SPEECH

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Internet of the Future and Internet of things: What is at stake and how are we getting prepared for them?

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Ladies and Gentlemen,

It's a pleasure to be with you today to share my views on "The Future Internet". Let me first seize this opportunity to warmly thank the organisers of this conference which brings us together in the beautiful city of Oslo. Oslo city and area are well known to be a key driver and centre for research, innovation, and business developments as well as for social innovation.

I commend Margaretha Mazura, whom I have the privilege to know well in her capacity of Project Manager and expert for the European Commission, for her stupendous work, sometimes invisible yet very effective indeed. In recent years, Margaretha has worked co-operatively with other partners around the world to build the support that's so essential for promoting ICT use, in particular in the field of e-Business. So, I would like to honour in front of you the inspiring leadership and extraordinary achievements of Margaretha.

In September 1969 – exactly 40 years ago – about 20 researchers at UCL were seeking to create an open network for freely exchanging information for military purposes. That was the beginning of the fledgling Arpanet network. The 1970s brought e-mail and the TCP/IP communications protocols, which allowed multiple networks to connect – and formed the Internet. The 1880s gave birth to an addressing system with suffixes like ''.com'' and ''.org'' in widespread use today. But the Internet didn't become a household word until the 1990s, after a British physicist, Tim Berners-Lee, invented the World Wide Web, a subset of the Internet that makes it easier to link resources across disparate locations.

There's still plenty of room for innovation today, yet while the Internet is more widely available and faster than ever, artificial barriers threaten to constrict its growth. You can call it a mid-life crisis. The ensuing debates about the future of the Internet are of utmost importance for Europe. Indeed, the Future Internet represents an opportunity to improve the competitiveness of European businesses, to create more innovation-based growth and jobs, and to further contribute to the social well being of European citizens.

Internet will continue to transform the world as well as our relation to the world. Let me mention a few figures: the number of Internet devices was 1,000 in 1984, 1,000,000 in 1992, and 1,000,000,000 in 2008. It's estimated that 4 exabytes (4.0 x 10^19) of unique information will be

generated in 2009. That's more info than was produced during the previous 5,000 years. And it is not finished – technical information is doubling every two years!

The Internet of today has already largely contributed to these policy goals. Over the last 15 years, it has enabled the creation of an entirely new economic sector. It has also deeply transformed our approach to social relations, to access to culture, education, or entertainment.

But more is to come. New challenges are ahead of us: an ageing population, environmental and energy concerns, the scarcity of raw materials, globalisation, and regional imbalances are typical examples. The OECD ministerial conference on "The future of the Internet economy" in Seoul last year stressed the vital role that Internet and ICT technologies can play to tackle these issues.

Novel socio-economic trends fuelled by restless technological developments also raise new challenges and opportunities for the Internet. Let me mention a few of these:

1. Web 2.0 and social networks are growing at viral rates. Popular social sites attract more than 120 millions regular users. This is only the beginning as web 2.0 applications will be more and more used by businesses, not only by individuals. The emergence of 'Enterprise 2.0' will bring about huge benefits to European companies and SMEs in particular. One cluster of projects that is managed by my unit – the Future Internet Enterprise Systems cluster (FInES) – has recently unveiled convincing evidence that pinpoints the exact challenges and opportunities of Enterprise 2.0.

2. Mobility and nomadic usages are becoming the norm. This year, the number of mobile users in the world has passed the 4-billion level. By 2012, at least 1 billion of those will use mobile as their only access to the Internet, adding to the today 1.5 billion of fixed users.

3. An ever richer content and media environment. Content is clearly one of the main drivers of Internet changes. Popular social video sites add 13 hours of user video content to the Internet every minute! Search engine systems refresh the equivalent of the entire library of Congress every four hours. Every year, the Internet traffic grows by 60%. This is mainly due to video and will be further amplified with the advent of on line 3D content.

4. The ever growing sensitivity to security, trust and privacy issues.

5. Last but certainly not least, the emergence of an Internet with "Things": In the near future, it will be possible to interconnect myriads of objects and devices, beyond the connectivity of today that covers computers, servers and web pages. This extended nervous system will make possible new types of applications combining information of the virtual world with a perception of the physical world. I will come back to this important trend.

So, the question that we can ask is the following: Is the Internet of today able to face the increasing number of requirements and expectations which we have? Concerns have been expressed by several prominent industrial and academic stakeholders that this is not the case.

A large part of the issues at stake is of technological nature and require collaborative research work. The "Future Internet Assembly", which has been meeting regularly over the last two years, is addressing them in depth.

However, the Internet of tomorrow also raises important policy issues. As the Internet becomes more pervasive and critical to our societies, new opportunities for innovation and growth have to be encouraged. On the other hand, new risks in terms of privacy, security or market distortion have to be addressed. These issues require a response from policy makers and the designers of tomorrow's Internet.

The approach of the European Commission is clear.

First, the Internet of tomorrow must preserve openness. It must also be based on the right governance principles.

Openness is one of the key ingredients that made the Internet so successful as an innovation place and as a tool to empower users. This key feature of the Internet should not be compromised through future evolution of its architecture. Open standards are an essential element of the response. We need to take advantage of the win-win of open interfaces and standards such that the market can grow for all, without consumer lock in, nor with undue royalties, ultimately stifling innovation and foreclosing market entry by new players.

From the governance point of view "*Net Neutrality*" is essential. It essentially means that a service provider could not favour certain forms of data traffic over others. The importance of Net Neutrality was highlighted when Apple recently blocked the Google Voice communications application, saying it overrides the iPhone's built-in

interface – the move, in fact, may be seen as thwarting Google's potentially competing phone services. New network management techniques allow traffic prioritisation. These tools may be used to guarantee good quality of service but may also be used for anti-competitive practices. The Commission has taken steps to empower national regulators to prevent such unfair abuse to the detriment of consumers. These measures are at the heart of the new telecoms regulatory package for which adoption is imminent.

Second, our vision of the Future Internet is also based on ubiquitous access to the Internet. Fixed and wireless technologies need to be widely available and interoperable to allow seamless high rate access to the Internet. With more than 100 millions broadband accesses and leading countries' penetration in the order of 40%, Europe is among the top broadband regions of the world. Europe is also a top "mobile player" and pioneering the deployment of very high rate Long Term Evolution (LTE) mobile networks.

The transition to high-speed broadband is crucial. The European Council after a proposal from the Commission made available up to €1.02 billion for investments in broadband in the EU. On the mobile side, our spectrum policy is aiming at making available the needed spectrum, for innovative broadband wireless networks to thrive.

Third, trust and security are crucial. 70% of the daily 200 billions of mails are spam. About 20% of the online PC population is reported to be compromised by botnets. Viruses, phishing are increasing at an alarming rate. Several recent attacks in Lithuania, Estonia and Georgia have illustrated how devastating cyber attacks may be. Security attacks are not anymore the unintended results of experimentation, but are often a lucrative economic activity for criminal organisations or the arena for politically motivated groups.

Technological responses must be found. On the other hand, policies need to be strengthened and, where necessary, created both in the European Union and at the international level so that we have the right tools to ensure security and resilience of our information infrastructure.

On 30 March 2009, the Commission adopted a Communication on "Critical Information Infrastructure Protection", (CIIP). It proposes an action plan to set up a framework for co-operation and collaboration across national activities. I believe that via this plan, and with a common effort of the Commission, of Member States, of the private sector and of

citizens we can tackle our most immediate challenges and create a more conducive environment for a secure and resilient information society in Europe.

We also need to find the right balance between security needs and the legitimate desire of users to protect their privacy. In this domain, the technological and scientific experts have to work hand in hand with the policy makers.

Fourth: Even in these hard times of economic downturn, forward-looking investments in research and innovation need to be preserved. This is why ambitious research initiatives have been launched, world-wide, with the objective of creating a renewed Internet architecture capable of performing its role as a critical infrastructure. The U.S. GENI/FIND programmes, the Japanese Akari programme, the Future Internet Forum of Korea, initiatives in many of our Member States represent bold steps to define the Internet of tomorrow.

In Europe, the 7th R&D Framework Programme provides a powerful tool to address the needed research on the multiple aspects of a Future Internet. Under this umbrella, European industrial and academic research actors benefit from a large scale co-ordinated effort of some € 400 million over two years, addressing the future of the Internet. With the launch of the FIRE initiative, European research actors will also have access to the experimental facility required by such a complex research domain.

The European approach is a truly holistic one: all network and service platforms technologies called upon to constitute the Internet of tomorrow are looked at as part of a single system. More than 90 research projects addressing the multiple facets of the Future Internet gather under the "Future Internet Assembly" (FIA), where they can exchange research results and approaches. The FIA is thus an important tool to have a better and global understanding of all the Future Internet issues at stake and to define research needs. Europe's commitment to long term Internet research is actually the most important one in the world.

In the nearer term, the European Commission is striving to closely couple EU's Future Internet technology research with applications of high societal value such as health, urban mobility, energy grids or smart cities. By so doing, we expect to provide an early "Internet response" to the current and emerging societal challenges. The goal is to establish a

Public Private Partnership with the industry to complement our longer term Future Internet research of the FP7 ICT Work Programme.

An important outcome of this Public Private Partnership will be a bold contribution to the economic recovery through innovation. This reinforces the measures taken in the "innovation driven" recovery package that the European Commission proposed last November. Indeed, the rapid take off of such applications supported by innovative Internet technologies can directly benefit our economies and citizens, because the target services will be provided locally. Our approach could hence be referred to as "Applying locally a global Internet technology thinking".

Currently, the European Commission is working with industry to define the content and structure of this Public Private Partnership, towards an operational kick-off in 2011. Incidentally, I hail the fact that the dismal present circumstances have brought back the enterprise at the centre of the policy decisions regarding research priorities!

In brief, we need to approach the Internet of tomorrow with a consistent policy mix, including the right approach to regulation and governance, incentives towards deployment of the needed infrastructures, and investments in research and innovation.

Let me add a few remarks:

- First remark: Innovation has been at the heart of the Internet. It has also been a key pillar of the EU's Lisbon strategy. At a moment when we are reflecting on our "post Lisbon" and "post i2010" strategies, it seems crucial that the Future Internet gets the right level of recognition under the innovation strategy that the next Commission will put in place.

- Second remark, more than ever, there is a need to establish tight links between technology developers, scientists and policy makers. This is not about putting a straight jacket on the creativity of the Internet research community. But as the Internet has become a critical backbone infrastructure of our economies and societies, such a dialogue becomes a prerequisite.

- Third remark: broadband, mobility, trust and security are key drivers towards the advent of a Future Internet. These are clear domains where both European industry and research community have world class expertise. European players should, therefore, be active drivers in the Future Internet debates, and not passive listeners or simple

solution adopters. This means that we in Europe should see the Future Internet developments as a golden opportunity to reinforce the competitiveness of the ICT industry and to foster the emergence of an innovative SME fabric.

- Fourth remark: The Internet is already global: services are offered and consumed without distance limitations. In the future the bulk of the users world-wide will neither be in Europe nor in North-America. They will be elsewhere. This inevitably leads to a strong requirement towards global Internet governance based on a reinforced global partnership and co-operation.

Let me turn now to what is currently my main activity in the European Commission and what I believe will be the biggest development brought about by the Future Internet – the Internet of Things.

The phrase "Internet of Things" is 10 years old, which corresponds more or less to the time it takes for new concepts, and associated technologies, to gain maturity and recognition – or to fall in the holes of history. It tells us about a time when networks will enable all kinds of devices, appliances and objects to interact and communicate among them and with the environment.

What is important is to consider the Internet of Things as an integral part of the Future Internet. This assertion was recently made by the cluster of European R&D projects on the Internet of Things (CERP-IoT), which is also managed by my unit. Technologies such as Near Field Communications (NFC) and Wireless Sensor and Actuator Networks (WSAN) together with RFID will provide the basic components that will link the real world with the digital world. Indeed, the integration of these basic components into wider networks, mobile or fixed, will allow their interconnection with the Future Internet.

The scope of the Internet of Things is very broad. It includes obviously the machine-to-machine communications (M2M), but it goes far beyond by enabling any object to connect and leverage the Internet. In order to become a reality the Internet of Things needs to involve three main functions:

- The identification of the object, which implies that the price of RFID and NFC tags, for instance, go down significantly so as to allow the tagging of objects in cost-effective ways;

- The connectivity to the Internet, which implies that we have interoperability and a coherent numbering system to connect the different objects and services;

- The information processing and storage, which implies the availability of large databases to provide information related to the object.

Today, I would like to give you an impression of what's happening by musing on the "who?", the "why?", the "when?" and the "what?". Let's start with the "Who?" – what I would call "Profiles in the Internet of Things".

Kevin Ashton is the first prophet of the Internet of Things, the first person who used the phrase "Internet of Things" as the title of a presentation he made at Procter & Gamble in the spring of 1998. He said then: "*Adding radio-frequency identification and other sensors to everyday objects will create an Internet of Things, and lay the foundations of a new age of machine perception.*"

Interestingly, it was one year later that Philips Research, in collaboration with the Massachusetts Institute of Technology (MIT) and with INRIA and Thomson Multimedia, proposed the concept of Ambient Intelligence. This concept was adopted in 2001 by the IST Advisory Group of the European Commission. Ambient Intelligence is different from the earlier concept of Pervasive Computing, in that the former is concerned less with basic technology than the use of the technology – by the individual, by business, and by the public sector. But it is very close to the concept of Internet of Things since it offers the vision of a world in which technology, in the form of small but powerful silicon chips, will be integrated into almost everything around us, from where it will create an environment that is sensitive to the presence of people and responsive to their needs.

Today computers are almost wholly dependent on human beings for information. Nearly all of the roughly 50 petabytes (a petabyte is 1,024 terabytes) of data available on the Internet were first captured and created by human beings – by typing, pressing a button, taking a digital picture or scanning a bar code. The Internet has today tremendous transmission possibilities but it leaves out the most numerous and important routers of all – people! The problem is, people have limited time, attention and accuracy. Ashton argues that if we had computers knowing everything there was to know about things, we would be able to

track and count everything, greatly reduce waste, loss and cost, and know when things need replacing, repairing or recalling. Looking ahead far beyond the supply chain dimension of the Internet of Things, he believes that the Internet of Things has the potential to change the world, just as the Internet did 40 years ago.

Vinton Cerf tells us that after the Internet which has been all about connectivity between computers and among people, after the World Wide Web which has opened great opportunities and motivations for the injection of content into the Internet, and after search engines, such as Google's, which provide an easy way for people to find the right content, the Internet continues to develop – in the next decade, he believes, around 70% of the human population will have fixed or mobile access to the Internet at increasingly high speeds and mobile devices, as well as appliances and sensors of all kinds, will become a major component of the Internet.

Bruce Sterling is a science fiction writer and a very inspiring speaker. In his famous book, Shaping Things, he describes how we will move from the age of products and gizmos to the age of what he calls "spimes". He imagines how physical objects will be part of the Internet as they become trackable in space and time.

A Spime is a location-aware, environment-aware, self-logging, self-documenting, uniquely identified object that flings off data about itself and its environment in great quantities. Spimes have to be virtually designed, they have to have a unique identity, they have to be fabricated, they have to be tracked, searched, and recycled at the end of their use, and they have to leave metadata behind. Otherwise they're not true spimes. Today a spime is rather speculative, because no real objects have these qualities. But as the Internet of Things changes how we interact with objects from the moment of invention to the moment of decay, spimes may well become a reality.

I also like the way Sterling explains how language shapes our understanding of technology. Think of phrases like Ambient Intelligence or Pervasive Computing; they have become frozen in time. This freezing of the language may have hindered the development of computers that have little to do with thinking and everything to do with linking, ranking and sorting. Therefore, considering that the Internet of Things may take up to thirty years to come about, there is no reason to expect the terminology of today to fully describe realities of the future.

Julian Bleecker is another seer of the Internet of Things. Where Sterling speaks of "spimes", he speaks of "blogjects", i.e. objects that blog. Bleecker sees three peculiarities of a blogject:

- Blogjects track and trace where they are and where they've been;
- Blogjects have self-contained histories of their encounters and experiences;
- Blogjects always have some form of agency — they can foment action and participate; they have an assertive voice within the social web.

The most interesting point made by Bleecker is for me that in the Internet of Things objects are active participants in the creation, maintenance and knitting together of social formations through the dissemination of meaningful insights. Therefore, the challenge ahead of us could be to design an Internet of Things as a framework for creating more habitable worlds, rather than a technical framework for a television talking to a reading lamp or for a refrigerator to be connected to grocery stores.

Daniel Kaplan is the founder and CEO of Fing (the next generation Internet Foundation). Since the 1990s, he has been deeply involved in the whole debate around the development and evolution of the Internet. Kaplan has been developing various visions of the Internet of Things, and the role of human beings within these visions. He is worried that these technologies are taking power away from the individual, which is exactly the opposite of what the Internet set out to do. Therefore, the Internet of Things carries no transformational vision – where the Internet always came with visions of social and cultural transformation, the Internet of Things so far has been just about service, comfort, optimisation, health, reliability, sustainability, quality and security, usually performed by others on our behalf. If there is a vision, Kaplan says, it is one of a control society. For him, the Internet of Things is not an Internet, not technically, not socially, and not economically. The way "things" are currently networked is entirely within silos — in terms of applications, services and organisations — and this has nothing to do with the view on pervasive interconnectedness that the Internet concept proposes.

Kaplan's vision is one of an entirely different Internet of Things, which would be open, modifiable, recyclable, social and evolutionary. He believes that a real "Internet of Things" would be driven by the thinking

of such people as Julian Bleecker and Bruce Sterling, and by cultures such as those of open source hardware (Arduino) or the fabrication movement ("Bricolabs"). In this respect, his vision is also akin to the one of Padmasree Warrior to which I'm turning now.

Padmasree Warrior has been Chief Technology Officer at Cisco since 2007. The company having connected much of the corporate world to the Internet, Warrior argues that it should now turn its energy to connecting cities. In the September 7 Europe edition of FORTUNE, Warrior mentions three successive phases of the Internet: increasing productivity, then enhancing collaboration, and now industrialising the Internet, that is using Internet protocols to connect devices, sensors and buildings to make smart, connected communities. As regards this third phase, there is broad commonalty between the academic vision of Kaplan and the industrial vision of Warrior.

The building of smart communities is one that is promised to large success. With its New Songdo city, South Korea is today at the forefront in implementing ubiquitous technology and the Internet of Things. While a large portion of the technology is being developed in the U.S. and European research labs, it is being tested in South Korea where there are less traditional, ethical and social blockades to prevent its acceptance and use. South Korea is undoubtedly willing to put off the hard questions to take the early lead and set standards. Of course, Cisco with Mrs Warrior does not want to be left behind.

Rob van Kranenburg has been teaching at various schools in the Netherlands and has worked at several Dutch cultural institutions. Currently he works as the Head of the Public Domain Program at Waag Society. Like Kaplan and Warrior, Van Kranenburg describes the cities of the future – instead of a nest of cameras monitoring individual behaviours, there will be a invisible network of wireless frequencies where almost any object and space can be located and tracked, found and logged as easily as an item on eBay or PriceMinister or the price of a flight on easyJet. Cities will become places where consumer goods are assigned IP addresses, just as Web pages today. Now, van Kranenburg sets for us the challenge of deciding which kind of city we want – a *City of Control* or a *City of trust*? He tells us that the adoption of the technologies of the City of Control is not something we must blindly accept as if it were inevitable. He seeks to convince us that it is still time to build technologies of trust that empower individuals to reclaim control of their thoughts, words and actions. He intelligently suggests that we should move from privacy to privacies, which acknowledges that

in the Internet of Things where we leave different traces we might want to build temporary personalities around these traces, thus avoiding to expose our entire personality all the time.

Besides these "Profiles in the Internet of Things", there are also of course an increasing number of organisations across the world, public and private, that work towards shaping the Internet of Things. The individuals who I have mentioned are of course, most of the time, key members of such organisations.

Intel, for example, proposes to cross the chasm between humans and machines. The company predicts that by 2050 machines will surpass the peak of human intelligence. This forecast is corroborated by other estimates of the progression of information technology. For example, U.S. professors Karl Fisch, Scott McLeod, and Jeff Bronman have determined that by 2013, a supercomputer exceeding the computational capabilities of the human brain will be built! Predictions are that by 2049, a $1000 computer will exceed the computational capabilities of the entire human species.

Therefore, in order to test this potential and develop the required technologies, Intel pushes forward research frontiers in the fields of social interaction, robotics, wireless communication, signalling and sensors, so as to help a computer sense the world around it.

This program owes much to the vision of I. J. Good, a famous British statistician who had studied mathematics at Cambridge University and worked with Alan Turing and others in the highly secret code-breaking labs at Bletchley Park. In 1965, Good had foretold the "singularity", that is the point where computers become better than humans at generating new computers. Well, the singularity seems today to be within reach…

IBM is also very active but by propelling another concept – *Smarter Planet*. Smarter Planet is IBM's point of view on how interconnected technologies are changing the way the world literally works to address major common problems: a financial crisis; climate disruption; energy geopolitics; food supply hazards. IBM's approach is based on the notion that we're all connected today like never before: economically, socially and technically. When a crisis occurs in one part of the planet, it can bring problems to another part, within days or even hours. The current financial and economic crisis strongly supports that view…

Yet the world big challenges are also opportunities. People around the world are ready for change. Today, we are seeing the infusion of

intelligence into the way the world should develop systems and processes that enable physical goods to be developed, manufactured, bought and sold, services to be delivered, everything from people and money to oil, water and electrons to move, and billions of people to work and live.

The IP for Smart Objects (IPSO) Alliance, formed in September 2008 by 25 founding companies, including Cisco, SUN Microsystems, Ericsson and SAP, represents the first major industrial initiative proving that the Internet of Things is today leaving the safe shores of science for the troubled waters of industrial competition.

A so-called "smart object" is any device which combines processing power, communications capabilities and a power source to provide real-time information to a computer system. Integration of the Internet Protocol, which allows the Internet to run smoothly, in turn allows smart objects to communicate directly with one another over the existing global network. The IP framework additionally provides scalability, which constitutes a vital feature for large organizations.

IPSO has grown its membership by more than 50 percent in only one year and it has set an agenda of multi-vendor product interoperability tests for 2009. Last May IPSO organised an interoperability demonstration at NetWorld+Interop in Las Vegas. Sensors from a variety of suppliers located on three continents, all addressable in IPv6, supplied over 100,000 readings on temperature, humidity, etc.

It seems that the whole industry is willing to cooperate on achieving the Internet of Things. IPSO, but also the ZigBee Alliance, the IETF and the IEEE work in the same direction of IP standards integration.

The U.S. National Intelligence Council published in April 2008 a Conference Report, prepared by SRI Consulting Business Intelligence, on Disruptive Civil Technologies. This report addresses six such technologies with potential impacts on U.S. national power, including the Internet of Things. It identifies the geopolitical and economic benefits that could be reaped from implementing the Internet of Things, but it doesn't hide the potential risks and threats – the report says "*An open market for aggregated sensor data could serve the interests of commerce and security no less than it helps criminals and spies identify vulnerable targets.*"

Seven months later, the NIC released another report outlining trends in technology that will shape the world to come in 2025. Among the technologies covered by the report is the development of the Internet

of Things. The report foresees that in the Internet of Things mundane objects such as food packages, furniture, room sensors, and paper documents will be located and identified, monitored, and remotely controlled through enabling technologies like RFID, sensor networks, tiny embedded servers, and energy harvesters connected via the next-generation Internet using abundant, low cost, and high-power computing.

The NIC reports show that the U.S., like Europe, is now investigating how the Internet of Things could eventually transform the world and become a source of enormous potential growth for national economies, increased efficiency for businesses, and improved quality of life for citizens.

Europe is not a mere spectator of the events happening around the Internet of Things. Like for the Future Internet, where the European Union is successfully striving to federate the skills and talents of all stakeholders, in particular through the Future Internet Assembly process, the Internet of Things has emerged during 2008 as a priority of both the European Commission and the EU Member States.

The European Commission has adopted in June 2009 a communication on the Internet of Things proposing an action plan for Europe. This communication followed a large public consultation on a Commission staff working paper which was commented during the French Presidency conference on "Internet of Things – Internet of the Future", held in Nice on 6 and 7 October 2008.

The communication includes fourteen lines of action addressing the whole set of policy issues. The European Commission is currently working with stakeholders towards implementing each and all of these lines of action.

The next question that comes to mind concerning the Internet of Things is: "why"? Let me give you four simple answers to that complex question.

First, we need the Internet of Things to "sense" the technium, as publisher and author Kevin Kelly understands it, i.e. the greater sphere of technology, one that goes beyond hard technology to include culture, law, social institutions, and intellectual creations of all types. In short, Kelly says, the technium is anything that springs from the human mind.

The two greatest inventions of the last 25 years – the link and the tag – have woven new levels of complexity into the web of information. The technium of today reflects eight thousand years of constant incremental

increases in its embedded knowledge. If we measure the technium by the amount of digital storage in use, today it contains 487 exabytes of information, which is many orders smaller than Lady Nature's total, but rapidly growing. Technology expands data by 66% per year, overwhelming the growth rates of any natural source in the neighbourhood of our planet.

So what does this mean? The laws of physics don't improve with time, but systems like life, mind and the technium do. Over billions of years they gain order, diversity, complexity and their own self-organised autonomy – all things not present in the universe before. The current migration from a material-based economy to a knowledge-based economy of intangible goods (such as software, design, and media products) is one strand of the steady move towards the immaterial.

I believe that the Internet of Things will make it possible to "sense" the evolution of the technium. My conviction stems from the three propositions made by Kevin Kelly. Firstly, computation can describe all things, be they logical arguments, scientific equation, literary work, formal creations such as video, music and art, and even emotion. Secondly, all things can compute. Almost any kind of material can serve as the matrix for a computer. Thirdly, all computation is one. According to the theorem of Alan Turing and Alonso Church, proved in 1937, one computer can do anything another can do. In other words, all computation is equivalent.

Research on optimal wireless connectivity and routing, data fusion, distributed processing, semantic data interpretation and querying the physical world, to name a few, will enable to sense the real-world, especially in the context of the real-time networked enterprise as well as the management of the large scale of sensor nodes and information flows.

Sensor data is not just mechanical data from RFID tags and other non-human sources. Actually, humans are producing sensor data of their own, in particular by using their mobile phones. Today's smartphones contain microphones, cameras, motion sensors, proximity sensors, and location sensors like GPS, cell-tower triangulation, and even in some cases, a compass. No matter what the source of sensor data, after it's gathered collective intelligence can be applied to it. Therefore, sensor-based applications get better the more people use them.

Beyond the sensing of the world, it is important to exploit the potential of the Internet of Things to adapt to the world.

The Internet of Things will provide the right means for better traceability and real-time decision making. By combining technological innovations such as intelligent sensors, agile middleware, and business back-end systems, it will make it possible to provide new forms of more intelligently managed production, distribution, and consumption on a point-to-point basis, for example for energy.

Furthermore, the Internet of Things will also improve collaboration along the manufacturing process, and in this way open up new opportunities for flexible business processes and introduce a swifter implementation of disruptive business models and products.

In the end, as the Internet of things is expected to provide autonomy to networked things, thus enabling these things to act on our behalf, humans will need to reflect upon the changes required in our notions of responsibility for our own actions and for our interactions with technology.

The Internet of Things will help prepare mankind for accelerated technological change. I have already mentioned some figures which, however accurate they may be, point to a continuous expansion of information.

Kevin Kelly suggests that the Internet of Things represents the fourth stage of the communication evolution. The first stage has been the Internet – linking and sharing computers. The second stage has been the World Wide Web – linking and sharing documents. The third phase is the World Wide Database – linking and sharing data in documents. We are the witnesses of the beginning of this phase. For example, instead of connecting to the airline's computer or later to the flight page, we can connect directly to the flight's information itself. The fourth stage will ultimately be the Internet of Things – linking up the things themselves.

But growing with the world will also increase responsibility. Though an open market for aggregated sensor data could serve the interests of business and security, it could also help criminals identify vulnerable targets. This means that in the Internet of Things, we may be unable to deny access to networks of sensors and remotely-controlled objects by all kinds of criminals. Moreover, some manufacturers could become both the single-source and single-point-of-failure for mission-critical Internet-enabled things. Other manufacturers could also become

vectors for delivering everyday objects containing malicious software that causes havoc in everyday life. Therefore, the Internet of Things will require a global governance and a global ethics. For example, any organisation hiding data to prevent a well-informed, timely and effective debate on climate change should be considered as committing a crime against mankind.

There are already many examples of the Internet of Things. They tell us that the Internet of Things is neither a fiction nor a scenario for the long-term. It is already there today. But we are witnessing only the beginning of a transformation that will continue over at least the next 25 years.

If you consider only the large organisations that are members of the IPSO Alliance, you have some of the pioneers of Internet of Things applications – IBM and its *Smarter Planet*, Cisco and its *Smart Grid*, Arch Rock and its *Energy Optimizer*, Alcatel-Lucent and its *touchatag*, and so on.

However, applications of the Internet of Things are also explored by SMEs and start-up companies. Perhaps the best recent examples have been the *nabaztag* ("the first smart rabbit") and *mir:ror* ("the first consumer RFID tag reader"), two inventions of a French company called Violet which, however, is now in protected receivership.

Besides the global challenges, supply chains and personal applications, another major application of the Internet of Things will be healthcare, in particular regarding the monitoring of high blood pressure, glucose levels and heart failure. Last month it was reported that an American woman had received a pacemaker with a wireless connection to the Internet. At least once a day, a server communicates with the pacemaker over the Internet, gets an update and, if there is anything unusual, may contact the doctor and patient.

When will we live in the Internet of Things? I have already argued that the Internet of things was already around us.

What is important to bear in mind is that, as video blogger and artist Bre Pettis said, "*things are changing faster than we can die*".

By the end of this decade the Internet of Things will have been used in supply chains and logistics. Over the next decade it will pervade most of our economies. After 2020, data will be analysed by intelligent software in a way resembling human reasoning. And some time in the foreseeable

future software will be able to make unsupervised decisions and act on behalf of humans.

The timing of developments, slow or fast development of the Internet of Things, depends on the capability of stakeholders in the public sector and the private sector to create favourable conditions in terms of policies, technological progress and business collaboration. The minimal scenario would be that the Internet of Things makes impacts in particular application areas (supply chains and logistics, industrial automation, security, health care) but fails to fulfil the promise of becoming pervasive, in particular to have limited impacts on everyday lifestyles and the conduct of government.

The maximal scenario would be an Internet of Things that arises rapidly and pervasively. Billions of everyday objects are connected to the Internet and sensor networks are common in workplaces, public spaces and households. By 2020, walk-through checkout procedures are the norm for the retail trade sector and widespread positioning technology is in place, including indoors. The potential risks and threats of the Internet of Things are contained by the appropriate mix of technology and regulations.

The space bordered by these two extreme scenarios could of course welcome a continuum of other scenarios involving more or less benefits and threats.

What is the Internet of Things all about?

First, it is about how to exploit the explosion of information which is taking place. A study conducted by the University of California at Berkeley differentiates between information that flows and information which is stored. Flowing information is that which is transmitted over the airwaves, on the internet, and on through the telephone. Stored information is that which is printed, on paper, film and other physical media. It is estimated that almost 800 megabytes of stored information are produced per person, per year.

Two days ago, IDC announced at EMC World in Orlando, Florida, that digital information will grow by 73% this year to represent almost 470 billion gigabytes. The digital universe is expected to double every 18 months.

As a society, our experience with the digital universe will be amazing. By 2013, there will be 2 billion people on the Internet and 3 billion mobile

phone users. All will be interconnected; all will be creating and consuming content at a very quick rate.

The Internet of Things will claim a major role as a tool to tame the digital universe. Thanks to the Internet of Things, information growth can be turned into economic growth and social well-being.

Second, over the next decade will prevail thing-to-person (and person-to-thing) communications, thanks to a number of technologies and applications wherein people interact with things and vice versa, including remote access to objects by humans and objects continuously reporting their status, whereabouts and sensor data. The applications which we see today belong to that category.

After 2015, but with greater momentum after 2020, thing-to-thing communications relying on technologies and applications wherein everyday objects and infrastructure interact with no human originator, recipient, or intermediary, will enable objects to monitor other objects, take corrective actions, and notify or prompt humans as required.

The actual evolution of the Internet of Things, especially the timing of developments and the depth of penetration, will depend not only on the exploitation of research results and the availability of sound and conducive policies, but also on the capability of the actors to collaborate.

Collaboration for building the Internet of Things should not take place only within a single organisation, a specific supply chain, or an individual country, but encompass all stakeholders across organisational and geographic borders.

Thank you for listening.

The views expressed in this paper are those of the author and do not necessarily represent the views of, and should not be attributed to, the European Commission.