case.

Gershenfeld and Vasseur believe that we are now at a major inflection point, namely a battle between an IoT based on open standards and a decentralized design versus an IoT of competing proprietary systems and centralized control.

<sup>4</sup><http://zigbeeproducts.com/>

<sup>5</sup>"As Objects Go Online - The Promise (and Pitfalls) of the Internet of Things", Neil Gershenfeld and JP Vasseur, Foreign Affairs, March/April 2014, p 63-64



**Figure 38**

Examples of the different network topologies that smart objects can form

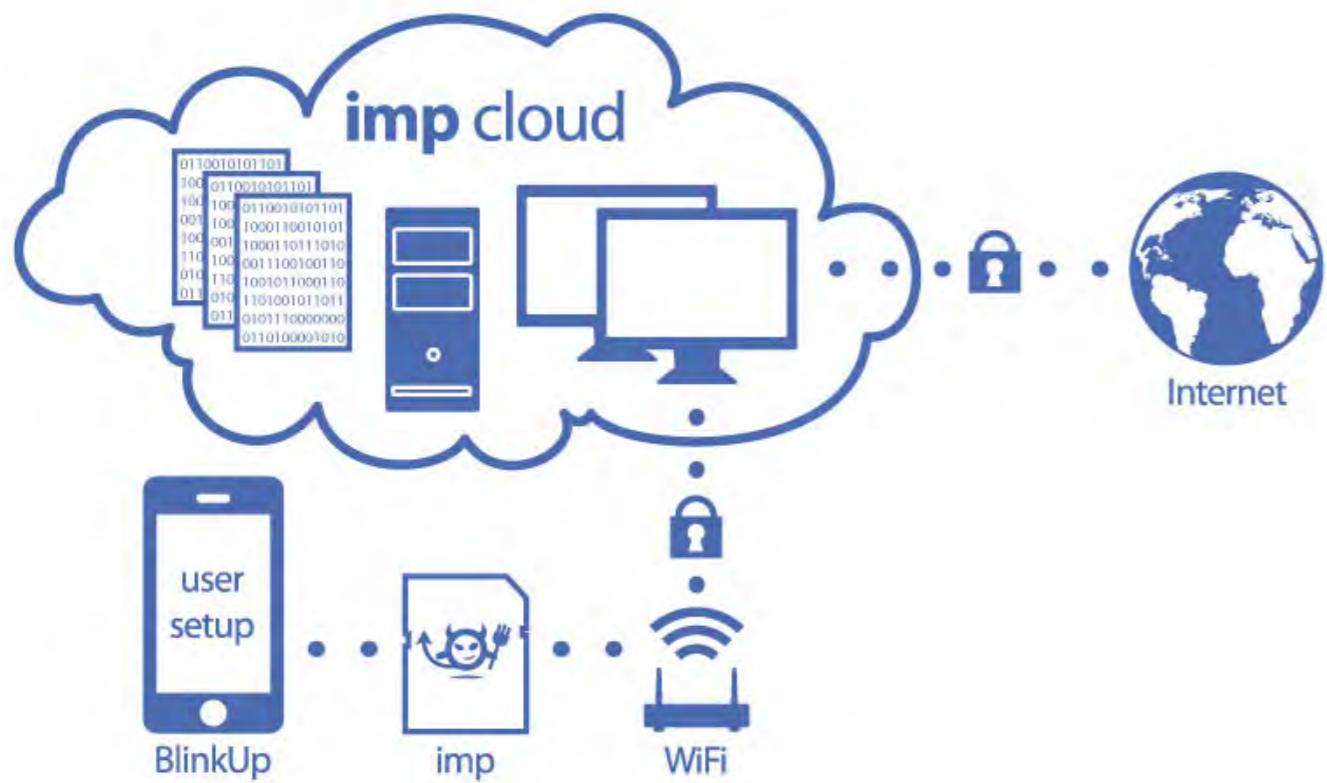
Source: Adapted from <http://upload.wikimedia.org/wikipedia/commons/9/97/NetworkTopologies.svg>

	NFC	RFID	Blue-tooth®	Blue-tooth® LE	ANT	Proprietary (Sub-GHz & 2.4 GHz)	Wi-Fi®	ZigBee®	Z-Wave	KNX	Wireless HART	6LoWPAN	WiMAX	2.5-3.5 G
Network	PAN	PAN	PAN	PAN	PAN	LAN	LAN	LAN	LAN	LAN	LAN	LAN	MAN	WAN
Topology	P2P	P2P	Star	Star	P2P Star Mesh Tree	Star Mesh	Star	Star Mesh Tree	Mesh	Star Mesh Tree	Star Mesh	Star Mesh	Mesh	Mesh
Power	Very Low	Very Low	Low	Very Low	Very Low	Very Low to Low	Low-High	Very Low	Very Low	Very Low	Very Low	Very Low	High	High
Speed	400 Kbs	400 Kbs	700 Kbs	1 Mbs	1 Mbs	250 Kbs	11-100 Mbs	250 Kbs	40 Kbs	1.2 Kbps	250 Kbs	250 Kbs	11-100 Mbs	1.8-7.2 Mbs
Range	<10 cm	<3 m	<30 m	5-10 m	1-30 m	10-70 m	4-20 m	10-300 m	30 m	800 m	200 m	800 m (Sub-GHz)	50 km	Cellular Network
Application	Pay, get access, share, initiate service, easy setup	Item tracking	Network for data exchange, headset	Health and fitness	Sports and fitness	Point to point connectivity	Internet, multimedia	Sensor networks, building and industrial automation	Residential lighting and automation	Building automation	Industrial sensing networks	Sensor networks, building and industrial automation	Metro area broadband internet connectivity	Cellular phones and telemetry
Cost Adder	Low	Low	Low	Low	Low	Medium	Medium	Medium	Low	Medium	Medium	Medium	High	High

**Figure 39**

Examples of the various communication technologies that smart objects can use

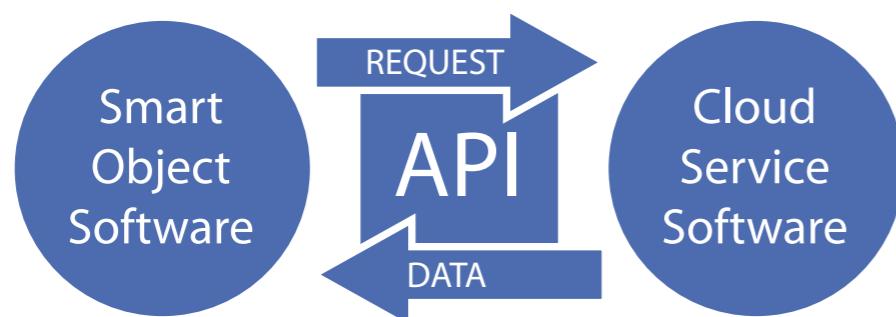
Source: "What the Internet of Things (IoT) Needs to Become a Reality", Kaivan Karimi of Freescale Semiconductor and Gary Atkinson of ARM



**Figure 40**

'Electric Imp' promote an IoT architecture centred around their proprietary 'Imp Cloud' service

Source: <https://electricimp.com/>



**Figure 41**

Application Programming Interfaces (APIs) make it possible to integrate smart objects with cloud services

Source: Carré & Strauss

They talk of a:<sup>6</sup>

*"... battle emerging between the Internet of Things and what could be called the Bitnet of Things. The key distinction is where information resides: in a smart device with its own IP address or in a dumb device wired to a proprietary controller with an Internet connection. Confusingly, the latter setup is itself frequently characterized as part of the Internet of Things. As with the Internet and BITNET, the difference between the two models is far from semantic. Extending IP to the ends of a network enables innovation at its edges; linking devices to the Internet indirectly erects barriers to their use."*

See the Annex for further details.

Karimi and Atkinson echo this analysis of the current situation:<sup>7</sup>

*"Since there are not yet industry-wide IoT best practices agreed upon and deployed, many component providers are approaching the connection between devices and the cloud as a connection to their niche cloud, as opposed to the cloud. Some companies promote that all devices will be 'dumb nodes,' with all the processing and decision-making done within 'their cloud.' Alternatively, some believe only minimal access to the cloud for basic Internet-related services will be required, with most of the 'thinking' done locally."*



For example, Electric Imp promote an IoT architecture where their proprietary 'Imp' microcontroller (pictured above)<sup>8</sup> is programmed and controlled centrally via their 'Imp Cloud', so all it has to do is connect to your WiFi network with its built in wireless connectivity.<sup>9</sup>

### Value Chain of the IoT

To capture the dynamics of the IoT marketplace, Ansgar Schlautmann and his colleagues at Arthur D Little have translated the IoT's technology architecture into a 'value chain for smart solutions' (see Figure 42). They note that this IoT value chain is scattered, as well as complex, and identify eight constituent parts and stakeholders.<sup>10</sup>

8) <http://www.crowdfundinsider.com/2012/11/4918-pintofeed-electric-imp-cloud-service/>

9) <https://electricimp.com/>

10) "Wanted: Smart market-makers for the 'Internet of Things'", Ansgar Schlautmann, Didier Levy, Stuart Keeping and Gregory Pankert, Arthur D Little, Prism 2011, p38

- Smart Module.** The sensors, actuators, wireless modules, modems, SIM cards, etc. that connect the smart object to the network. Stakeholders traditionally operating in this territory include Cinterion, Sierra Wireless and Telit, with Asian heavyweights such as Huawei and ZTE now starting to enter this space.

- Smart Object.** The vending machines, appliances, cars, cameras, etc. LG, Bosch and Volvo belong to the increasing number of product manufacturers that are active in this segment.

- Network Operator.** The operator enabling and managing the fixed or wireless communication with the smart object. Here the stakeholders include traditional telcos such as, Verizon, Comcast and AT&T, as well as newcomers such as Google Fibre.

- Service Enabler.** The cloud and software platforms that provide the intelligence to the smart objects and distribute information correctly to third parties. Arthur D Little draw attention to the fact that the service enabler is the most attractive position in the value chain, with a 30-40% share of total value. As a result large players, such as Nokia Siemens Networks, Alcatel Lucent and IBM are positioning themselves in this area, as are network operators such as Vodafone and Telefonica.

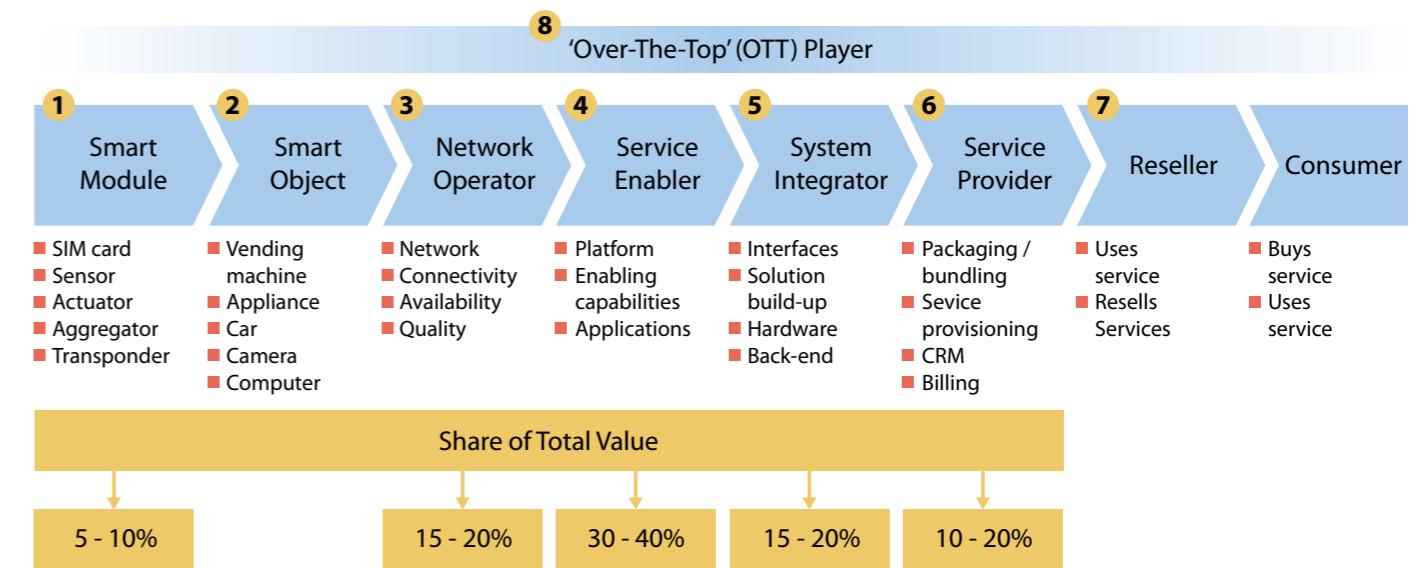
- Systems Integrator.** The stakeholder that physically integrates the smart module into the smart object and then integrates this smart object with cloud services through standardized Application Programming Interfaces (APIs) (see Figure 41). This area has been traditionally dominated by players such as Axeda, Aeris and Telenor's Connexion and is now being entered into by larger system integrators, such as Ericsson and IBM.

- Service Providers.** Those that take care of bundling the solutions, setting the tariffs, billing and customer care. Wireless Car and Hughes Telematics operate in this space with network operators increasingly joining the action.

- Reseller.** The stakeholder that markets both the smart object and the related smart services. Often the manufacturer of the smart object also acts as the reseller.

- 'Over-The-Top' (OTT) players.** OTT is the provision of a service over the Internet that bypasses traditional distribution thereby disrupting existing business models. OTT examples include Skype, Netflix, YouTube and Uber.

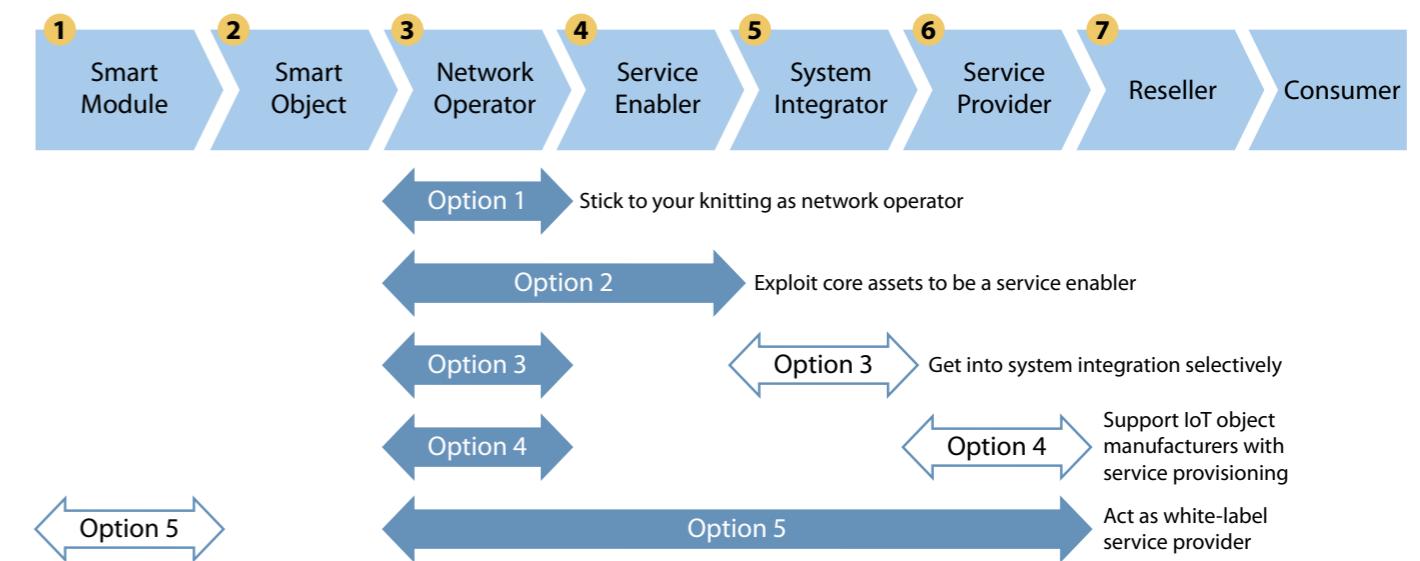
Schlautmann and his colleagues have gone on to explore the strategic moves that telcos may make in the IoT value chain (see Figure 43).



**Figure 42**

The scattered and complex value chain for IoT solutions

Source: Adapted from "Wanted: Smart market-makers for the 'Internet of Things'", Ansgar Schlautmann, Didier Levy, Stuart Keeping and Gregory Pankert, Arthur D Little, Prism 2011



**Figure 43**

Options for telcos in the value chain for IoT solutions

Source: Ibid



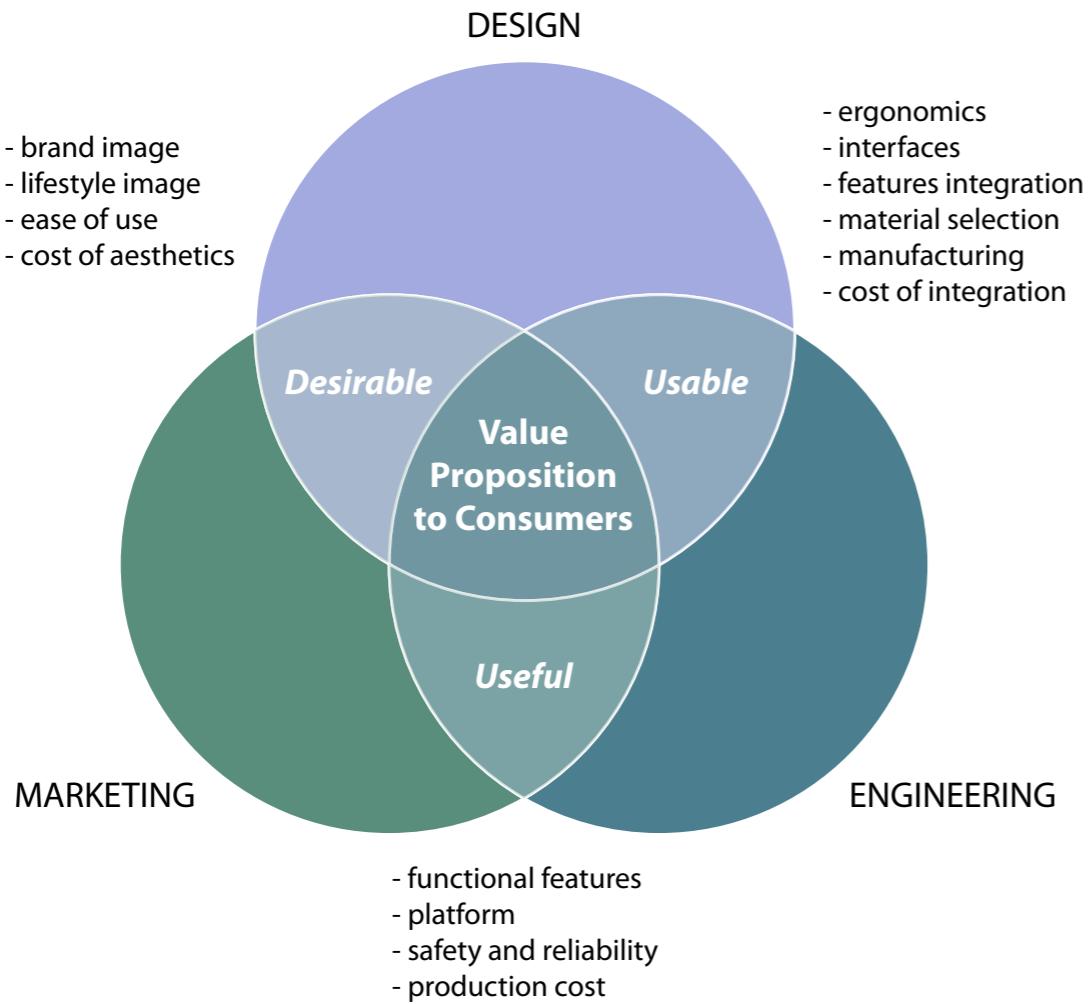
**Figures 44-47**

Positions in the IoT value chain are very fluid at the moment. For instance, Uber are challenging traditional taxi and limousine business models (i.e. entering the market as 'Over-The-Top' (OTT) players). Volvo are in the process of transforming their cars into roaming delivery services (i.e. evolving into service providers). Google are starting to manufacture self-driving cars (i.e. entering the IoT object space). Whilst, SK Telecom are now enabling real time engine checks via their mobile phones (i.e. integrating with third party IoT objects).

**Sources:**

- <http://mashable.com/2014/06/11/uber-protests-europe/>
- <http://www.businessweek.com/articles/2014-02-27/volvo-wants-your-parked-car-to-accept-deliveries>
- <http://recode.net/2014/05/27/googles-new-self-driving-car-ditches-the-steering-wheel/>
- <http://www.koreaittimes.com/story/4026/kt-and-sk-telecom-struck-smooth-competition>





**Figure 48**

A solution is valuable to the end consumer if it is 'useful, usable and desirable' - a perfect fusion of design, engineering and marketing

Source: Adapted from "Creating Breakthrough Products", Jonathan Cagan and Craig M. Vogel

A similar analysis can be conducted for any one of the numerous stakeholders active in the value chain. To re-emphasise, currently positions in the value chain are very fluid as stakeholders seek to position themselves strategically in the IoT (see Figures 44-47).

Regardless of all this jostling, the value chain should ultimately deliver enhanced value to the end consumer. For Cagan and Vogel this means marshalling the disciplines of design, engineering and marketing to provide solutions to consumers that are 'useful, usable and desirable' (see Figure 48).<sup>11</sup>

### The Big Picture

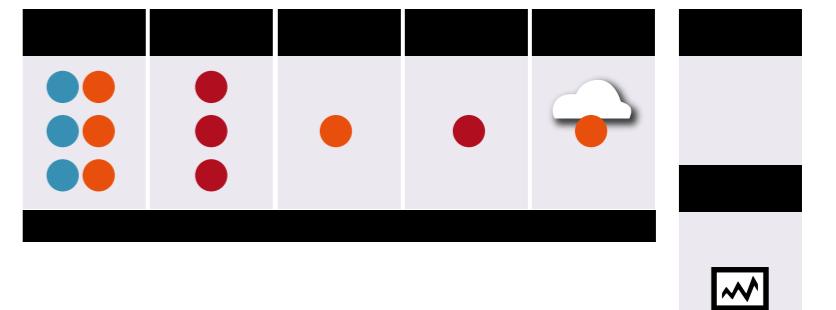
At this juncture it is worth taking stock of the overarching architecture of the IoT. In short, the IoT's technology backbone is made possible by the IoT value chain. This value chain enables XaaS solutions that, properly executed, deliver value to consumers - i.e. smarter solutions (see Figure 49).

The question of what constitutes 'properly executed', brings this Roadmap to now examine the future governance of the IoT.

**Figure 49**

The overarching architecture of the IoT  
Source: Carré & Strauss

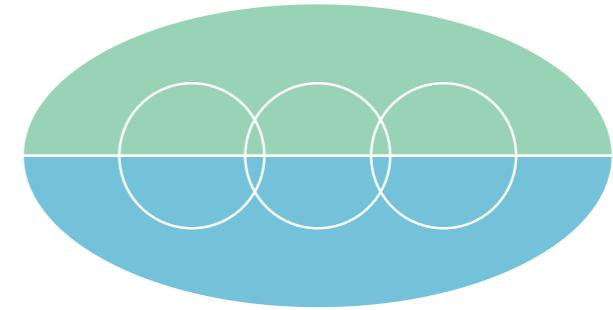
**The IoT's technology backbone ...**



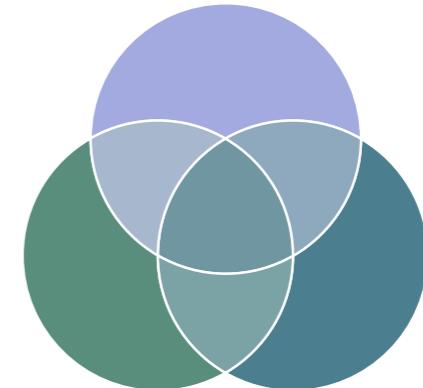
**... is made possible by the IoT value chain ...**



**... which enables XaaS solutions ...**



**... that, properly executed, deliver enhanced value to consumers.**



<sup>11)</sup>"Creating Breakthrough Products", Jonathan Cagan and Craig M. Vogel, p67, 73 and 165

# Governance of the IoT

## Definition of Governance

This roadmap defines governance as:<sup>1</sup>

*"The collection of control mechanisms that a society adopts to prevent or dissuade potentially self-interested stakeholders from engaging in activities detrimental to the welfare of other stakeholders"*

Establishing a framework for good governance is important because the IoT distributes significant powers to various stakeholders in the value chain. These powers are (see Figure 50):

- Power over network standards
- Power over products and their distribution
- Power over network traffic
- Power over services and their distribution

Each of these powers can be potentially exercised to the detriment of other stakeholders in the chain as outlined below.

## Power over Network Standards

It is worth reiterating that network standards specify not only how a device communicates, but also what it can communicate. Therefore closed standards create the possibility of controlling IoT networks. For example, deciding that one

brand of smart watch cannot talk to another brand of smart phone because they do not speak the same technical language - not very useful from the consumer perspective and potentially anti-competitive.

Neil Gershenfeld and JP Vasseur therefore urge the use of the Internet to link things rather than reinventing the networking wheel for each industry.<sup>2</sup> They champion IPv6 and draw attention to the fact that closed standards have struggled with the same problems that the Internet has already solved: how to assign network names to devices, how to route messages between networks, how to manage the flow of traffic, and how to secure communication.

Nevertheless, Ronak Sutaria and Raghunath Govindachari at Mindtree Research Labs believe that:<sup>3</sup>

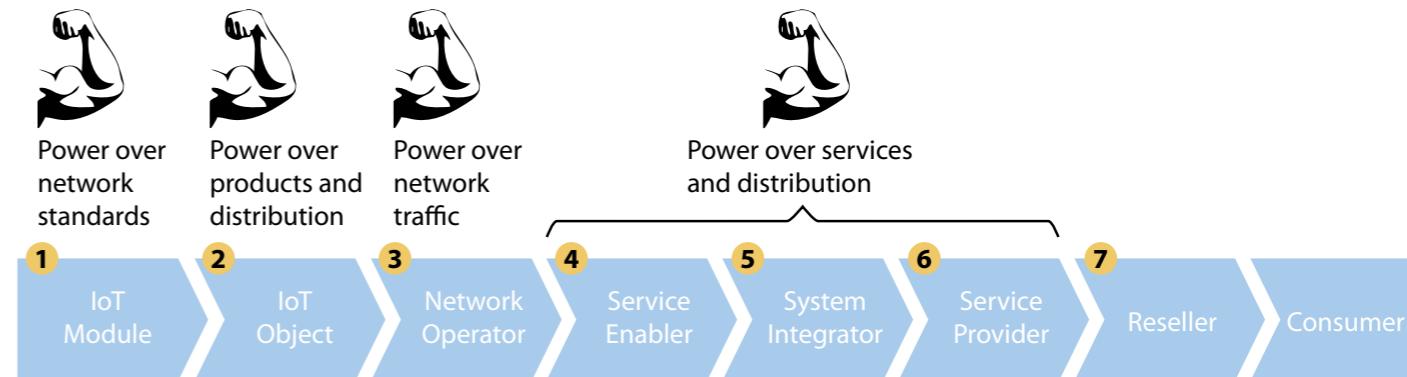
*"...in the near term, disparate islands of solutions are likely to outpace deployment of interoperable standards-based solutions."*

## Power over Products and their Distribution

Product manufacturers have traditionally relied on distribution systems and intellectual property rights to control the supply of their products. These practices have the potential to inhibit IoT networks.

2) "As Objects Go Online - The Promise (and Pitfalls) of the Internet of Things", Neil Gershenfeld and JP Vasseur, Foreign Affairs, March/April 2014, p 63

3) "Making sense of interoperability: Protocols and Standardization initiatives in IoT" Ronak Sutaria and Raghunath Govindachari, Mindtree Research Labs



**Figure 50**

The IoT distributes significant powers to various stakeholders in the value chain which can be potentially exercised to the detriment of other stakeholders in the chain

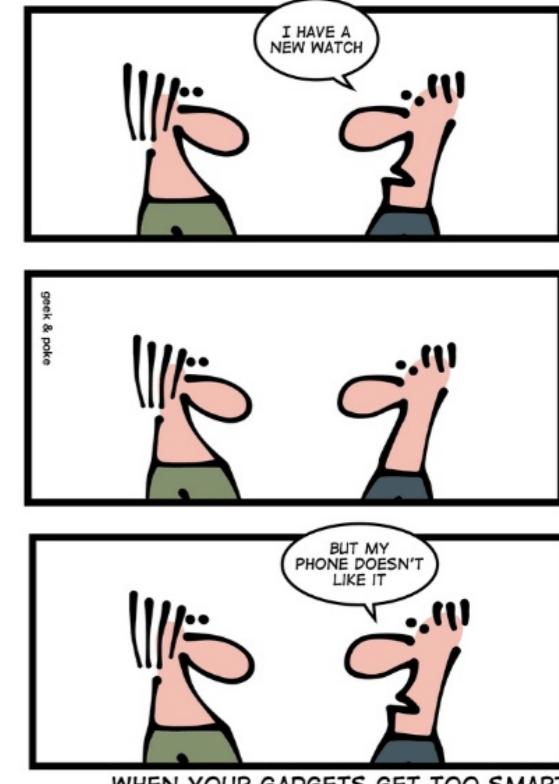
Source: Carré & Strauss



**Figure 51**

Keurig's new coffee machine is reported to reject coffee pods that do not have a "proprietary taggant material"

Source: CNN



1) Adapted from a definition of corporate governance by David Larcker and Brian Tayan in their book, "Corporate Governance Matters", p8

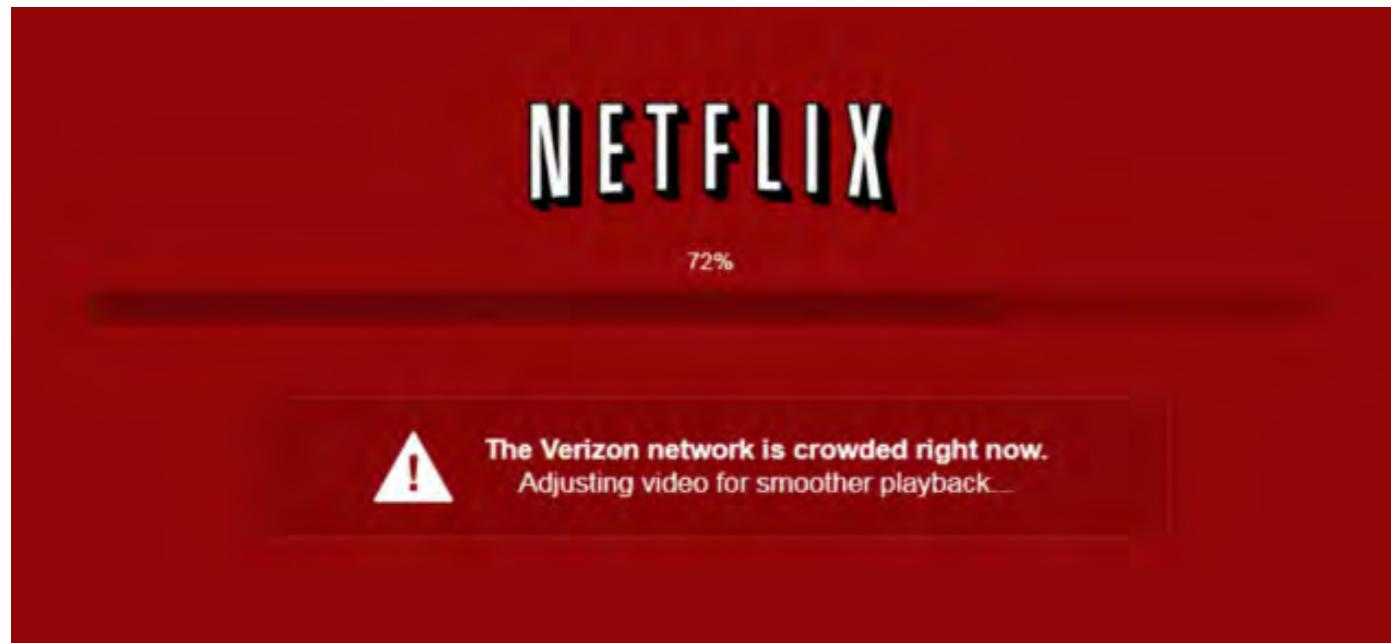
## Netflix-Comcast Deal Marks The End Of Net Neutrality

Average Netflix connection speeds on Comcast's broadband network



Source: Netflix

statista



**Figure 52**

This chart illustrates how the Netflix connection speeds of Comcast subscribers have improved dramatically after the two companies struck a deal allowing Netflix direct access to Comcast's broadband network.

Source: <http://www.statista.com/chart/2255/netflix-comcast-deal/>

**Figure 53**

The buffer screen that Netflix has been displaying to some of its users

Source: <http://www.cnet.com/news/netflix-takes-aim-at-verizon-over-slow-data-speeds/>

For instance, an IoT product may employ a third party product, such as a smart phone or tablet, as its interface. Both products therefore need to be available in a given market for this XaaS solution to be viable for consumers. Otherwise the solution is unlikely to be very 'useful, usable or desirable'.

Moreover, even if both products are present in a market, one of them may refuse to cooperate. CNN reports that Keurig's new coffee machine will be equipped with a camera that inspects coffee pods.<sup>4</sup> If these pods do not have a 'proprietary taggant material' embedded on their lid then they will be rejected by the machine. In other words, unlicensed cups won't work with Keurig's new coffee maker. Kate Binette from Green Mountain Coffee Roasters, the parent company of Keurig, maintains that:

*"It is critical for performance and safety reasons that the system only brews Keurig brand packs."<sup>5</sup>*

Others, such as Jon Rogers, President of the company that makes San Francisco Bay coffee, argue that this constitutes an anti-competitive practice that stifles innovation and leads to higher prices for the consumer:

*"If Green Mountain Coffee Roasters is allowed to introduce Keurig 2.0 with the feature that, in our opinion, is clearly in restraint of trade, the Keurig 2.0 monopoly would be reinstated as it was when Keurig 1.0 was the only brewer on the market."<sup>6</sup>*

## Power over Network Traffic

Network operators have the power to disrupt IoT networks. This is because they can potentially cripple the service component of an IoT solution. For example, they can block or slow down traffic on their broadband networks based on individual users or the type of traffic those users are accessing or by the type of service that is sending the content.

4) See CNN's story "Apparently This Matters: Keurig 2.0" by Jarrett Bellini: <http://edition.cnn.com/2014/03/07/tech/social-media/apparently-this-matters-keurig-drm/>  
5) Ibid.

6) Ibid.

Take the example of Netflix and their current fight over the issue of net neutrality. Network neutrality is the principle that all Internet traffic should be treated the same. Netflix maintains that their traffic is being unfairly degraded. As a result they claim that they are being forced to sign interconnect deals that they hope will improve video quality.<sup>7</sup> Netflix CEO Reed Hastings has therefore called for stronger net neutrality. He argues that:<sup>8</sup>

*"Strong Net neutrality prevents ISPs from charging a toll for interconnection to services like Netflix, YouTube, or Skype, or intermediaries such as Cogent, Akamai, or Level 3, to deliver the services and data requested by ISP residential subscribers. Instead, they must provide sufficient access to their network without charge."*

Nor is network neutrality the only challenge when it comes to network traffic. Consumers also need to be able to afford to pay for their IoT data use. This use is likely to be sizeable given that there are projected to be 50 billion connected devices by 2020. Moreover, many of these devices will be mobile and hence potentially prone to roaming fees. New business models for data usage are therefore going to need to be pioneered.

7) <http://www.cnet.com/news/netflix-takes-aim-at-verizon-over-slow-data-speeds/>

8) <http://www.cnet.com/news/comcast-vs-netflix-is-this-really-about-net-neutrality/>

Issues such as the ability of consumers to change network operator are also going to come into play if IoT markets are to be competitive. For instance, SIM cards that are embedded in IoT objects may not easily be changed via physical access to the device. The GSMA, which represents the interests of mobile operators worldwide, believe that they have a solution:<sup>9</sup>

*"The GSMA's Embedded SIM delivers a technical specification to enable the remote provisioning and management of Embedded SIMs to allow the 'over the air' provisioning of an initial operator subscription and the subsequent change of subscription from one operator to another."*

At the most fundamental level the question is whether IoT networks should be treated as public utilities.

## Power over Services and their Distribution

Pursuing a XaaS business model vests considerable power with the service enabler and service provider. For instance, Richard Bremner at Autocar reports that Mini is:<sup>10</sup>



**Figure 54**

Mini are considering providing options, such as heated seats, as service that can be switched on or off

Source: <http://www.autocar.co.uk/car-news/detroit-motor-show/mini-should-have-uk-design-studio>

*"... considering downloadable apps that would allow the car to be upgraded, and downgraded too if the next owner didn't want to pay for the feature. As an example he [Mini brand boss, Peter Schwarzenbauer] cites seat heater elements, which would be built into all Minis and activated by buying an app that the next owner could decline if they didn't want it. In effect, it would be like renting certain options."*

Whereas today a consumer can resell their Mini with heated seats for say, €10,000, in the future they may have to resell it without heated seats for say, €9,000. In other words, less money is going to the reseller. Moreover, it is unclear whether under this new arrangement the second owner of the car would end up with a better deal for their heated seats or whether the sole

benefactors would now be the service enabler and service provider.

In fact, XaaS potentially opens up the door for sophisticated market segmentation strategies by service enablers and service providers. Smart devices have 'unique identifiers', such as RFID tags, IMIE numbers, MAC and IP addresses. These identifiers can be employed to control the delivery of services to a very granular level. After all, IMIE numbers are already routinely used to disable stolen mobile phones. RFID tags embedded in metro tickets decide whether or not someone can travel. Whilst, IP addresses are often used to decide if consumers are allowed to watch online television depending on their location. Similar approaches could be employed by all manner of IoT solutions.

9) <http://www.gsma.com/connectedliving/embedded-sim/>

10) <http://www.autocar.co.uk/car-news/detroit-motor-show/mini-should-have-uk-design-studio>

Basically, the whole notion of who holds which property rights in the IoT is up for re-examination. Typically these rights are bundled into four categories:<sup>11</sup>

1. The right to exclude
2. The right to transfer
3. The right to possess and use
4. The right to destroy

Nor does the Mini example end here. If Mini were to deploy their heated seat service using a third party app store then they too may fall foul of the terms and conditions imposed by this service enabler. For instance, the app store may at some point choose to remove their Mini app for some reason. This is one of the dangers of walled gardens in the IoT.

To try mitigate against this eventuality Mini could instruct their systems integrator to roll out their service in multiple app stores; that is assuming that there is a competitive market for app stores.

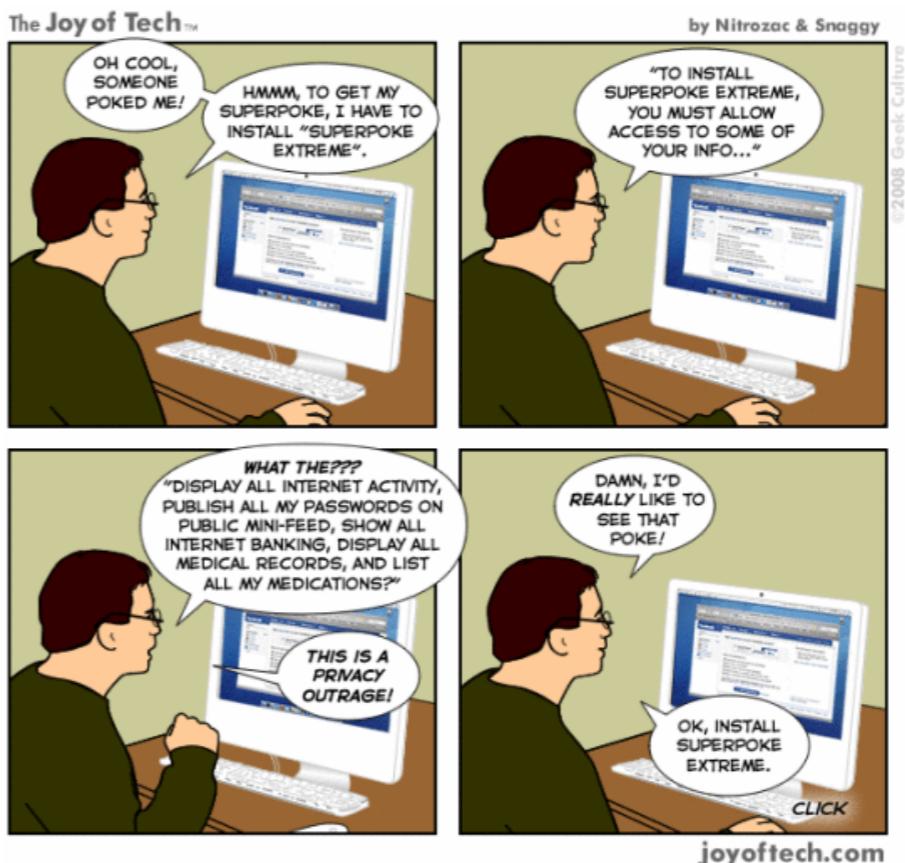
They could also seek to develop a web app instead of native apps. This is the route that the Financial Times took back in June 2011 in response to Apple's introduction of new rules governing subscription-based iOS apps. According to The Guardian newspaper:<sup>12</sup>

*"The sticking point for the FT was less about Apple's demand for a 30% cut of subscription revenues for people signing up from its native app, and more about a lack of access to data on those subscribers."*

The amount of power that systems integrators have over services also depends on other factors, such as the level of access that they have to cloud service APIs, as well as the degree to which they implement 'Service Oriented Architecture' (SOA). SOA joins services together in a way that enables them to be coupled and decoupled more easily.

Then there are questions surrounding privacy when consumers use IoT services. It is worth remembering that the majority of data in the IoT is machine-generated, not user-generated, and also just how much data one sensor can create. Moreover much of this data is processed in complex and dynamic networks. Concepts of users providing informed consent or opting out become unworkable in such a context.

Tim O'Reilly of O'Reilly Media adopts a contrarian view on privacy.<sup>13</sup> He does not support the view of Scott McNealy who maintains that one no longer has any privacy, 'so get over it'. However he



**Figure 55**  
Privacy conundrums in the IoT  
Source: <http://stevenduque.com/2010/05/facebook-privacy-the-tell-all-generation-learning-discretion/>

notes that often the services that people find so useful require them to give up their privacy. As a result they will do so and there will be many third parties who have access to a lot of data about them.

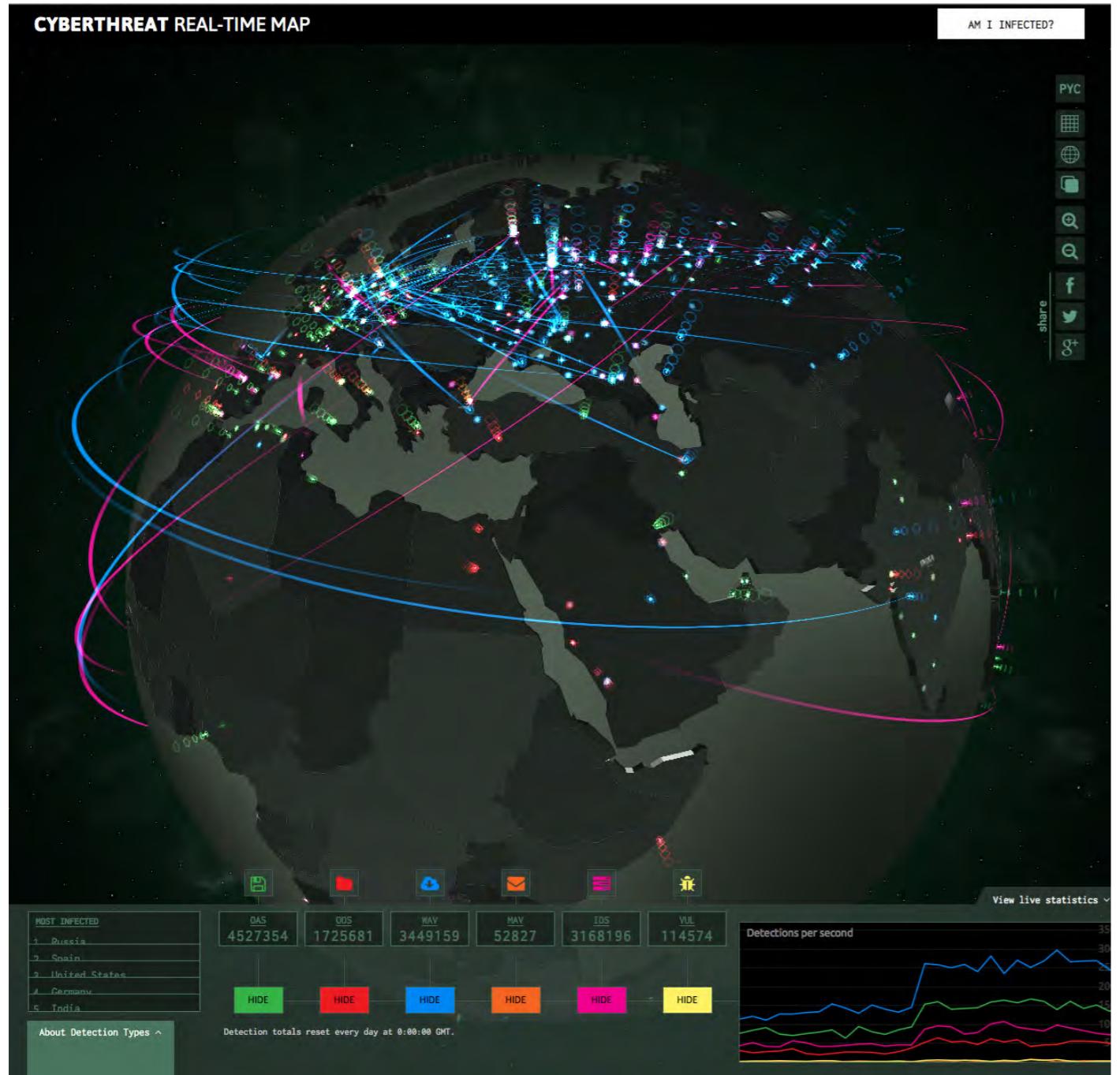
Assuming this future, O'Reilly sees one of two options. Either one makes these third parties throw the data away, but then the service will not work. Alternatively one regulates what these parties can and cannot do with the data. He observes that there are already data regimes that follow this model and cites the example of insider trading:

*"You can get all the material and non public information you want, but if you have it, guess what, you can't trade on it, so then people don't want to have it. And sure, people cheat and sometimes they get away with it, but sometimes they go to jail. And I think we need to figure out, I've sequenced my genome, you have my personal health information, so now you can't discriminate against me by denying me insurance. That's the way the law needs to go to deal with the future that we're heading into. Yes, you're going to know these things about me, so you can't sell that to certain kinds of parties, you can't trade against me."*

11) "Property Law", John G. Sprankling, p5

12) <http://www.theguardian.com/media/appsblog/2012/apr/24/financial-times-web-app-2m>

13) See 27 minutes into the video: <http://www.youtube.com/watch?v=zhUEvsq1xOo>



**Figure 56**

A snapshot of the world's cyberthreats in real time at 2040hrs CET 16 June 2014

Source: <http://cybermap.kaspersky.com/>

Linked to privacy issues, consumers also need to be confident that their IoT services are secure. Marc Rogers, principal security researcher at Lookout, observes that when devices are connected then their value to potential aggressors fundamentally changes:<sup>14</sup>

*"Once a thermostat is connected you can tell what's going on inside the house, when it is empty, and if it is harvested with a whole lot of other thermostats, it could be used as a weapon."*

In fact in January 2014 Proofpoint researchers discovered evidence of a much theorized, but never before seen, IoT cyber-attack.<sup>15</sup> IoT home appliances, such as TV's and refrigerators, sent out malicious email spam. For several weeks they participated in three campaigns a day of approximately 100,000 emails per campaign.

Aside from the direct consequences of such attacks, there are interesting questions of who should be held liable for the damage done - service enablers, service providers, resellers, end consumers or some other stakeholder?

Even if an IoT service is secure, it might not always be safe for its

consumer. After all, whose interests is the service serving - the users or society at large? David Weinberger has asked whether a Google car would sacrifice its user for the sake of the many:

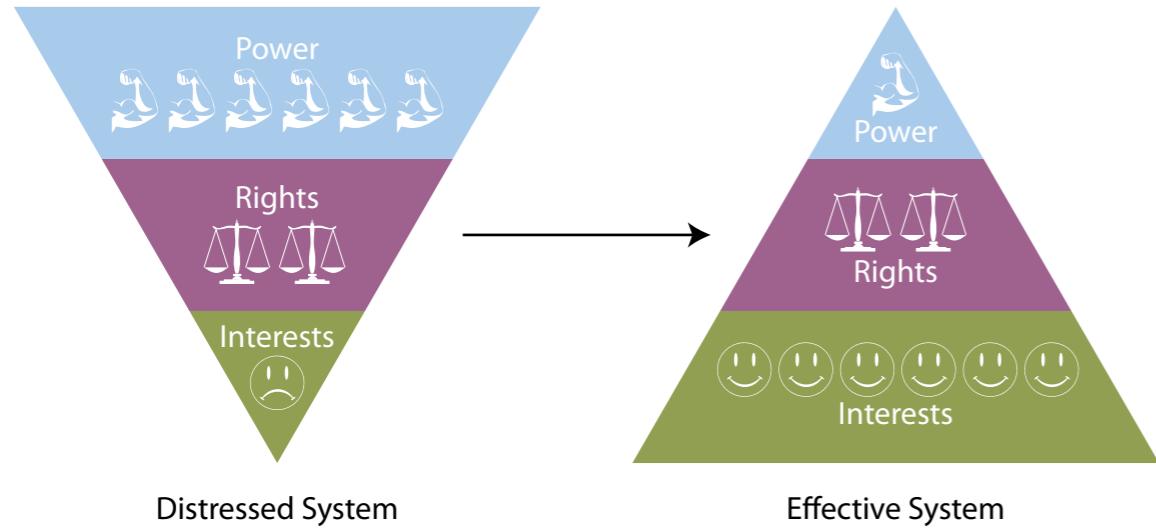
*"Google self-driving cars are presumably programmed to protect their passengers. So, when a traffic situation gets nasty, the car you're in will take all the defensive actions it can to keep you safe. But what will robot cars be programmed to do when there's lots of them on the roads, and they're networked with one another? We know what we as individuals would like. My car should take as its Prime Directive: "Prevent my passengers from coming to harm." But when the cars are networked, their Prime Directive well might be: "Minimize the amount of harm to humans overall." And such a directive can lead a particular car to sacrifice its humans in order to keep the total carnage down."<sup>16</sup>*

On a separate point, Marc O'Neil, vice-president for innovation at Axway, notes that:<sup>17</sup>

*"Companies also risk being defrauded by their own technologically-minded customers, who can hack, say, an electric car system to charge their vehicle for free."*

14) <http://www.ft.com/cms/s/0/4f90671c-55e9-11e3-b6e7-00144feabdc0.html?siteedition=uk#axzz34pMNRtgE>  
 15) <http://www.proofpoint.com/products/targeted-attack-protection/internet-of-things.php>

16) <https://medium.com/@dweinberger/e9d6abcf6fed>  
 17) <http://www.ft.com/cms/s/0/4f90671c-55e9-11e3-b6e7-00144feabdc0.html?siteedition=uk#axzz34pMNRtgE>



**Figure 57**

Distressed versus effective systems for conflict resolution

Source: "Getting Disputes Resolved - Designing Systems to Cut the Costs of Conflict", William L. Ury, Jeanne M. Brett and Stephen B. Goldberg

### Balancing Power, Rights and Interests in the IoT

With this power distribution and all these issues, the potential for conflict in the IoT is significant. William L. Ury and his colleagues at Harvard Law School observe that conflicts can be resolved in one of three ways. IoT stakeholders may seek to:<sup>18</sup>

1. Reconcile their underlying interests
2. Determine who is right, and/or
3. Determine who is more powerful

Ury and his colleagues recommend the following approach:

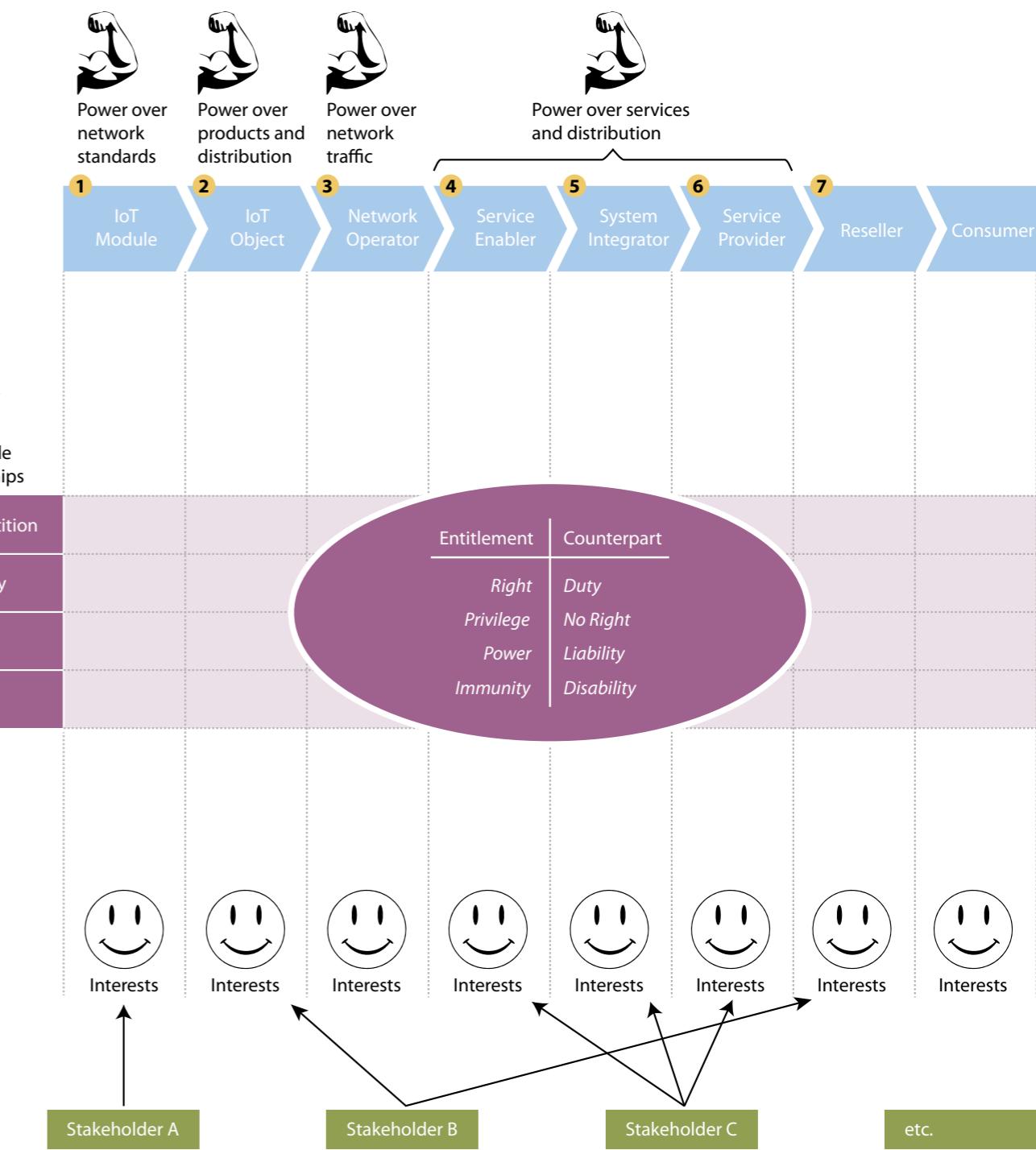
*"The goal then is for a dispute resolution system that looks like the pyramid on the right ... most disputes are resolved through reconciling interests, some through determining who is right, and the fewest through determining who is more powerful. By contrast a distressed dispute resolution system would look like the inverted pyramid on the left ... Comparatively few disputes are resolved through reconciling interests, while many are resolved through determining rights and power. The challenge for the systems designer is to turn the pyramid right side up. It is to design a system that promotes the reconciling of interests but that also provides low-cost ways to determine rights or power for those disputes that cannot or should not be resolved by focusing on interests alone."*

<sup>18)</sup>"Getting Disputes Resolved: Designing Systems to Cut the Costs of Conflict", William L. Ury, Jeanne M. Brett and Stephen B. Goldberg, The Program on Negotiation at Harvard Law School, p18

**Figure 58**

A regulatory framework for addressing the challenge of balancing power, rights and interests in the IoT

Source: Carré & Strauss



This then is the governance challenge for the IoT. Thankfully there is already a point of departure. The value chain is known, as are some of the potential power-plays in the IoT. Many of the key rights that need to be addressed can be identified, such as the rights to property, privacy and security, as well as the need for competition in the marketplace. It is known that there are wide range of interests at stake and that one stakeholder may hold multiple interests in the value chain. Putting this altogether provides a regulatory framework for addressing the challenge of balancing power, rights and interests in the IoT (see Figure 58).

This framework expands the concept of 'rights' to one of 'relationships between interests', such as between network operators, system providers and consumers. It draws on insights provided by Professor John G. Sprankling in his book 'Property Law'. He states:<sup>19</sup>

*"Professor Wesley Newcomb Hohfeld revolutionized property law theory in the early twentieth century by envisioning property as a complex web of legally enforceable relationships. He developed an analytical framework for*

*precisely classifying these relationships. Under this view, a property owner may hold four distinct entitlements: rights, privileges, powers, and immunities. Each entitlement is linked to a 'correlative' counterpart: right-duty; privilege-no right; power-liability; and immunity-disability."*

Newcomb's approach can be extended to all of the rights in the IoT - privacy, security, etc.

### Towards Smarter Intervention in the IoT

'Smarter Intervention in Complex Systems' is a methodology that can help guide the fleshing out of this IoT governance framework. It is based on three tenets, namely a smarter intervention mindset, mechanism and principle:

- Mindset.** The systems that one is seeking to shape are often complex. They are nonlinear. A does not always lead to B to C to D to E. Instead they can be full of surprises. One cannot predict-and-control their behaviour. Instead a far more iterative trial-and-error approach needs to be pursued. One in which the decisions that are taken are survivable.

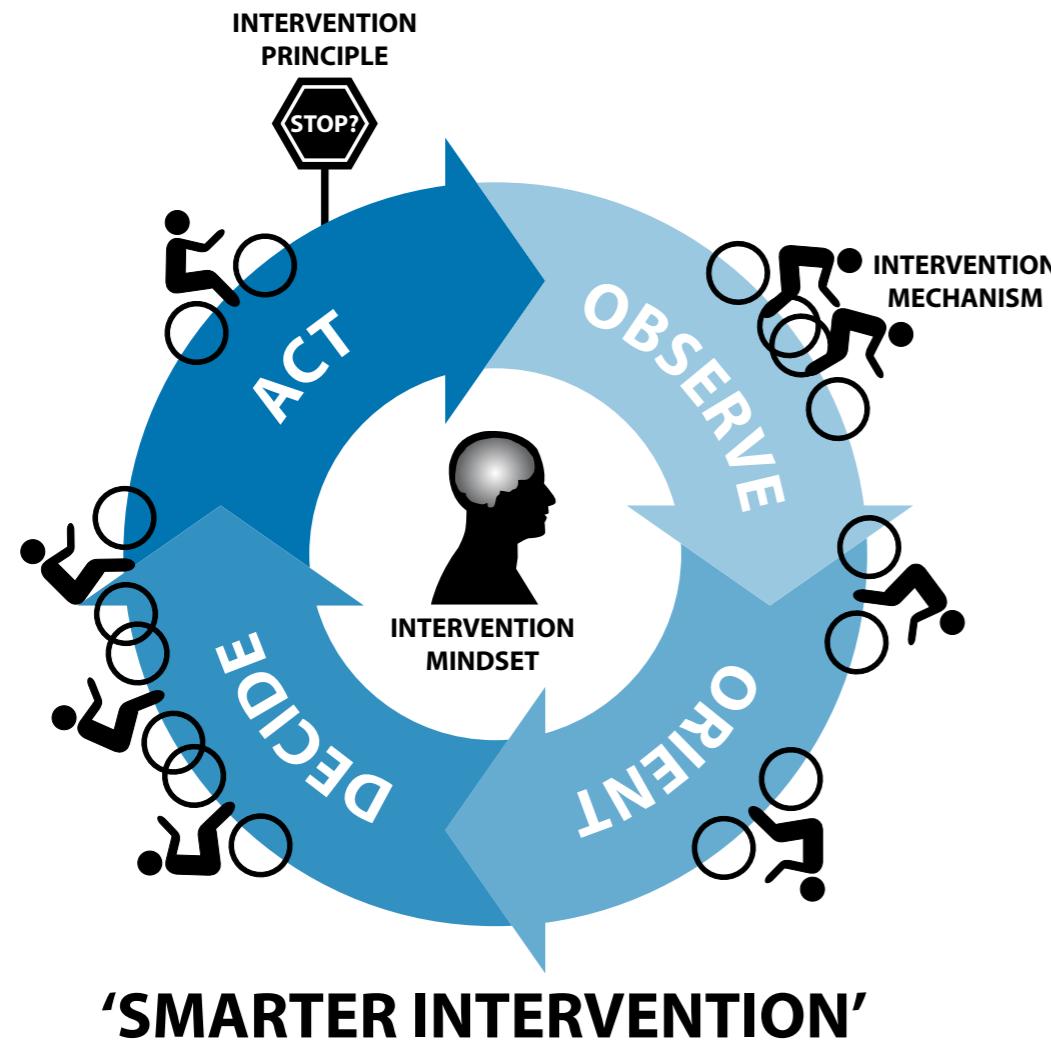
<sup>19</sup>"Property Law", John G. Sprankling, p8 - also see: [http://digitalcommons.law.yale.edu/cgi/viewcontent.cgi?article=5383&context=fss\\_papers](http://digitalcommons.law.yale.edu/cgi/viewcontent.cgi?article=5383&context=fss_papers)

AGENT CONFIGURATION	AGENT TYPE		
	Non-Expert	Expert	Algorithm
Individual	<p>People have 'common sense' - in more formal terms, 'sensitivity to context' - computers do not. This is also the domain of 'personal choice'.</p> 	<p>Experts come into their own in the area between 'rote rule following' and 'probabilistic prediction' - an area in which a combination of knowledge and initiative is required.</p> 	<p>People can be replaced by computers when it comes to making certain types of 'rule-based decisions' if the requisite hardware, software and data exists and it makes economic sense to do so.</p> 
Crowd	<p>To figure out the value of something it's best to take an average of a group's answers. For choosing the right answer from a small number of possible alternatives majority opinion serves us better. The right conditions need to be in place to take advantage of either method.</p> 	<p>Groups of experts will outperform most, if not all, individual experts.</p> 	<p>Machine-to-Machine (M2M) communication is resulting in the abrupt rise of new behavioural regimes that are beyond human response times. Researchers are at the early stages of understanding this new machine ecology.</p> 
<b>EACH OF THESE SQUARES IS A POTENTIAL 'INTERVENTION AGENT'</b> 			

**Figure 59**

Intervention in systems can emanate from non-experts, experts or algorithms and can be configured in different ways, either in the form of individuals or of crowds

Source: Adapted from "Smarter Intervention in Complex Systems", Mark Fell, Carré & Strauss



**Figure 60**

Smarter intervention in complex systems is a methodology based on embracing a new intervention 'mindset', 'mechanism' and 'principle'

Source: "Smarter Intervention in Complex Systems", Mark Fell, Carré & Strauss

**2. Mechanism.** The OODA Loop (Observe-Orient-Decide-Act) is a practical method for actioning this trial-and-error approach. It asks who is best placed to gather sensory inputs from an environment (Observe)? Who is best equipped to make sense of this situational reality (Orient)? Who should use this new knowledge as the basis for decisions (Decide)? And, who ought to translate these decisions into action (Act)? One can cycle this OODA loop by using experts or non-experts. They may be individuals or groups - i.e. crowds. Increasingly the loop is being cycled by software algorithms, often in the form of Machine-to-Machine (M2M) communication. Each of these 'Intervention Agents' has its strengths and weaknesses (see Figures 59 and 62). Agents can emanate from any stakeholder group, be they from the public sector, the private sector or civil society. The key message is that none of these agents is the panacea to cycling the loop. In each specific case one needs to identify the appropriate combination of these agents. An 'Intervention Mix' is required. In other words, one needs to move beyond the false choice between more or less government intervention in systems. It is the wrong way to frame the challenge.

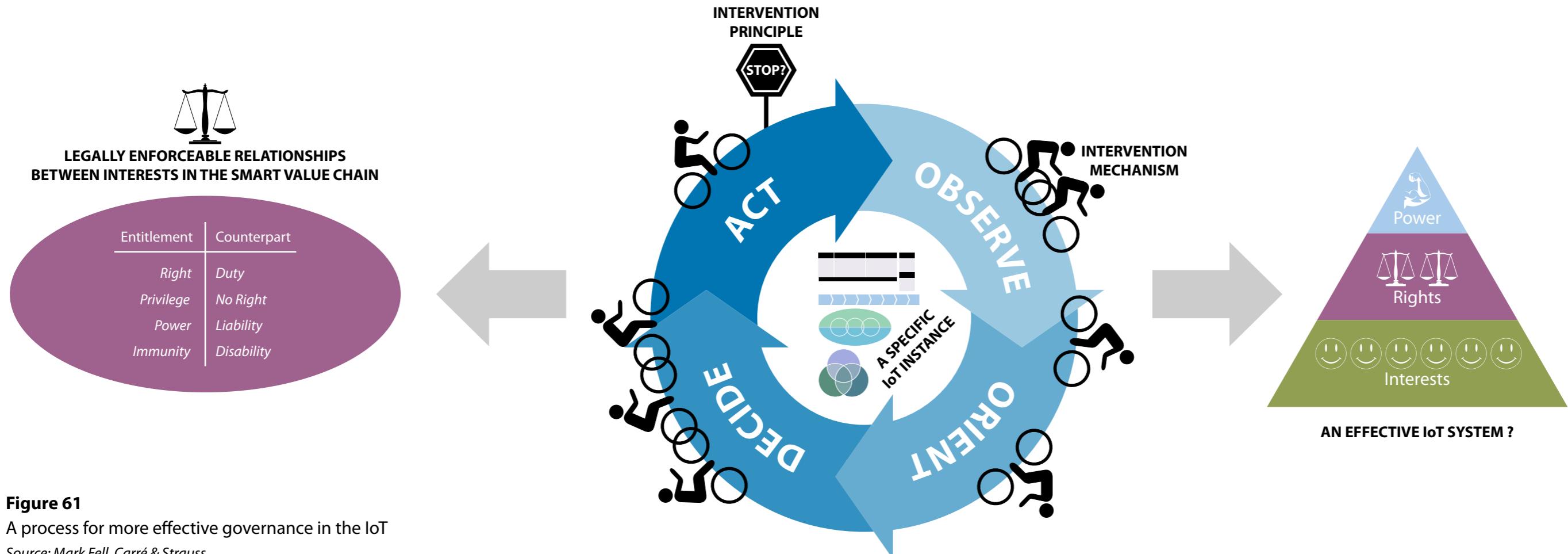
### THE INTERVENTION PRINCIPLE

*"An intervention agent is to intervene in the Observe-Orient-Decide-Act (OODA) loop only if, and in so far as, it is reasonably foreseeable that the objectives of the proposed intervention cannot better be achieved by the system running itself or in default of this by another agent"*

**3. Principle.** To achieve this mix an 'Intervention Principle' is proposed (see above). To the extent that a system can successfully self organise, it should be left to do so. Put simply, one should remain out of the loop. Where intervention is necessary, then the case has to be made for why a given intervention agent should be involved in the OODA loop - i.e. the best agent to solve this type of challenge. The aim is to get all of these different agents cycling around the loop as a team, at the right tempo and to be able to hold them to account.

A fuller explanation of the methodology is available at:

[http://www.carre-schroeders.com/documents/Smarter\\_Intervention\\_In\\_Complex\\_Systems.pdf](http://www.carre-schroeders.com/documents/Smarter_Intervention_In_Complex_Systems.pdf)



## Pulling It Altogether

The preceding architecture, framework and methodology can be synthesized into a three step process for more effective governance in the IoT:

## Step 1 - Define Scope

The IoT is potentially an Internet of Everything so first decide on where to focus ones attention. In other words, primarily operate at a sectorial level rather than trying to address generically IoT governance – a far too nebulous approach.

For example, one can proceed by concentrating on the specific instance of Smart Commerce (equally this could be Smart Health, Smart Energy, etc.).

## Step 2 - Observe and Orient

Next identify and make sense of all the interests, rights and power at play in Smart Commerce value chain - those providing smart modules, smart objects, as well as network operators, service enablers, system integrators, service providers, resellers, over-the-top players, consumers, etc.

Then determine whether this configuration of interests, rights and power constitutes an effective system or a distressed system for Smart Commerce. Recall that in effective systems most disputes are resolved through reconciling interests, some through determining who is right, and the fewest through determining who

is more powerful. Whereas distressed systems are ones in which few disputes are resolved through reconciling interests, with many being resolved through determining rights and power.

### Step 3 - Decide and Act

If the Smart Commerce system is distressed in some way, then revisit what should be its objectives. Agree on what outcomes the system should deliver – what should be its ultimate goals?

For example, the Smart Commerce value chain should: (a) deliver XaaS solutions to consumers that are increasingly ‘useful, usable and desirable’; (b) ensure that those that

supply, operate and support the value chain can make a profit so that they can invest in innovation and satisfy shareholders; and, (c) safeguard property, consumer and privacy rights from abuses of power, as well as ensure security.

In light of these objectives, employ the 'Intervention Principle' to guide if, when and how to intervene in the Smart Commerce system:

*"An intervention agent is to intervene in the Observe-Orient-Decide-Act (OODA) loop only if, and in so far as, it is reasonably foreseeable that the objectives of the proposed intervention cannot better be achieved by the system running itself or in default of this by another agent."*

Remember that these intervention agents may emanate from the public sector, private sector or civil society. They may be individuals or crowds, experts or non-experts, human or algorithmic. Most likely a combination of these agents is required – i.e. an Intervention Mix.

If in this mix there is a role for government regulation, then institute the requisite legally enforceable relationships between the interests in the Smart Commerce value chain. Here Wesley Newcomb's framework provides a point of departure, as it identifies four distinct entitlements – rights, privileges, powers and immunities – as well as their correlative counterparts – right-duty, privilege-no right, power-liability and immunity-disability.

Critically, throughout these three steps maintain an Intervention Mindset that remembers that systems such as Smart Commerce are complex and non-linear – they can be full of surprises. They cannot be predicted-and-controlled.

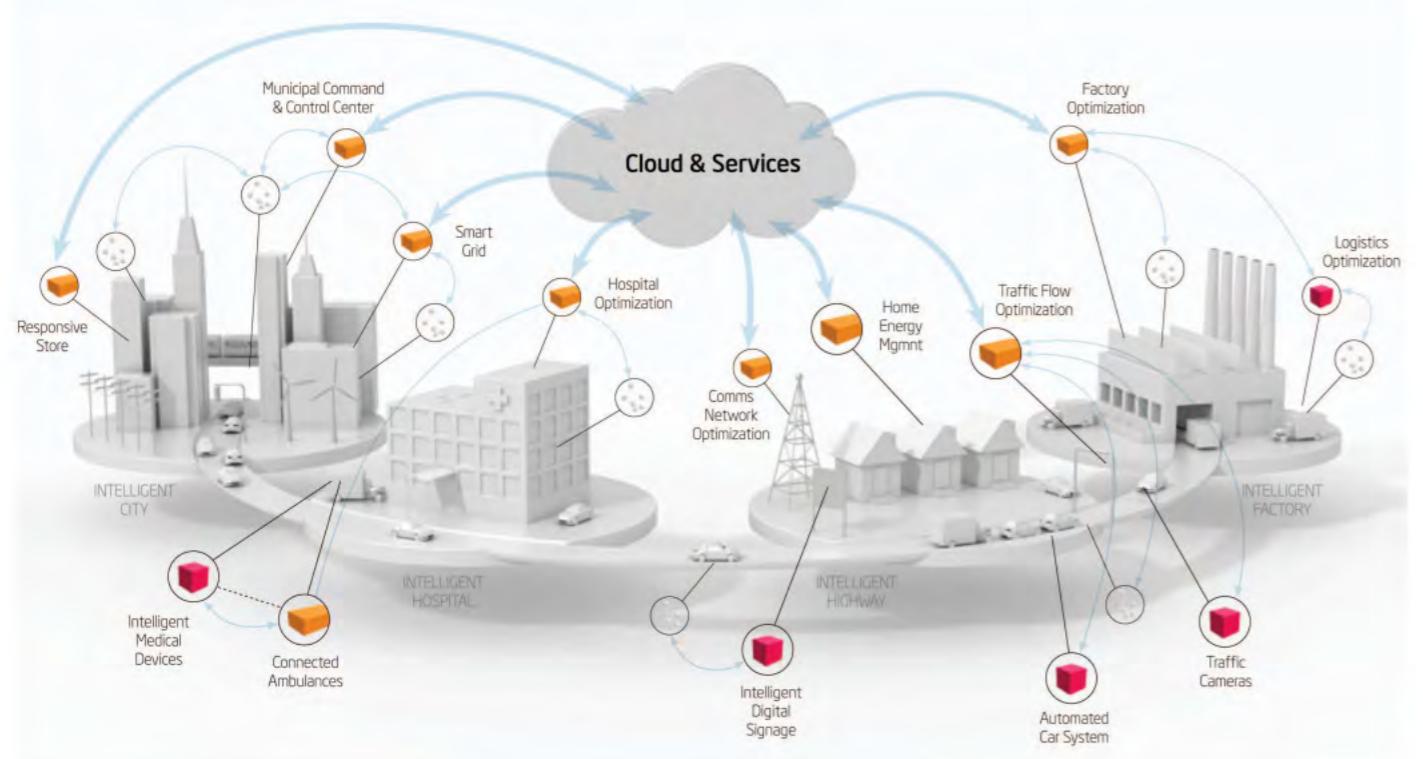
Limits	Engineering	Design and validation	Energy, time	Space, time	Information, complexity
Fundamental	Abbe (diffraction); Amdahl; Gustafson	Error-correction and dense codes; fault-tolerance thresholds	Einstein ( $E = mc^2$ ); Heisenberg ( $\Delta E \Delta t$ ); Landauer ( $kT \ln 2$ ); Bremermann; adiabatic theorems	Speed of light; Planck scale; Bekenstein; Fisher ( $(T(n))^{1/(d+1)}$ )	Shannon channel capacity; Holevo bound; NC, NP, #P; decidability
Material	Dielectric constant; carrier mobility; surface morphology; fabrication-related	Analytical and numerical modelling	Conductivity; permittivity; bandgap; heat flow	Propagation speed; atomic spacing; no gravitational collapse	Information transfer between carriers
Device	Gate dielectric; channel charge control; leakage; latency; cross-talk; ageing	Compact modelling; parameter selection	CMOS; quantum; charge-centric; signal-to-noise ratio; energy conversion	Interfaces and contacts; entropy density; entropy flow; size and delay variation; universality	
Circuit	Delay; inductance; thermal-related; yield; reliability; input-output	Interconnect; test; validation	Dark, darker, dim and grey silicon; interconnect; cooling efficiency; power density; power supply; two or three dimensions		Circuit complexity bounds
System and software	Specification; implementation; validation; cost		Synchronization; physical integration; parallelism; <i>ab initio</i> limits (Lloyd)		The 'consistency, availability, partitioning tolerance' (CAP) theorem

**Figure 62**

Some of the known limits to computation - i.e. algorithms

Source: *Nature*, Igor L. Markov

## Conclusion



In nature's ecosystems organisms interact with one another in three ways: competitively, symbiotically or as predator-prey. Moving forward the IoT can play out as any of these three ecosystems.

In financial markets there are already studies that indicate that a predator-prey ecosystem is forming on High Frequency Trading (HFT) platforms.

If instead society wants an IoT that fosters competitive and symbiotic relationships then it requires an effective governance process - one that

continually balances power, rights and interests across the smart value chain.

Achieving this has the potential to unlock an exciting future - a world in which every single social, economic, environmental and political challenge can be tackled in new and unconventional ways.<sup>1</sup>

In the words of Mahatma Ghandi:

*"The future depends on what you do today"*

1) Image above sourced from: <http://hutgrip.com/wp-content/uploads/2013/06/iot1.jpg>

## Annex

According Neil Gershenfeld and Jean-Philippe Vasseur there are four reasons for the Internet's success to date and these should be safeguarded:<sup>1</sup>

**1. Distributed Network.** No central hub instead network analogous to web of streets. Design lets data bypass traffic jams and lets managers add capacity where needed.

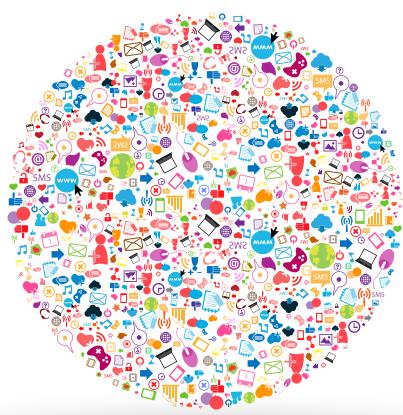
**2. Packet Switching.** Breaks data down into individual chunks that can be reassembled after their different online journeys. Makes Internet more reliable, robust and efficient.

**3. Internet Protocol (IP).**  
Standardizes the way packets of data are addressed. Enables data to flow over different types of networks.

**4. End-to-End Principle.** Functions of the network reside at end of the network, rather than at intermediate nodes which are reserved for routing traffic. This enables new applications to be invented and added without having to upgrade whole network. Online messaging, audio / video streaming, e-commerce, search engines, social media were all developed on top a system designed decades earlier

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<sup>1)</sup>"As Objects Go Online - The Promise (and Pitfalls) of the Internet of Things", Neil Gershenfeld and JP Vasseur, Foreign Affairs, March/April 2014, p 62-63



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