International Telecommunication Union

ITU INTERNET REPORTS 2005

EXECUTIVE SUMMARY

The Internet of Things

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International Telecommunication Union

ITU Internet Reports 2005: The Internet of Things

Executive Summary

November 2005

International Telecommunication Union

This *Executive Summary* provides a brief *résumé* of the ITU report "*The Internet of Things*", which has been specially prepared for the World Summit on the Information Society held in Tunis, 16-18 November 2005. It includes a selection of tables, illustrations and analysis of the full report, which can be purchased online or in printed copy. For further information, please visit the website at: www.itu.int/internetofthings. This report is the latest in the "*ITU Internet Reports*" series, which includes the following titles:

- The Portable Internet (2004)
- The Birth of Broadband (2003)
- Internet for a Mobile Generation (2002)
- IP Telephony (2001)
- Internet for Development (1999)
- Challenges to the Network: Telecommunications and the Internet (1997)

Each of these publications is available for purchase online from the ITU website at: www.itu.int/osg/spu/publications for CHF 100. Printed copies are also available from the ITU Sales Service
(www.itu.int/publications, Fax: +41 22 730 51 94, e-mail: sales@itu.int),
with reductions for ITU Member States and Sectors Members, and for purchasers from the least developed countries (LDC).

The full report (approximately 130 pages) gives an in-depth introduction to the Internet of Things and its effect on businesses and individuals around the world. It contains information on key emerging technologies, market opportunities and policy implications. A 65-page statistical annex to the report presents the latest available data on over 200 economies worldwide.

The report was prepared by a team from the ITU Strategy and Policy Unit (SPU). Much of the original research was carried out for workshops under the ITU New Initiatives Programme, with generous funding from a number of ITU Member States, including MIC (Japan).

The views expressed in the report are those of the authors and do not necessarily reflect the opinions of ITU or its membership.

Contents

About the Report

"*The Internet of Things*" is the seventh in the series of *ITU Internet Reports* originally launched in 1997 under the title "*Challenges to the Network*". This edition has been specially prepared for the second phase of the World Summit on the Information Society (WSIS), to be held in Tunis, 16-18 November 2005.

Written by a team of analysts from the Strategy and Policy Unit (SPU) of ITU, the report takes a look at the next step in "always on" communications, in which new technologies like radio-frequency identification (RFID) and smart computing promise a world of networked and interconnected devices. Everything from tyres to toothbrushes might soon be in communications range, heralding the dawn of a new era; one in which today's Internet (of data and people) gives way to tomorrow's Internet of Things.

The report consists of six chapters as follows:

- Chapter one, *Introducing the Internet of Things,* explores the key technical visions underlying the Internet of Things, such as ubiquitous networks, next-generation networks and ubiquitous computing;
- Chapter two, *Enabling Technologies*, examines the technologies that will drive the future Internet of Things, including radio-frequency identification (RFID), sensor technologies, smart things, nanotechnology and miniaturization;
- Chapter three, *Shaping the Market*, explores the market potential of these technologies, as well as factors inhibiting market growth. It looks at new business models in selected industries to illustrate how the Internet of Things is changing the way firms do business;
- Chapter four, *Emerging Challenges*, contemplates the hurdles towards standardization and the wider implications of the Internet of Things for society, such as growing concerns over privacy;
- Chapter five, *Opportunities for the Developing World*, sets out some of the benefits these technologies offer to developing countries that may themselves become lead users and drivers of the market;
- Chapter six, *The Big Picture*, draws these threads together and concludes on how our lifestyles may be transformed over the next decade.

The *Statistical annex* presents the latest data and charts for more than 200 economies worldwide in their use of ICTs.

This Executive Summary, published separately, provides a synopsis of the full report, which is available for purchase (at the catalogue price of CHF 100) on the ITU website at www.itu.int/publications under General Secretariat.

1 What is the Internet of Things?

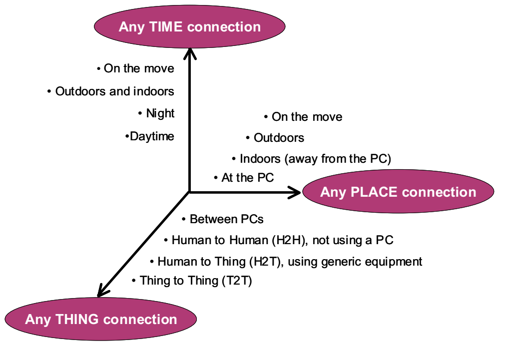
Over a decade ago, the late Mark Weiser developed a seminal vision of future technological ubiquity – one in which the increasing "availability" of processing power would be accompanied by its decreasing "visibility"

We are standing on the brink of a new ubiquitous computing and communication era, one that will radically transform our corporate, community, and personal spheres. Over a decade ago, the late Mark Weiser developed a seminal vision of future technological ubiquity – one in which the increasing "availability" of processing power would be accompanied by its decreasing "visibility". As he observed, "the most profound technologies are those that disappear…they weave themselves into the fabric of everyday life until they are indistinguishable from it". Early forms of ubiquitous information and communication networks are evident in the widespread use of mobile phones: the number of mobile phones worldwide surpassed 2 billion in mid-2005. These little gadgets have become an integral and intimate part of everyday life for many millions of people, even more so than the internet.

Today, developments are rapidly under way to take this phenomenon an important step further, by embedding short-range mobile transceivers into a wide array of additional gadgets and everyday items, enabling new forms of communication between people and things, and between things themselves. A new dimension has been added to the world of information and communication technologies (ICTs): from *anytime*, *any place* connectivity for *anyone*, we will now have connectivity for *anything* (Figure 1).

Connections will multiply and create an entirely new dynamic network of networks – an Internet of Things. The Internet of Things is neither science fiction nor industry hype, but is based on solid technological advances and visions of network ubiquity that are zealously being realized.

Figure 1 – A new dimension



Source: ITU adapted from Nomura Research Institute

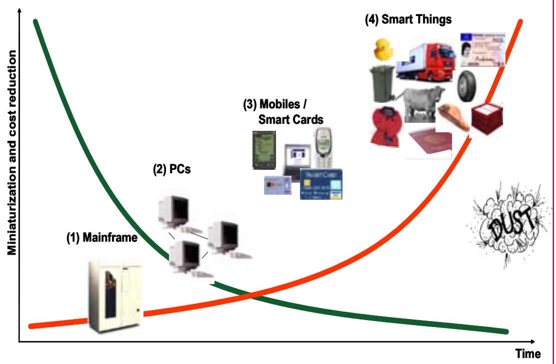
2 Technologies for the Internet of Things

The Internet of Things is a technological revolution that represents the future of computing and communications, and its development depends on dynamic technical innovation in a number of important fields, from wireless sensors to nanotechnology.

First, in order to connect everyday objects and devices to large databases and networks – and indeed to the network of networks (the internet) – a simple, unobtrusive and cost-effective system of item identification is crucial. Only then can data about things be collected and processed. Radio-frequency identification (RFID) offers this functionality. Second, data collection will benefit from the ability to detect changes in the physical status of things, using sensor technologies. Embedded intelligence in the things themselves can further enhance the power of the network by devolving information processing capabilities to the edges of the network. Finally, advances in miniaturization and nanotechnology mean that smaller and smaller things will have the ability to interact and connect (Figure 2). A combination of all of these developments will create an Internet of Things that connects the world's objects in both a sensory and an intelligent manner.

Indeed, with the benefit of integrated information processing, industrial products and everyday objects will take on smart characteristics and capabilities. They may also take on electronic identities that can be queried remotely, or be equipped with sensors for detecting physical changes around them. Eventually, even particles as small as dust might be tagged and networked. Such developments will turn the merely static objects of today into newly dynamic things, embedding intelligence in our environment, and stimulating the creation of innovative products and entirely new services.

Figure 2 – Miniaturization towards the Internet of Things



Source: ITU "Ubiquitous Network Societies and their impact on the telecommunication industry", April 2005, available at www.itu.int/ubiquitous

RFID technology, which uses radio waves to identify items, is seen as one of the pivotal enablers of the Internet of Things. Although it has sometimes been labelled as the next-generation of bar codes, RFID systems offer much more in that they can track items in real-time to yield important information about their location and status. Early applications of RFID include automatic highway toll collection, supply-chain management (for large retailers), pharmaceuticals (for the prevention of counterfeiting) and e-health (for patient monitoring). More recent applications range from sports and leisure (ski passes) to personal security (tagging children at schools). RFID tags are even being implanted under human skin for medical purposes, but also for VIP access to bars like the Baja Beach Club in Barcelona. E-government applications such as RFID in drivers' licences, passports or cash are under consideration. RFID readers are now being embedded in mobile phones. Nokia, for instance, released its RFID-enabled phones for businesses with workforces in the field in mid-2004 and plans to launch consumer handsets by 2006.

The Internet of Things is a technological revolution that represents the future of computing and communications, and its development depends on dynamic technical innovation in a number of important fields, from wireless sensors to nanotechnology.

In addition to RFID, the ability to detect changes in the physical status of things is also essential for recording changes in the environment. In this regard, sensors play a pivotal role in bridging the gap between the physical and virtual worlds, and enabling things to respond to changes in their physical environment. Sensors collect data from their environment, generating information and raising awareness about context. For example, sensors in an electronic jacket can collect information about changes in external temperature and the parameters of the jacket can be adjusted accordingly.

Figure 3 – Smart home for smart people

Source: ITU adapted from Line9

Embedded intelligence in things themselves will distribute processing power to the edges of the network, offering greater possibilities for data processing and increasing the resilience of the network. This will also empower things and devices at the edges of the network to take independent decisions. "Smart things" are difficult to define, but imply a certain processing power and reaction to external stimuli. Advances in smart homes, smart vehicles and personal robotics are some of the leading areas. Research on wearable computing (including wearable mobility vehicles) is swiftly progressing. Scientists are using their imagination to develop new devices and appliances, such as intelligent ovens that can be controlled through phones or the internet, online refrigerators and networked blinds (Figure 3).

Embedded intelligence in things themselves will further enhance the power of the network.

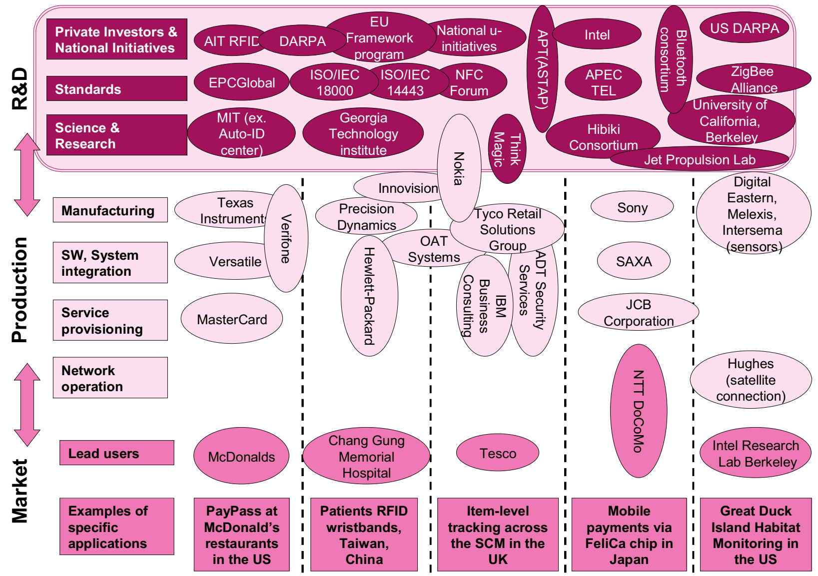
Image Source: Toyota

The Internet of Things will draw on the functionality offered by all of these technologies to realize the vision of a fully interactive and responsive network environment.

3 Market Opportunities

The technologies of the Internet of Things offer immense potential to consumers, manufacturers and firms. However, for these ground-breaking innovations to grow from idea to specific product or application for the mass market, a difficult process of commercialization is required, involving a wide array of players including standard development organizations, national research centres, service providers, network operators, and lead users (Figure 4).

Figure 4 – The Internet of Things – from idea to market



Source: ITU

From their original inception and throughout the R&D phase, new ideas and technologies must find champions to take them to the production phase. The time to market, too, requires key "lead users" that can push the innovation forward. To date, the technologies driving the Internet of Things are notable for the strong involvement of the private sector, e.g. through industry fora and consortia. Yet public sector involvement is growing, through national strategies for technical development (e.g. nanotechnology) and in sector-specific investments in healthcare, defence or education.

RFID is the most mature of the enabling technologies with established standardization protocols and commercial applications reaching the wider market. The global market for RFID products and services is growing fast, with sizeable revenues of between USD 1.5-1.8 billion by 2004. However, this is dwarfed by the total revenues expected over the medium- to long-term, with the spread of smart cards and RFID in all kinds of consumer products, including mobile phones.

Wireless sensor networks are widely used in industries such as automotive, homeland security, medical, aerospace, home automation, remote monitoring, structural and environmental monitoring. Estimates of their market potential vary (partly due to different definitions), but analysts forecast that as their unit price falls, the number of units deployed will grow significantly. Meanwhile, robotics is expanding into new markets. At present, the market share of industrial robotics is larger than that of personal and service robotics, but this is set to change, as the personal robotics segment is expected to lead future market growth.

Changing business strategies is the name of the game…

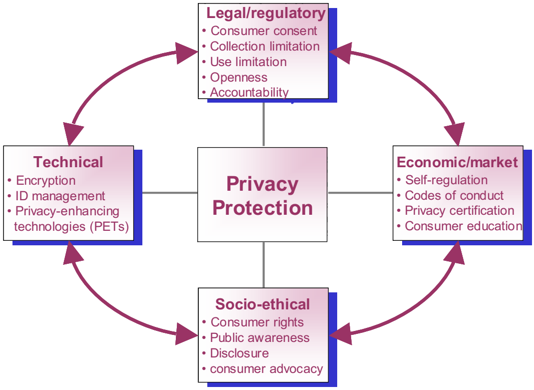
Changing business strategies is the name of the game, in particular in the retail, automotive and telecommunication industries. Firms are embracing the underlying technologies of the Internet of Things to optimize their internal processes, expand their traditional markets and diversify into new businesses.

4 Challenges and Concerns

Building on the potential benefits offered by the Internet of Things poses a number of challenges, not only due to the nature of the enabling technologies but also to the sheer scale of their deployment. Technological standardization in most areas is still in its infancy, or remains fragmented. Not surprisingly, managing and fostering rapid innovation is a challenge for governments and industry alike. Standardization is essential for the mass deployment and diffusion of any technology. Nearly all commercially successful technologies have undergone some process of standardization to achieve mass market penetration. Today's internet and mobile phones would not have thrived without standards such as TCP/IP and IMT-2000.

Successful standardization in RFID was initially achieved through the Auto-ID Center and now by EPC Global. However, efforts are under way in different forums (ETSI, ISO, etc...) and there have been calls for the increased involvement of ITU in the harmonization of RFID protocols. Wireless sensor networks have received a boost through the work of the ZigBee Alliance, among others. By contrast, standards in nanotechnology and robotics are far more fragmented, with a lack of common definitions and a wide variety of regulating bodies.

Figure 5 – The many facets of privacy protection



Source: ITU

One of the most important challenges in convincing users to adopt emerging technologies is the protection of data and privacy. Concerns over privacy and data protection are widespread, particularly as sensors and smart tags can track users' movements, habits and ongoing preferences. When everyday items come equipped with some or all of the five senses (such as sight and smell) combined with computing and communication capabilities, concepts of data request and data consent risk becoming outdated. Invisible and constant data exchange between things and people, and between things and other things, will occur unknown to the owners and originators of such data. The sheer scale and capacity of the new technologies will magnify this problem. Who will ultimately control the data collected by all the eyes and ears embedded in the environment surrounding us?

When everyday items come equipped with some or all of the five senses… combined with computing and communication capabilities, concepts of data request and data consent risk becoming outdated.

Public concerns and active campaigns by consumers have already hampered commercial trials of RFID by two well-known retailers. To promote a more widespread adoption of the technologies underlying the Internet of Things, principles of informed consent, data confidentiality and security must be safeguarded. Moreover, protecting privacy must not be limited to technical solutions, but encompass regulatory, market-based and socio-ethical considerations (Figure 5). Unless there are concerted efforts involving all government, civil society and private sector players to protect these values, the development of the Internet of Things will be hampered if not prevented. It is only through awareness of these technological advances, and the challenges they present, that we can seize the future benefits of a fair and user-centric Internet of Things.

5 Implications for the Developing World

The technologies discussed in this report are not just the preserve of industrialized countries. These technologies have much to offer for the developing world and can lead to tangible applications in, *inter alia,* medical diagnosis and treatment, cleaner water, improved sanitation, energy production, the export of commodities and food security.

world summit
on the information society
Geneva 2003 - Tunis 2005

www.itu.int/wsis

In line with the global commitment to achieving the Millennium Development Goals (MDGs), the World Summit on the Information Society (WSIS) focuses on ICT development through the creation of national e-strategies, the guarantee of universal, ubiquitous, equitable and affordable access to technology and the wider dissemination and sharing of information and knowledge. WSIS commitments go far beyond technological diffusion – there is a pledge for common action towards poverty alleviation, the enhancement of human potential and overall development through communication technologies and related emerging technologies. In this regard, the technologies underlying the Internet of Things offer many potential benefits.

The enabling technologies of the Internet of Things have much to offer developing countries in their goals for improving quality of life

Image Source: UNICEF

One does not have to look far to find examples. In the production and export of commodities, sensor technologies are being used to test the quality and purity of different products, such as coffee in Brazil and beef in Namibia. RFID has been used to track shipments of beef to the European Union to verify their origin, integrity and handling – essential given present trends in food tracability standards. Such applications help ensure the quality and market expansion of commodities from developing countries.

The enabling technologies of the Internet of Things have much to offer developing countries in their goals for improving quality of life. Nanofilters in Bangladesh are removing pollutants and ensuring that water is safe to drink. Nano-sensors can be used to monitor water quality at reduced cost, while nanomembranes can assist in the treatment of wastewater. Research is under way to apply nanotechnology in the diagnosis and treatment of disease, including the diagnosis of HIV and AIDS, as well as nano-drugs for other diseases. Emerging technologies could also improve the quality and reliability of conventional drugs for the developing world: RFID, for example, can track the origin of safe drugs thereby reducing counterfeit.

Sensor technologies can monitor vulnerable environments and prevent or limit natural disasters. Extensive and effective systems are needed to ensure early warning and evacuation, thereby reducing loss of life due to natural disasters. Special robots have for instance been used for mine detection to save lives and limbs in conflict zones. Commercial applications are already being deployed in countries like India, Thailand and Turkey, among others.

Next-generation communication technologies may well originate in the larger growth markets of the developing world – China and India, in particular. The substantial research programmes currently being undertaken by these developing giants mean that the implementation of the Internet of Things will be adapted to local conditions and circumstances, as well as to international trade. Wal-Mart, for instance, now requires its suppliers to be RFID-compliant. In 2002, Wal-Mart sourced billions of dollars worth of products from China, i.e. around 12% of the total value of US imports from China during that year. Not surprisingly, China is rapidly preparing itself to become a leader in RFID deployment. Far from being passive followers of the Internet of Things, the developing world stands to greatly influence the implementation and widespread adoption of these emerging technologies.

6 2020: A Day in the Life

But what does the Internet of Things mean in a practical sense for a citizen of the future? Let us imagine for a moment a day in the life of Rosa, a 23-year-old student from Spain, in the year 2020.

Rosa has just quarrelled with her boyfriend and needs a little time to herself. She decides to drive secretly to the French Alps in her smart Toyota to spend a weekend at a ski resort. But it seems she must first stop at a garage – her car's RFID sensor system (required by law) has alerted her of possible tyre failure. As she passes through the entrance to her favourite garage, a diagnostic tool using sensors and radio technology conducts a comprehensive check of her car and asks her to proceed to a specialized maintenance terminal. The terminal is equipped with fully automated robotic arms and Rosa confidently leaves her beloved car behind in order to get some coffee. The "Orange Wall" beverage machine knows all about Rosa's love of iced coffee and pours it for her after Rosa waves her internet watch for secure payment. When she gets back, a brand new pair of rear tyres has already been installed with integrated RFID tags for monitoring pressure, temperature and deformation.

What does the Internet of Things mean in a practical sense for a citizen of the future?

The robotic guide then prompts Rosa on the privacy-related options associated with the new tyres. The information stored in her car's control system is intended for maintenance purposes but can be read at different points of the car journey where RFID readers are available. However, since Rosa does not want anyone to know (especially her boyfriend) where she is heading, such information is too sensitive to be left unprotected. She therefore chooses to have the privacy option turned on to prevent unauthorized tracking.

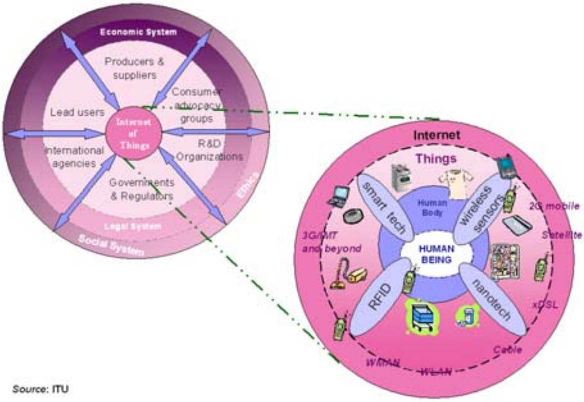
Finally, Rosa can do some shopping and drives to the nearest mall. She wants to buy that new snowboard jacket with embedded media player and weather-adjusting features. The resort she is heading towards uses a network of wireless sensors to monitor the possibilities of avalanches so she feels both healthy and safe. At the French-Spanish border, there is no need to stop, as Rosa's car contains information on her driver's licence and passport which is automatically transmitted to the minimal border control installations.

Suddenly, Rosa gets a video-call on her sunglasses. She pulls over and sees her boyfriend who begs to be forgiven and asks if she wants to spend the weekend together. Her spirits rise and on impulse she gives a speech command to the navigation system to disable the privacy protection, so that her boyfriend's car might find her location and aim directly for it. Even in a world full of smart interconnected things, human feelings continue to rule.

7 A New Ecosystem

The internet as we know it is transforming radically. From an academic network for the chosen few, it became a mass-market, consumer-oriented network. Now, it is set to become fully pervasive, interactive and intelligent. Real-time communications will be possible not only by humans but also by things at anytime and from anywhere. The advent of the Internet of Things will create a plethora of innovative applications and services, which will enhance quality of life and reduce inequalities whilst providing new revenue opportunities for a host of enterprising businesses.

Figure 6 – The Ecosystem of the Internet of Things



Source: ITU

The development of the Internet of Things will occur within a new ecosystem that will be driven by a number of key players (Figure 6). These players have to operate within a constantly evolving economic and legal system, which establishes a framework for their endeavours. Nevertheless, the human being should remain at the core of the overall vision, as his or her needs will be pivotal to future innovation in this area. Indeed, technology and markets cannot exist independently from the over-arching principles of a social and ethical system. The Internet of Things will have a broad impact on many of the processes that characterize our daily lives, influencing our behaviour and even our values.

For the telecommunication industry, the Internet of Things is an opportunity to capitalize on existing success stories, such as mobile and wireless communications, but also to explore new frontiers. In a world increasingly mediated by technology, we must ensure that the human core to our activities remains untouched. On the road to the Internet of Things, this can only be achieved through people-oriented strategies, and tighter linkages between those that create technology and those that use it. In this way, we will be better equipped to face the challenges that modern life throws our way.

> *Technology and markets cannot exist independently of the over-arching principles of a social and ethical system*

Statistical Annex: Mobile market data for top 20 economies (ranked by total subscriber numbers) as at 31 December 2004

Total subscribers, penetration rate, proportion of which are 3G (IMT-2000) subscribers and price of OECD low-user basket in USD

Economy	Total subscribers (millions)	Penetration (per 100 inhabitants)	Of which, total 3G (IMT-2000) subscribers (millions)*	OECD low-user basket (USD)
1. China	334.8	25.5	8.71	$3.70
2. United States	181.1	61.0	49.50	$11.85
3. Japan	91.5	71.6	25.70	$28.27
4. Russia	74.4	51.6	018	$6.40
5. Germany	71.3	86.4	0.25	$24.16
6. Brazil	65.6	36.3	1.71	$23.68
7. Italy	62.8	109.4	2.80	$14.11
8. United Kingdom	61.1	102.8	2.83	$19.20
9. India	47.3	4.4	**	$2.53
10. France	44.6	73.7	0.04	$30.46
11. Spain	38.6	93.9	0.08	$21.64
12. Mexico	38.5	36.6	0.02	$33.26
13. Korea (Rep.)	36.6	76.1	27.51	$14.18
14. Turkey	34.7	48.0	n/a	$6.62
15. Philippines	32.9	39.9	n/a	$4.03
16. Indonesia	30.0	13.5	0.05	$4.00
17. Thailand	28.0	44.1	0.61	$6.71
18. Poland	23.1	59.9	0.001	$7.53
19. Taiwan, China	22.8	100.0	0.30	$4.99
20. South Africa	19.5	43.1	0.003	$14.96
WORLD	**1'751.9**	**38.8**	**133.7**	**$13.65**

* 3G mobile or IMT-2000 , as defined by ITU includes subscribers to commercially available services using CDMA 2000 1x, CDMA 2000 1x EV-DO and W-CDMA standards.

** Limited mobility Wireless Local Loop service available, for which WLL 9,921,780 subscribers at 31 December 2004.

Statistical Annex: Broadband market data for top 20 economies (ranked by broadband penetration) as at 31 December 2004
Total subscribers, penetration rate, as percentage of total internet subscribers and price in USD per 100 kbps

Economy	Total broadband subscribers (millions)	Penetration (per 100 inhabitants)	As % Internet subscribers (millions)	Price in USD per 100 kbps
1. Korea (Rep.)	11.92	24.9	99.1	$0.08
2. Hong Kong, China	1.51	21.3	60.3	$0.83
3. Netherlands	3.21	19.8	45.8	$0.73
4. Denmark	1.01	18.9	36.6	$3.27
5. Iceland	0.05	18.3	n/a	$0.20
6. Switzerland	1.28	17.9	41.4	$3.35
7. Canada	5.63	17.7	69.3	$1.05
8. Taiwan, China	3.75	16.5	28.0	$0.18
9. Israel	1.07	16.3	92.6	$3.25
10. Belgium	1.62	15.6	79.6	$1.22
11. Finland	0.80	15.3	57.1	$0.73
12. Japan	1.91	14.9	56.4	$0.07
13. Norway	0.68	14.9	43.3	$6.26
14. Sweden	1.30	14.7	40.6	$0.25
15. United States	37.89	12.8	59.5	$0.49
16. Singapore	0.51	11.9	23.0	$1.59
17. France	6.75	11.2	56.6	$3.67
18. United Kingdom	6.26	10.5	39.6	$1.35
19. Austria	0.83	10.2	61.8	$6.51
20. Macao, China	0.05	9.7	58.6	$1.16
WORLD	**158.9**	**2.5**	**n/a**	**$69.58**

ITU Internet Reports:
The Internet of Things

Table of Contents

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