Intellectual Property Office

Eight Great Technologies

The Internet of Things

A patent overview

#8Great

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Contents

1 Introduction

The UK Government has identified ‘eight great technologies’ plus a further two which will propel the UK to future growth. These are:

- the big data revolution and energy-efficient computing;
- satellites and commercial applications of space;
- robotics and autonomous systems;
- life sciences, genomics and synthetic biology;
- regenerative medicine;
- agri-science;
- advanced materials and nanotechnology;
- energy and its storage;
- quantum technologies;
- the internet of things.

Patent data can give a valuable insight into innovative activity, to the extent that it has been codified in patent applications, and the IPO Informatics team is producing a series of patent landscape reports looking at each of these technology spaces and the current level of UK patenting on the world stage. As an aid to help people understand the eight great technologies and to consider the direction of future funding, the IPO is offering a comprehensive overview of what is already patented in the each of these technologies. This information should not be taken as a direct measure of the level of innovation in the UK; it should be considered in conjunction with other sources of information to form a fuller picture.

This is the final report in the series and gives an analysis of the worldwide patent landscape for the Internet of Things (IoT). The IoT is a concept where a network of everyday physical objects are accessed through the internet and are able to automatically identify themselves to other devices because of their inherent “ambient intelligence” [1], creating a smarter world[2]. In 2012 it was estimated that there were 8.7 billion connected devices and this is predicted to rise to between 50 billion and 75 billion devices by 2020[3]. Examples in the home include smart metering and remote control appliances, and in the wider world include traffic congestion/optimisation, intelligent shopping, smart monitoring, e-health, industrial auto-diagnosis and smart farming.

The IoT is the most widely used term to describe this concept but a number of other terms are also used in the field[4], including the Cloud of Things (CoT), Industrial Internet, Internet

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[1] *http://www.techopedia.com/definition/28247/internet-of-things-iot*
[2] *http://images.libelium.es/content/applications/libelium_smart_world_infographic_big.png*
[3] *http://www.businessinsider.com/75-billion-devices-will-be-connected-to-the-internet-by-2020-2013-10*
[4] *http://www.wired.com/2014/02/web-semantics-synonyms-internet-things/*

of Everything, Web of Things, Machine to Machine (M2M), Smarter Planet, and Digital Life.

The dataset used for analysis was extracted from worldwide patent databases following detailed discussion and consultation with patent examiners from the Intellectual Property Office who are experts in the field. The search strategy for this dataset was designed to reflect smart internet-connected devices as well as genuine IoT technologies with ambient intelligence for automatic identification and connection. For example, current smart electricity meters are internet-connected devices but they are not a core IoT technology because they do not automatically identify themselves to the network and to other devices and they require manual user setup. However these smart meters are only one small step away from being a true IoT device and it would be misleading to exclude them from analysis of the IoT patent landscape.

This report is based on the analysis of published patent application data rather than granted patent data. Published patent application data gives more information about technological activity than granted patent data because a number of factors determine whether an application ever proceeds to grant; these include the inherent lag in patent processing at national IP offices worldwide and the patenting strategies of applicants who may file more applications than they ever intend to pursue.

2 Worldwide patent analysis

2.1 Overview

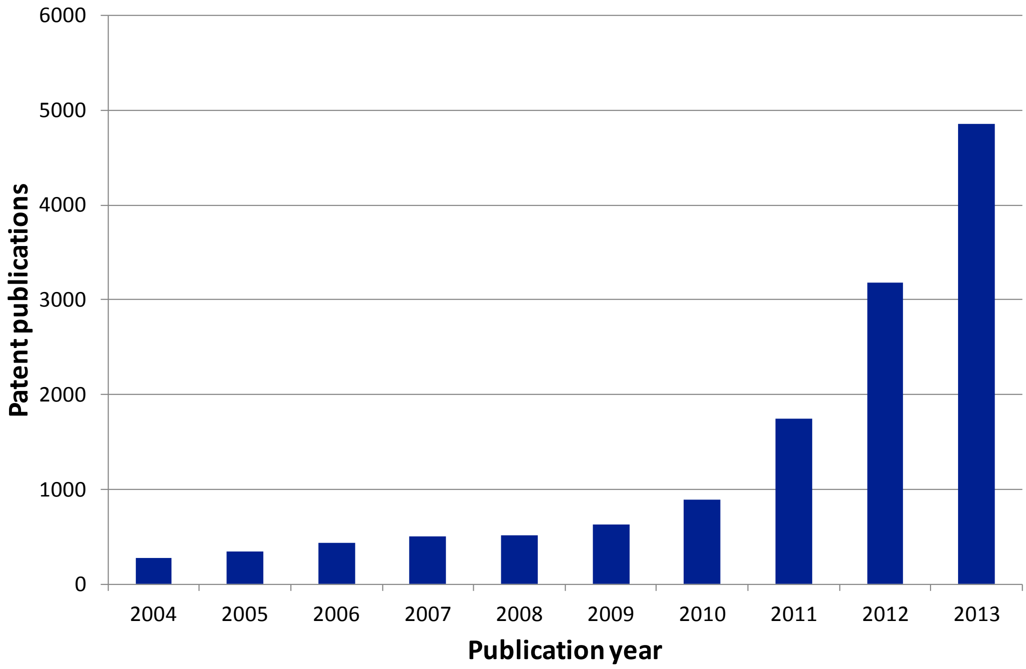
Table 1 gives a summary of the worldwide dataset used for the analysis of the IoT patent landscape. All of the analysis undertaken in this report was performed on this dataset or a subset of this dataset. The worldwide dataset for IoT patents published between 2004 and 2013 contains almost 22,000 published patents equating to almost 10,000 patent families.

Published patents may be at the application or grant stage, so are not necessarily granted patents. A patent family is one or more published patent originating from a single original (priority) application. Analysis by patent family more accurately reflects the number of inventions present because generally there is one invention per patent family, whereas analysis by raw number of patent publications inevitably involves multiple counting because one patent family may contain dozens of patent publications if the applicant files for the same invention in more than one country. Hence analysis by patent family gives more accurate results regarding the inventive effort that patenting activity represents.

Table 1: Summary of worldwide patent dataset for the internet of things

Number of patent families	9860
Number of patent publications	21,956
Publication year range	2004-2013
Peak publication year	2013
Top applicant	ZTE (China)
Number of patent assignees	7238
Number of inventors	17,756
Priority countries	42
IPC sub-groups	4547

Figure 1 shows the total number of published patents by publication year (top) and the total number of patent families by priority year (bottom – considered to be the best indication of when the original invention took place). Figure 1 suggests a significant and rapid increase in IoT patenting in recent years with over five times the number of IoT patents published in 2013 compared to 2010. The patent family chart in red does not show any patents filed after 2011 because a patent application is normally published 18 months after the priority date or the filing (application) date, whichever is earlier. Hence, the 2012 and 2013 data is incomplete and has been ignored.



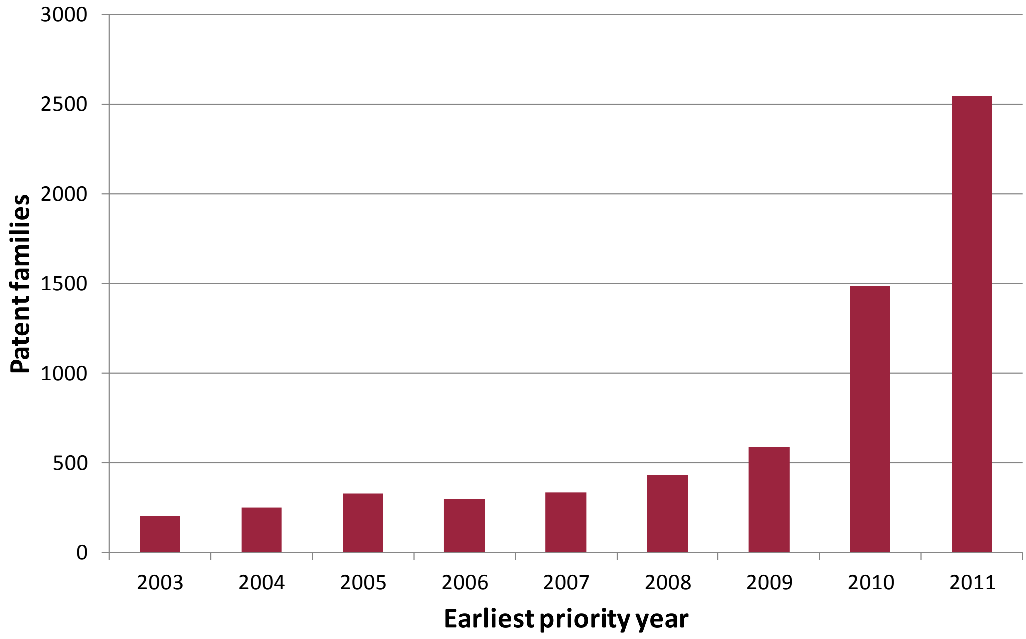


Figure 1: Patent publications by publication year (top) and patent families by priority year (bottom)

In real-world terms only limited information can be gleaned from the upward trends shown in Figure 1 because overall patenting levels globally continue to grow at an ever-increasing rate. Figure 2 addresses this issue by normalising the data shown in Figure 1 and presenting the annual increase in the size of worldwide patent databases across all technologies against the year-on-year increase in the size of the IoT dataset. For example, between 2011 and 2012 worldwide patenting across all areas of technology increased by 12.7% and this can be compared to an 82.0% increase in IoT patenting over the same time period.

Figure 2 shows that the year-on-year change in IoT patenting has been well above the annual increase in overall patent publications over the last ten years. Patenting within the IoT technology space is clearly rapidly expanding with an average year-on-year growth of over 40% between 2004 and 2013 compared to an average 6% year-on-year increase across all technologies.

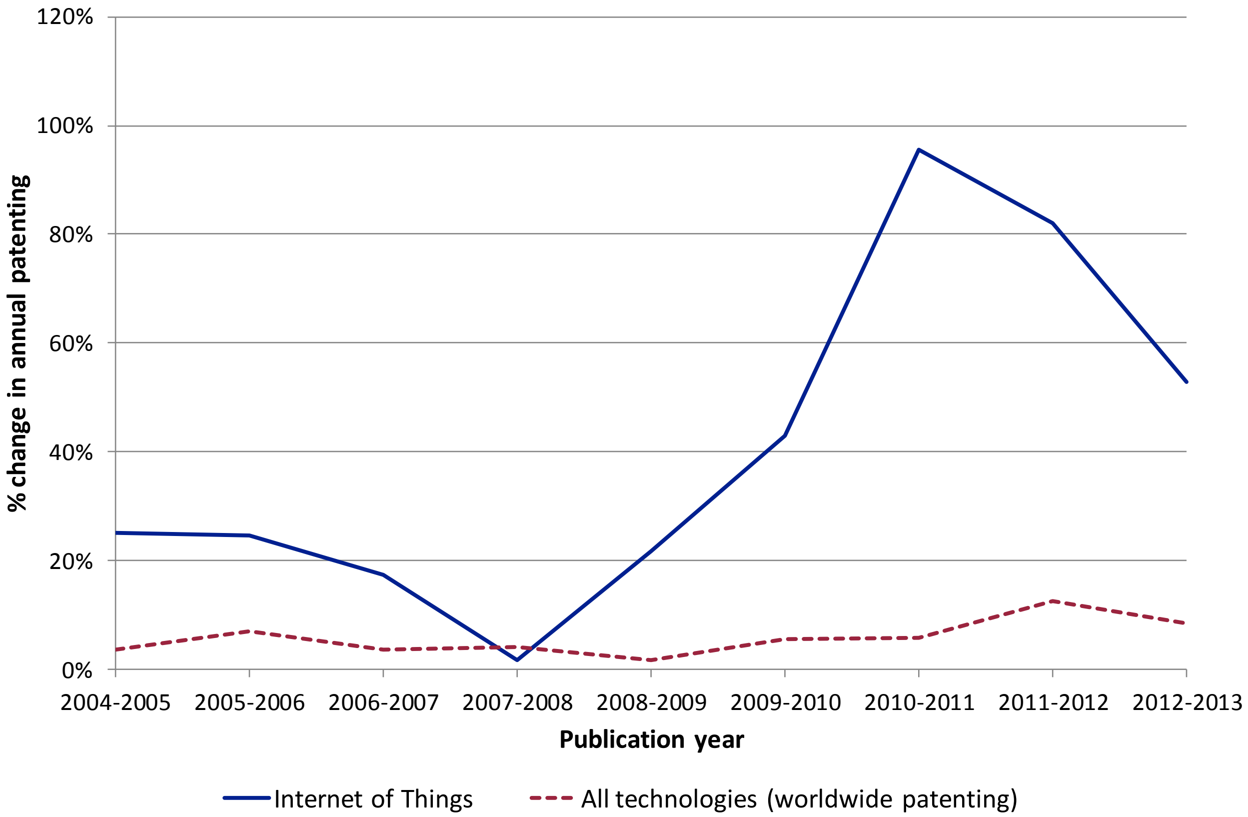


Figure 2: Year-on-year change in the internet of things patenting compared to worldwide patenting across all technologies

Figure 4 shows the priority country distribution across the dataset with over three-quarters of IoT patent families having their first filing in China, the USA or Korea. 2% of IoT patent families are first filed in the UK. Traditionally priority country analysis has been a good indicator of where the invention is actually taking place because many applicants will file patent applications first in the country in which they reside[5], but in recent years drawing firm conclusions from this data is harder because there may be other strategic reasons for an applicant choosing the country of first filing (*e.g.* tax treatment).

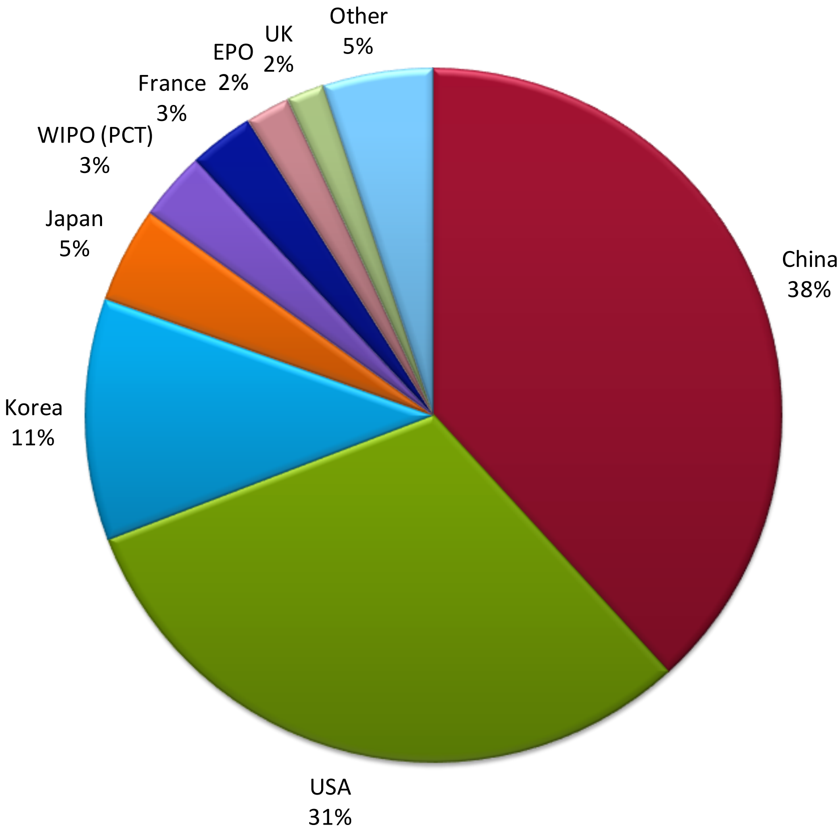


Figure 3: Priority country distribution

[5] In some countries this is/was a requirement (*e.g.* in the UK this was a requirement until 2005).

It is very difficult to draw accurate conclusions from simply presenting data based on the country of residence of patent applicants because there is a greater propensity to patent in certain countries than others. However the Relative Specialisation Index (RSI)[6] for each applicant country (Figure 4) has been calculated to give an indication of the level of invention in IoT patenting for each country compared to the overall level of invention in that country.

The priority country distribution shown in Figure 4 is dominated by China, the USA and Korea and suggests that these three countries are relatively specialised in IoT since they account for almost three-quarters of the first filings of all IoT patent families. However the RSI shown in Figure 4 appears to suggest a slightly different picture. When the RSI is applied, China is still ranked 1st, but the USA is ranked 8th and Korea 4th, below countries such as Sweden and Finland. These high-ranking countries show much greater levels of patenting in IoT than expected despite their absolute levels of patenting, although these high rankings are primarily due to high patenting activities from a single company – Ericsson in Sweden and Nokia in Finland. The UK is ranked 11th with a negative RSI value of -0.30, suggesting that there are fewer IoT patents filed by UK applicants compared to the overall level of patenting from UK applicants across all technology areas.

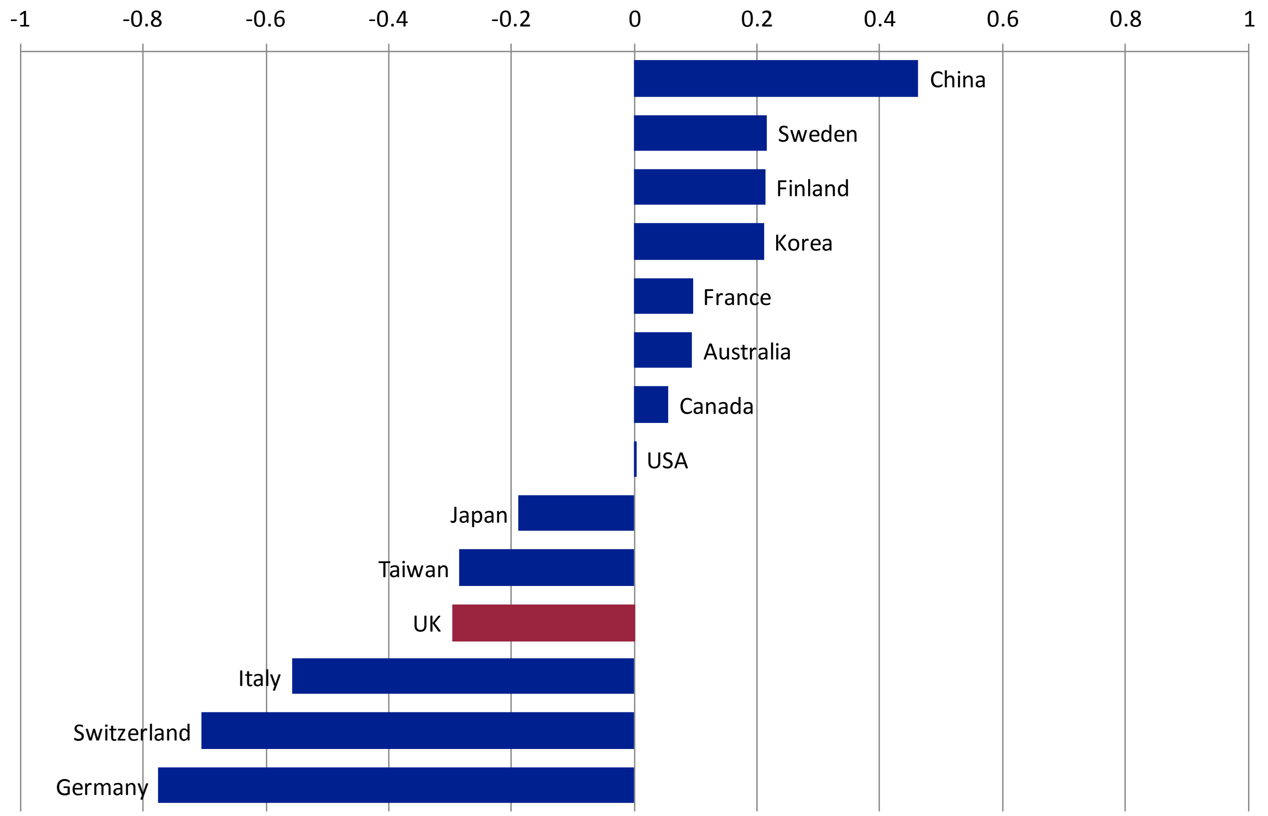


Figure 4: Relative Specialisation Index (RSI) by applicant country

Figure 5 shows the countries in which applicants in the IoT field are interested in seeking patent protection, with the strength of colour reflecting the quantity of published patents in

[6] See Appendix B for full details of how the Relative Specialisation Index is calculated.

each jurisdiction. The strong coverage of China and the USA is expected given the propensity to patent in these countries. Published patents filed via the EPO [] and WIPO (PCT) [] routes are also presented, with Figure 5 showing a strong level of patenting via the PCT route evidenced by the dark orange colour given to the blob that represents WIPO.

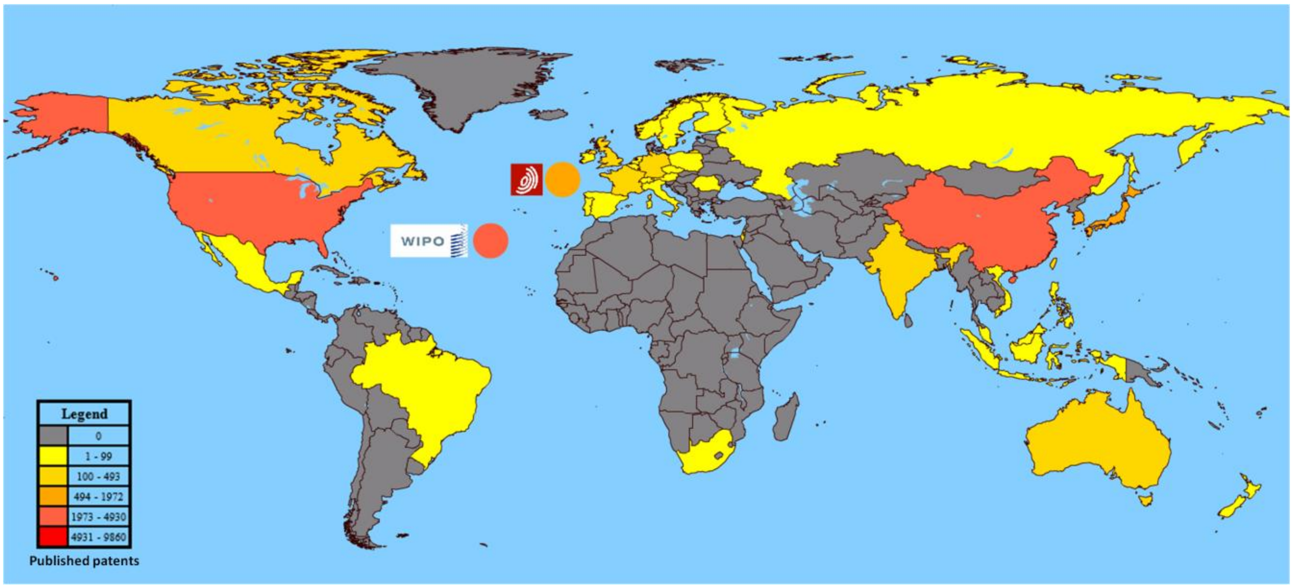


Figure 5: Patent coverage (publication country coverage)

2.2 Top applicants

Patent applicant names within the dataset were cleaned to remove duplicate entries arising from spelling errors, initialisation, international variation and equivalence[7]. Figure 6 shows the top 20 applicants which primarily consists of a mix of Chinese, Korean, US and Japanese companies.

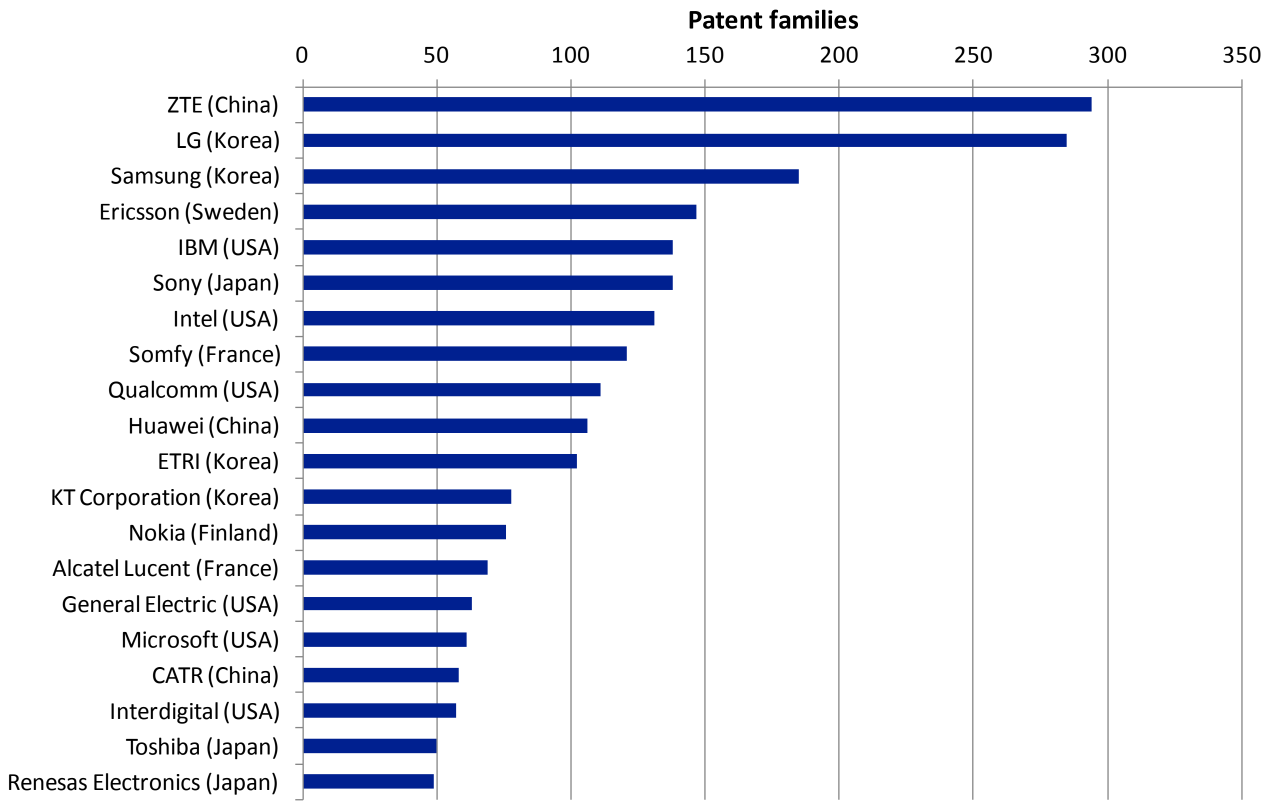


Figure 6: Top applicants

ZTE is a Chinese multinational telecommunications equipment and systems company and it has the most patent families of any of the applicants in the IoT patent landscape. The inventions that these families seek to protect relate to a variety of different aspects of the IoT with many inventions relating to machine-to-machine (M2M) communication, vehicle remote control, IoT security (*e.g.* authentication devices) and wireless network arrangements.

LG and Samsung both have a number of IoT patent applications relating to data transmission and data storage, but primarily they are interested in home automation. For example many applications relate to smart TVs, smart washing machines, smart refrigerators and air-conditioning units that can be controlled via smartphones, connect with smart meters to turn on when lower-cost energy is available, and analyse food quantities available against stored recipes.

[7] See Appendix A.4 for further details.

The media have reported the interest of the 'tech-giants' Apple and Google in the IoT[8] but detailed information is limited at present[9]. Apple is ranked 27th in the list of top IoT applicants with 129 published patent applications relating to 37 patent families (inventions). Google is ranked 84th with 39 published patent applications relating to 14 patent families, although Google has recently acquired home-security company Nest Labs for $3.2 billion[10], who specialise in smart thermostats and smart smoke alarms, and Nest Labs own a further 16 published patent applications relating to 7 patent families.

Figure 7 is a bubble map showing a timeline for the top 20 applicants and shows the filing activity of these applicants in the last 10 years. It shows absolute number of patent publications whereas Figure 6 shows patent families (inventions). Figure 7 highlights the large increase in recent years with very little patenting activity before 2011. For example, LG had only 6 published IoT patent applications in 2010 compared to 189 in 2013.

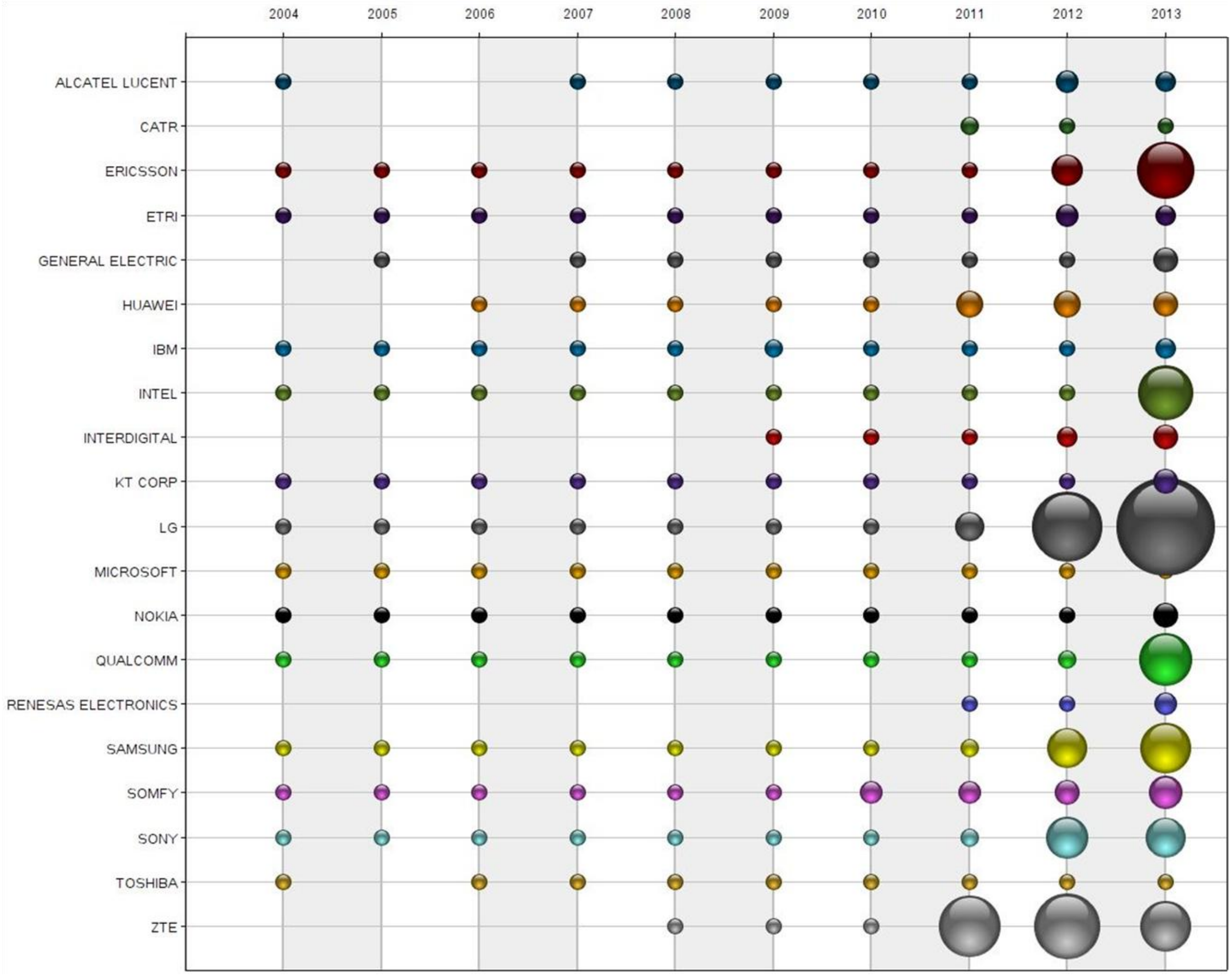


Figure 7: Applicant timeline of published patents by publication year

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8 http://www.forbes.com/sites/brucerogers/2014/07/08/apple-and-google-dominate-internet-of-things-influence-with-home-automation-efforts/

9 http://thestack.com/apple-and-google-eye-up-opportunity-for-internet-of-things

10 http://www.theverge.com/2014/1/13/5305282/google-purchases-nest-for-3-2-billion

2.3 Technology breakdown

Figure 8 shows the top IPC subgroups, and Table 2 lists the description of each of these subgroups. The IPC provides for a hierarchical system of language-independent symbols for the classification of patent applications according to the different areas of technology to which they relate. However the classifications are not mutually exclusive and each patent family may have several of these classifications applied.

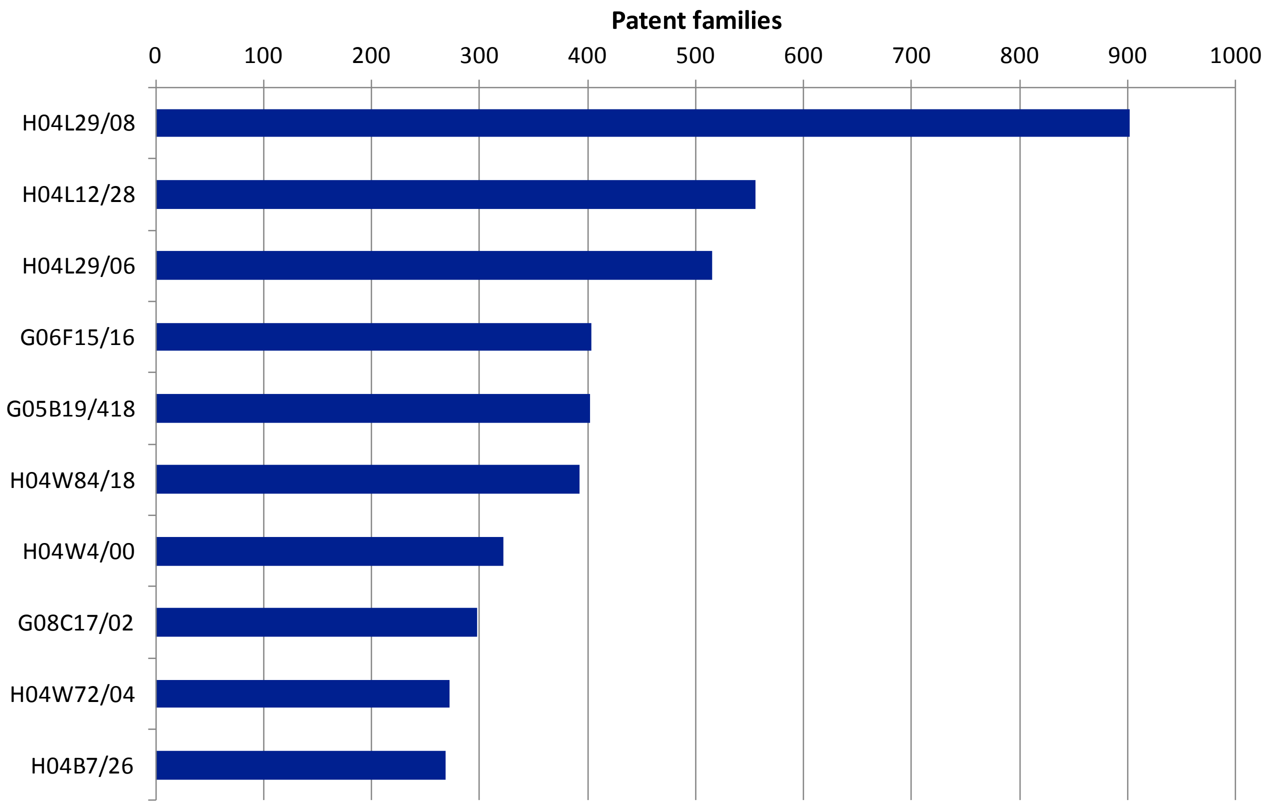

Figure 8: Top IPC sub-groups

Table 2: Key to IPC subgroups referred to in Figure 8

H04L29/08	Communication control; Communication processing -> characterised by a protocol -> Transmission control procedure, *e.g.* data link level control procedure
H04L12/28	Data switching networks -> characterised by path configuration, *e.g.* LAN (Local Area Networks) or WAN (Wide Area Networks)
H04L29/06	Communication control; Communication processing -> characterised by a protocol
G06F15/16	Digital computers in general; Data processing equipment in general -> Combinations of two or more digital computers each having at least an arithmetic unit, a programme unit and a register, *e.g.* for a simultaneous processing of several programmes
G05B19/418	Programme-control systems -> electric -> Total factory control, *i.e.* centrally controlling a plurality of machines, *e.g.* direct or distributed numerical control (DNC), flexible manufacturing systems (FMS), integrated manufacturing systems (IMS), computer integrated manufacturing (CIM)
H04W84/18	Network topologies -> Self-organising networks, *e.g.*ad hoc networks or sensor networks
H04W4/00	Services or facilities specially adapted for wireless communication networks
G08C17/02	Arrangements for transmitting signals characterised by the use of a wireless electrical link -> using a radio link
H04W72/04	Local resource management, e.g. selection or allocation of wireless resources or wireless traffic scheduling -> Wireless resource allocation
H04B7/26	Radio transmission systems, *i.e.* using radiation field -> for communication between two or more posts -> at least one of which is mobile

3 The UK landscape

3.1 UK applicants

Figure 9 shows Neul is the top UK applicant for IoT patents with 19 patent families (inventions). Neul is based in Cambridge and was incorporated in 2010. Neul develop and supply the technology to allow network operators to provide a scalable, low-power network service to connect small, low-power devices to their online digital presence in the Cloud[11]. To date they have two granted UK patents (GB2491908B and GB2494724B) relating to networked data communications.

Toshiba Research Europe has a telecommunications research laboratory in Bristol[12] and they have six granted UK patents within their eight IoT patent families. These granted patents relate to smart grid and smart electricity meter systems and methods for managing smart utility supplies. Landis+Gyr, Navetas Energy Management and Onzo also own a number of patent applications that relate to smart metering.

IoT patents applied for by ECEBS relate to contactless smartcards for financial payments and e-ticketing, Eldon Technology's relate to set-top boxes for home automation, and the University of Warwick are researching smart gas sensors.

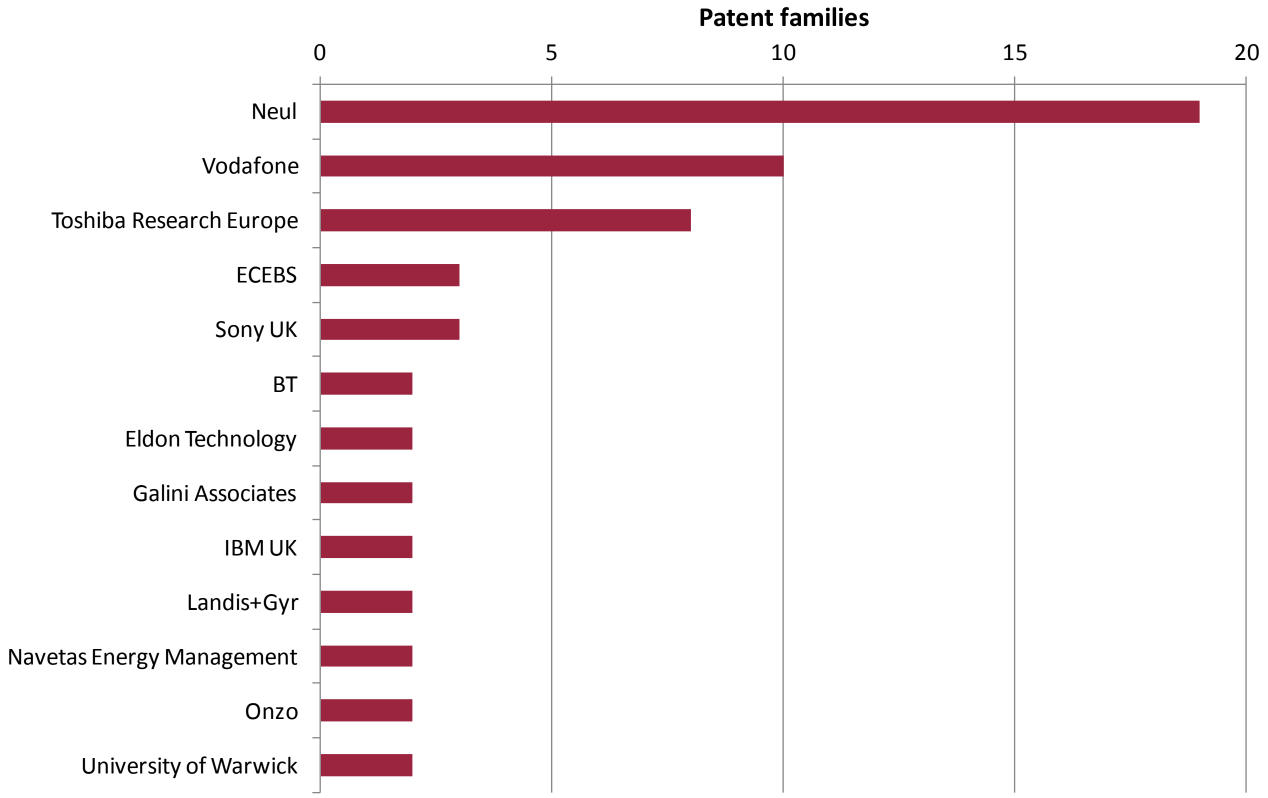

Figure 9: UK applicants

[11] http://www.neul.com
[12] http://www.toshiba.eu/eu/Telecommunications-Research-Laboratory/

3.2 Collaboration

Figure 10 is a collaboration map showing all collaborations between the top UK applicants in the dataset and their collaborators. Each dot on the collaboration map represents a patent family and two applicants are linked together if they are named as joint applicants on a patent application. A collaboration map indicates instances where joint work in solving a problem has resulted in a shared application for a patent. Figure 10 shows that there is very little collaboration amongst the top UK IoT patent applicants.

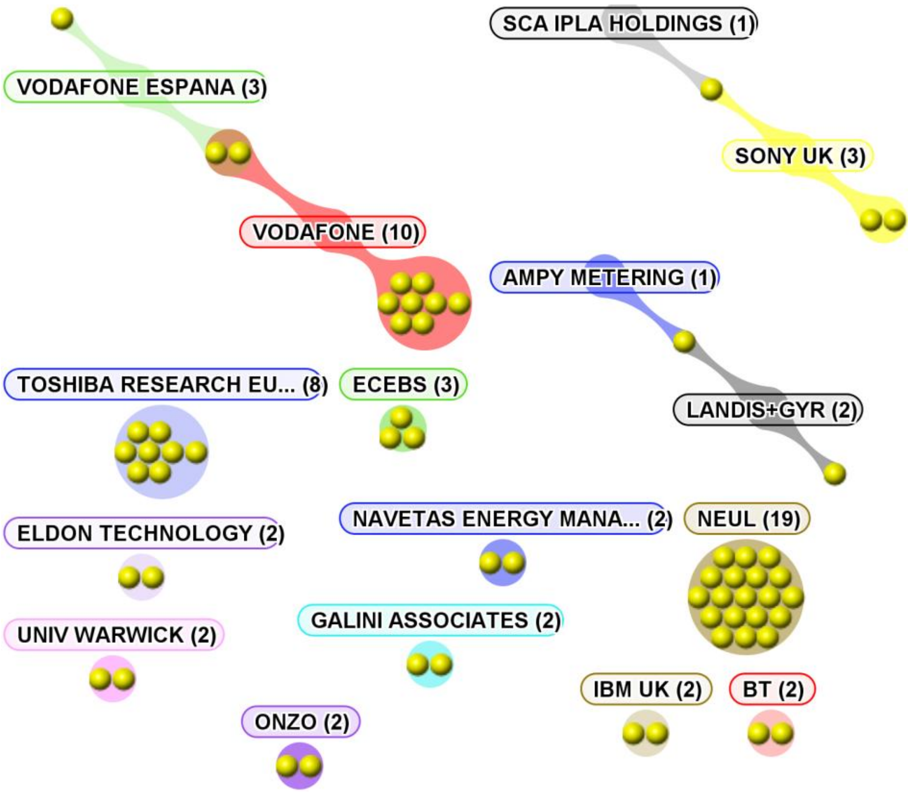

Figure 10: Map of collaborations between the top UK applicants and their collaborators

3.3 UK inventor mobility

Figure 11 shows the top worldwide applicants with named UK inventors on their published patents. Comparison with the number of patent families from the top UK applicants, Figure 9, suggests that many UK inventors work for international applicants, including Alcatel Lucent, Nokia and Research in Motion. This potentially highlights the mobility of the UK knowledge base since UK inventors are innovating for other non-UK companies.

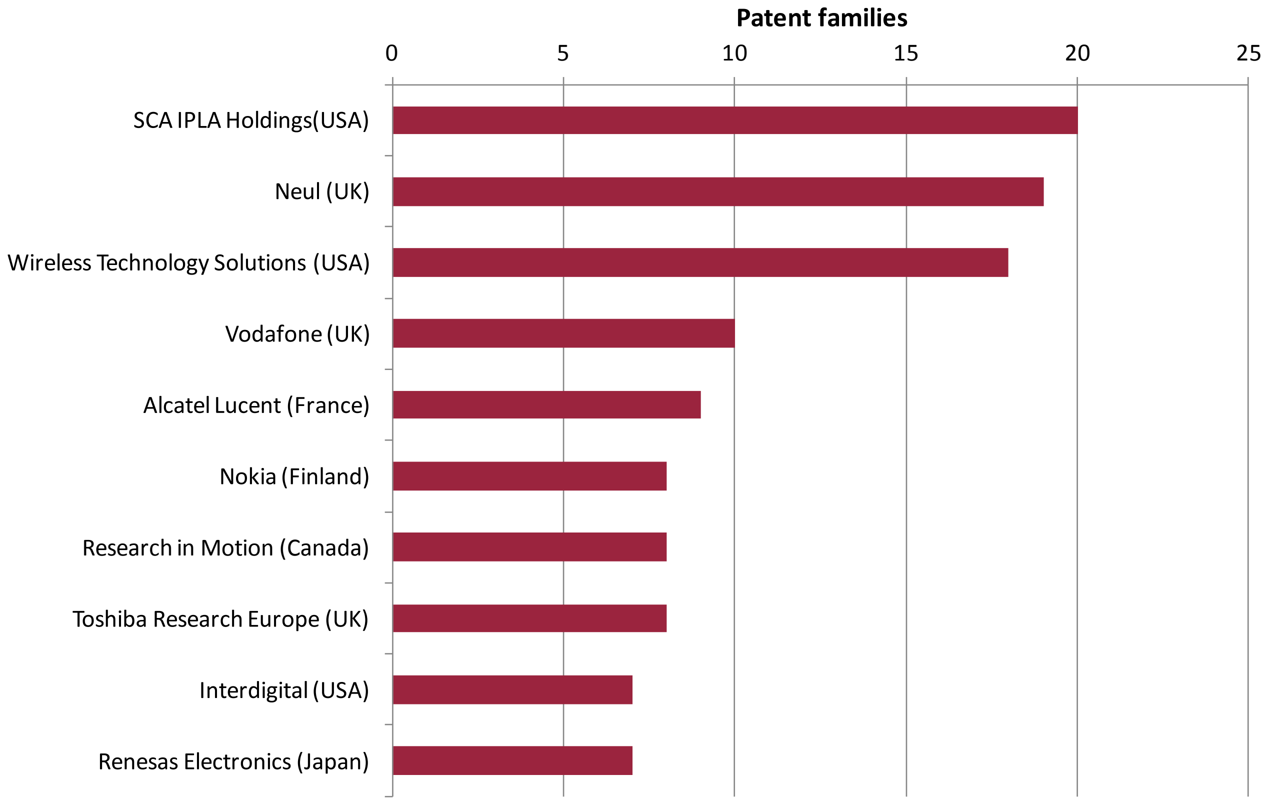

Figure 11: Top worldwide applicants with named UK-based inventors

3.4 How active is the UK?

A subset of the main worldwide patent dataset designed to reflect UK patenting activity was selected. Figure 12 shows the annual change in IoT patenting arising from UK patenting activity against the worldwide year-on-year change in this field shown in Figure 2. It is clear from Figure 1 that worldwide IoT patenting has risen sharply in the last three years; this is reflected in Figure 12 which shows that worldwide patenting activity jumped 98% between 2010 and 2011, with UK patenting activity taking a little longer to react and showing a similarly large jump between 2011 and 2012 of 152%. Although the surge in patenting activity in the UK took a year longer, over the time period measured the UK year-on-year change in IoT patenting activity appears to be on a par with the worldwide year-on-year change because it averages out to a similar level.

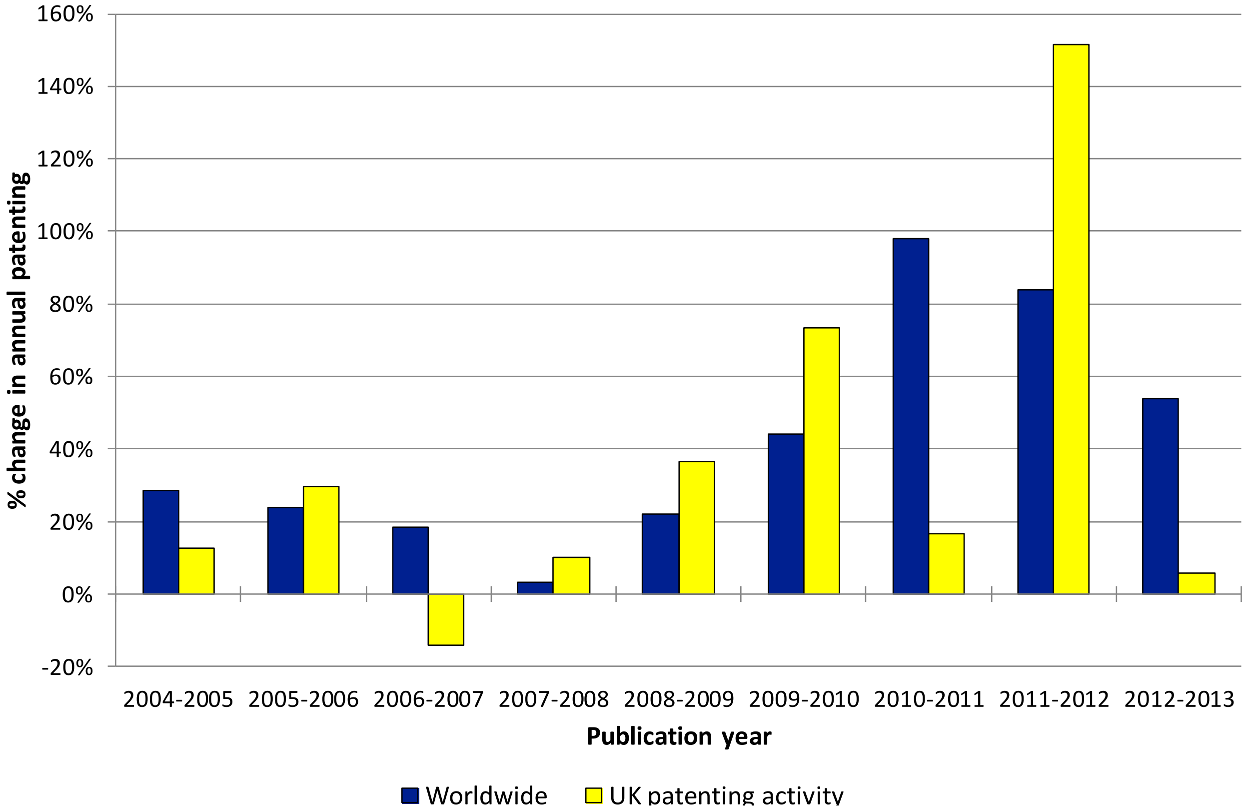

Figure 12: Year-on-year change in UK and worldwide internet of things patenting

Similar patent subsets were created to reflect patenting activity taking place in several comparator countries (France, Germany, USA, Korea, Japan and China) to produce the comparison chart shown in Figure 13.

Chinese patenting activity overshadows most countries across many of the data points in the time period analysed, especially the 319% increase in Chinese patenting activity between 2006 and 2007 and the even larger 447% increase between 2010 and 2011. As seen in several of the other reports in the series, a large proportion of Chinese patenting activity in the step-shift since 2006 are applications from Chinese universities. This sharp increase in Chinese university patenting is explained by a change in Chinese government policy to give Chinese universities grants to pay for filing patent applications and a change to rank Chinese universities against each other according to how many patents they have filed[13]. In 2005 Chinese IoT patenting activity resulted in just 16 patent families compared to over 6000 in 2013 and the average annual growth of Chinese IoT patenting activity over the time period measured is over 130% (the average annual growth in the last four years is over 200%). This significant and rapid growth resulting from Chinese patenting activity is not specific to the IoT and is often seen in a wide range of different technology areas.

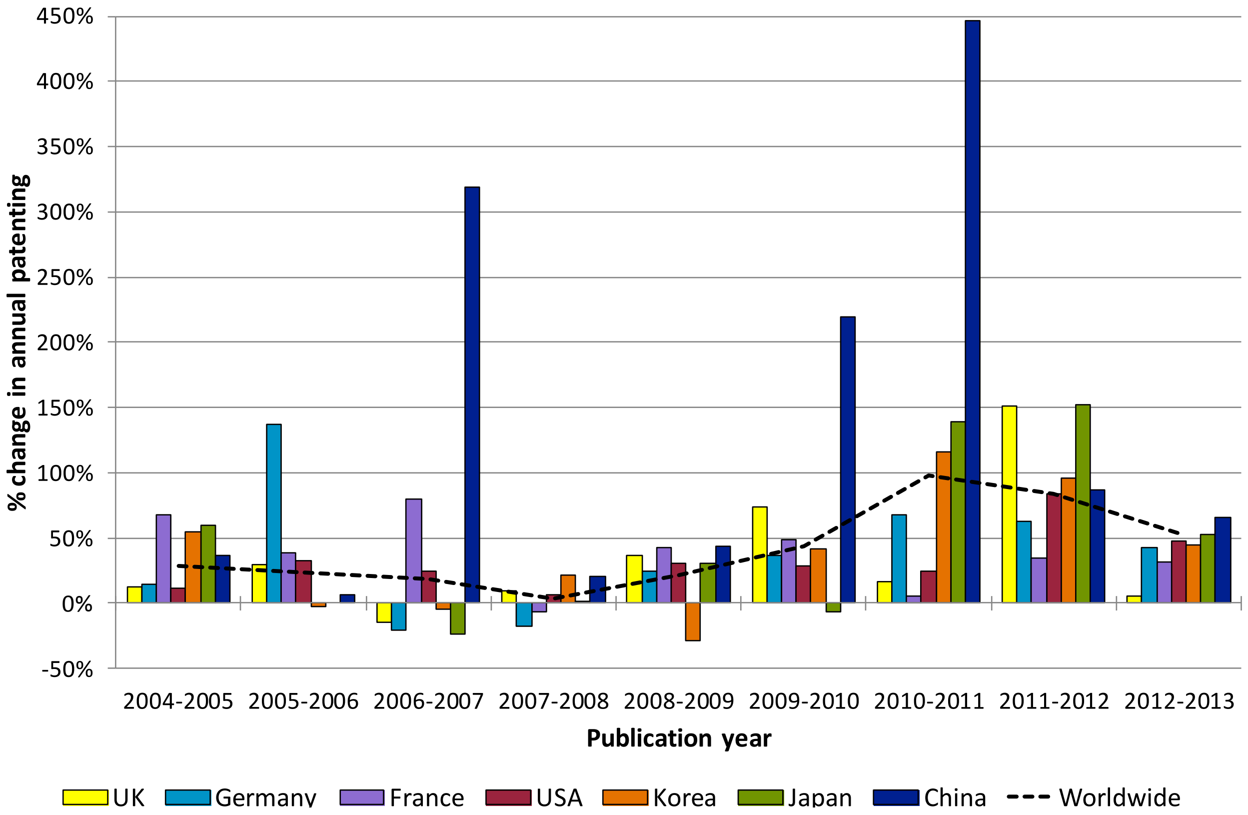

Figure 13: Year-on-year change in UK internet of things patenting against comparison countries

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[13] Fisch et al - *http://www.uni-patente.de/wordpress/wp-content/uploads/Download.pdf*

The influence of the significant increase in Chinese patenting activity makes it difficult to draw comparisons between the other countries presented in Figure 13, so the same content has been reproduced in Figure 14 but with Chinese patenting activity removed. Figure 14 makes it a lot easier to compare UK patenting activity against the other comparator countries and the worldwide trend.

Although the quantity of US patenting in the IoT is high (as shown in Figure 3), Figure 14 highlights that US patenting activity has shown a smaller change than all of the other comparison countries with an average year-on-year growth over the time period analysed of 32%. This is in direct comparison to the growth arising from Japanese patenting activity which has averaged over 45% year-on-year growth over the ten-year time period studied, with a 139% increase between 2010 and 2011 that was then followed by a 152% increase on this between 2011 and 2012.

Figure 3 shows that UK patenting activity in the IoT is relatively small but Figure 14 shows that, on a side-by-side comparison, UK growth appears to be on a par with all of the comparator countries (except China). The UK has an average year-on-year growth of the time period studied of 36% which compares favourably with Germany (39%), France (38%), Korea (38%), Japan (45%) and the USA (32%), and it is only slightly lower than the worldwide average year-on-year growth of 42% between 2004 and 2013.

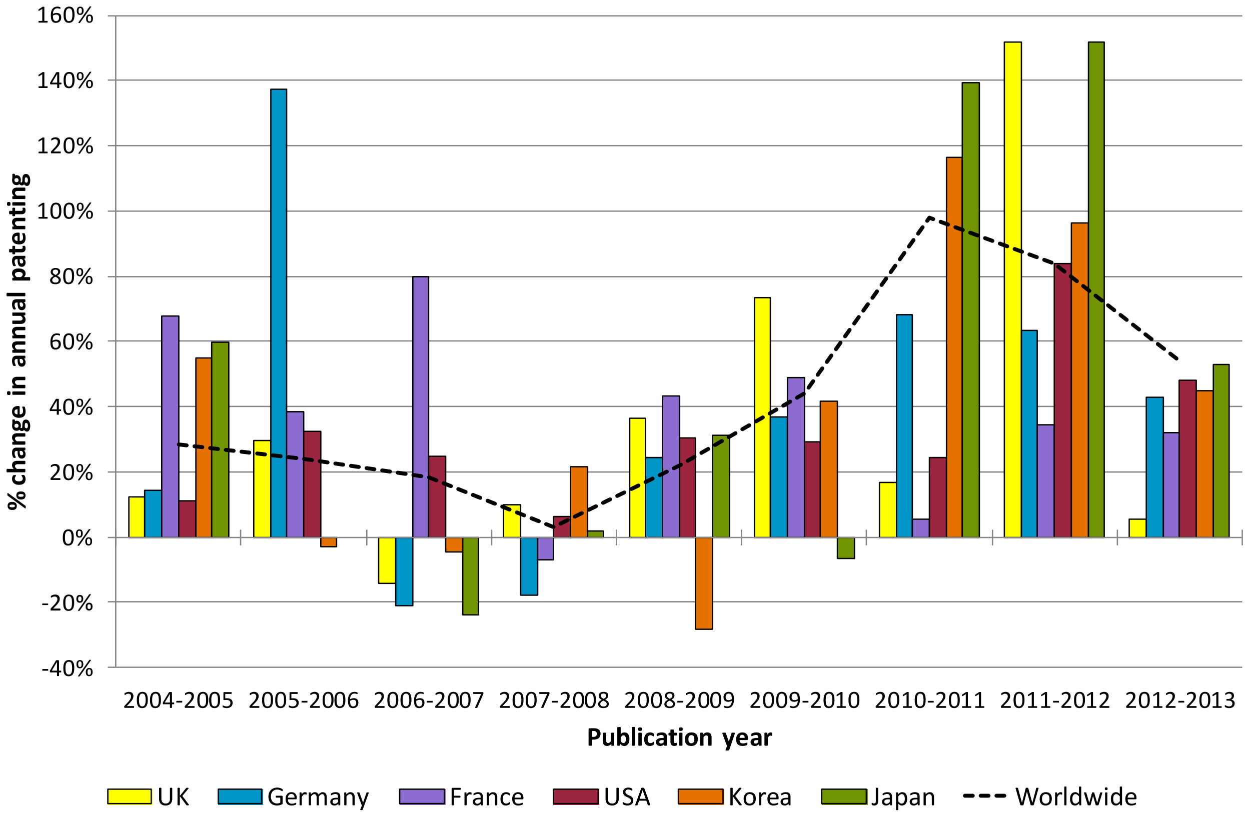

Figure 14: Year-on-year change in UK internet of things patenting against comparison countries (excluding China)

4 Patent landscape map analysis

In order to give a snapshot as to what the IoT patent landscape looks like, a patent map provides a visual representation of the dataset. Patent families are represented on a patent map by dots and the more intense the concentration of patents (*i.e.* the more closely related they are) the higher the topography as shown by contour lines. The patents are grouped according to the occurrence of keywords in the title and abstract and examples of the reoccurring keywords appear on the patent map[14]. Figure 15 shows the IoT patent landscape map for all IoT patents between 2004 and 2013.

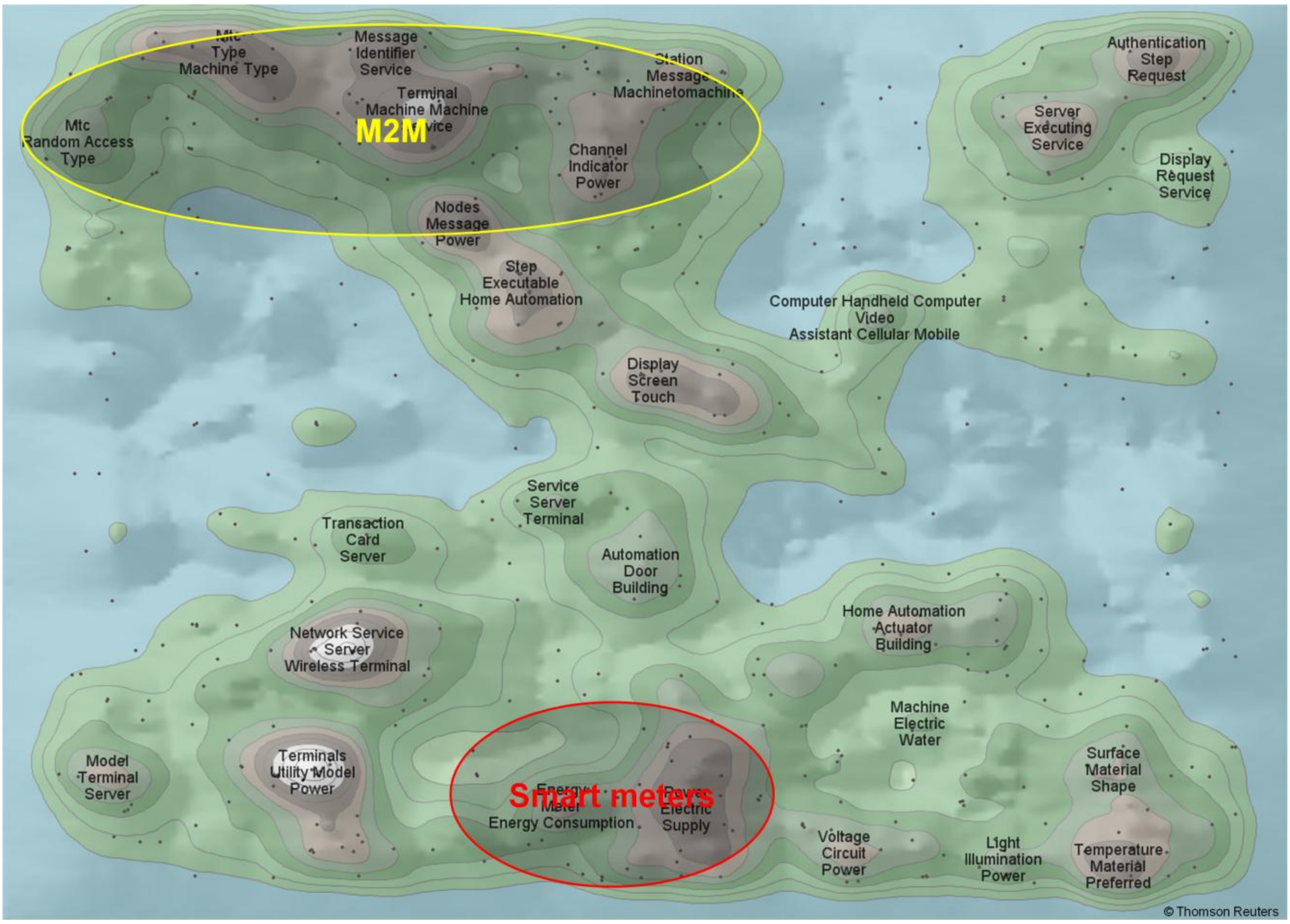

Figure 15: Patent landscape map of all patents relating to the internet of things

The largest 'mountain range' in the top-left of the map shows that a large proportion of the IoT patent landscape relates to machine-to-machine (M2M) technologies. M2M allows both wireless and wired systems to communicate with other devices of the same type. It has a wide range of applications including industrial automation, logistics, smart cities,

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[14] Further details regarding how these patent landscape maps are produced is given in Appendix C.

health and defence, and is used for both monitoring and control purposes[15].

The other region highlighted in Figure 15 relates to smart metering patents. Smart meters are one of the first IoT home automation technologies that many of the public will see and use in their homes because the UK government has announced that they aim to fit every home in the UK with a smart meter by 2020[16] with the official national smart meter roll-out commencing in 2015. Smart meters are connected via the internet to energy suppliers, allowing more accurate meter readings and domestic energy management[17] with the ability to offer 'time of day' energy tariffs with cheaper rates of electricity at off-peak times to smooth out national energy usage throughout the day.

The patent landscape map shown in Figure 16 is the same patent map shown in Figure 15, but with the individual IoT patents of the top five worldwide applicants (shown in Figure 6) highlighted. Figure 16 shows that the top applicant, ZTE, is predominately seeking patent protection around M2M technologies whereas LG, Samsung and Ericsson have a broader portfolio of both M2M and smart home automation IoT patent applications.

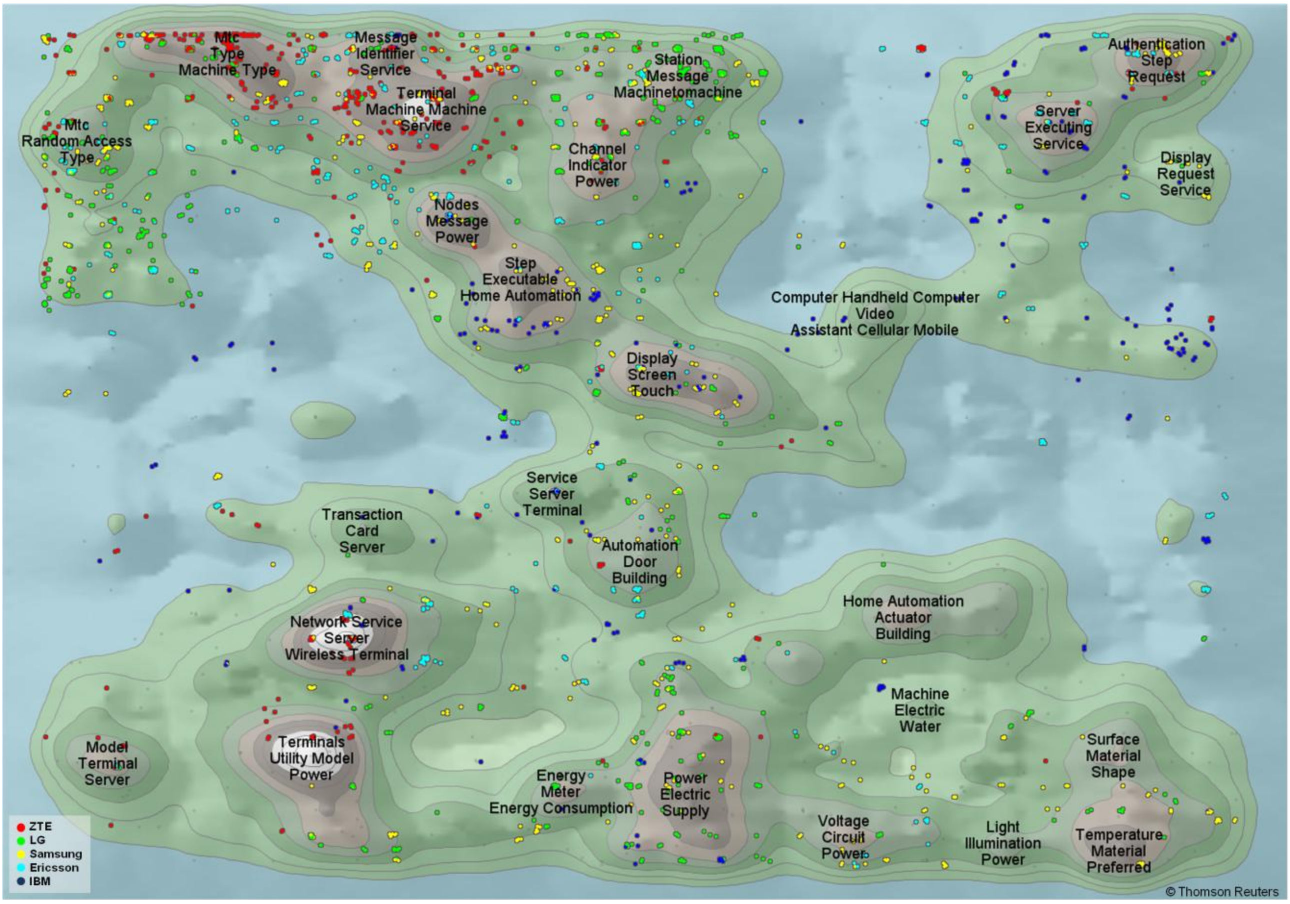

Figure 16: Patent landscape map of all patents relating to the internet of things with top three UK applicants highlighted

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[15] http://en.wikipedia.org/wiki/Machine_to_machine
[16] http://news.bbc.co.uk/1/hi/business/8389880.stm
[17] http://www.uswitch.com/gas-electricity/guides/smart-meters-explained/

The patent landscape map shown in Figure 17 highlights the top three UK applicants, namely Neul, Vodafone and Toshiba Research Europe. As mentioned previously, Neul operate in the M2M side of the IoT with patents in the area of networked data communication. Vodafone also operate in a similar part of the IoT technology space with patents relating to M2M control and messaging. Figure 17 confirms the discussion in section 3.1 and shows that Toshiba Research Europe focus on smart electricity meters and methods for controlling the smart grid by reporting electricity consumption data over the internet and allowing a user to verify the data using their smartphone.

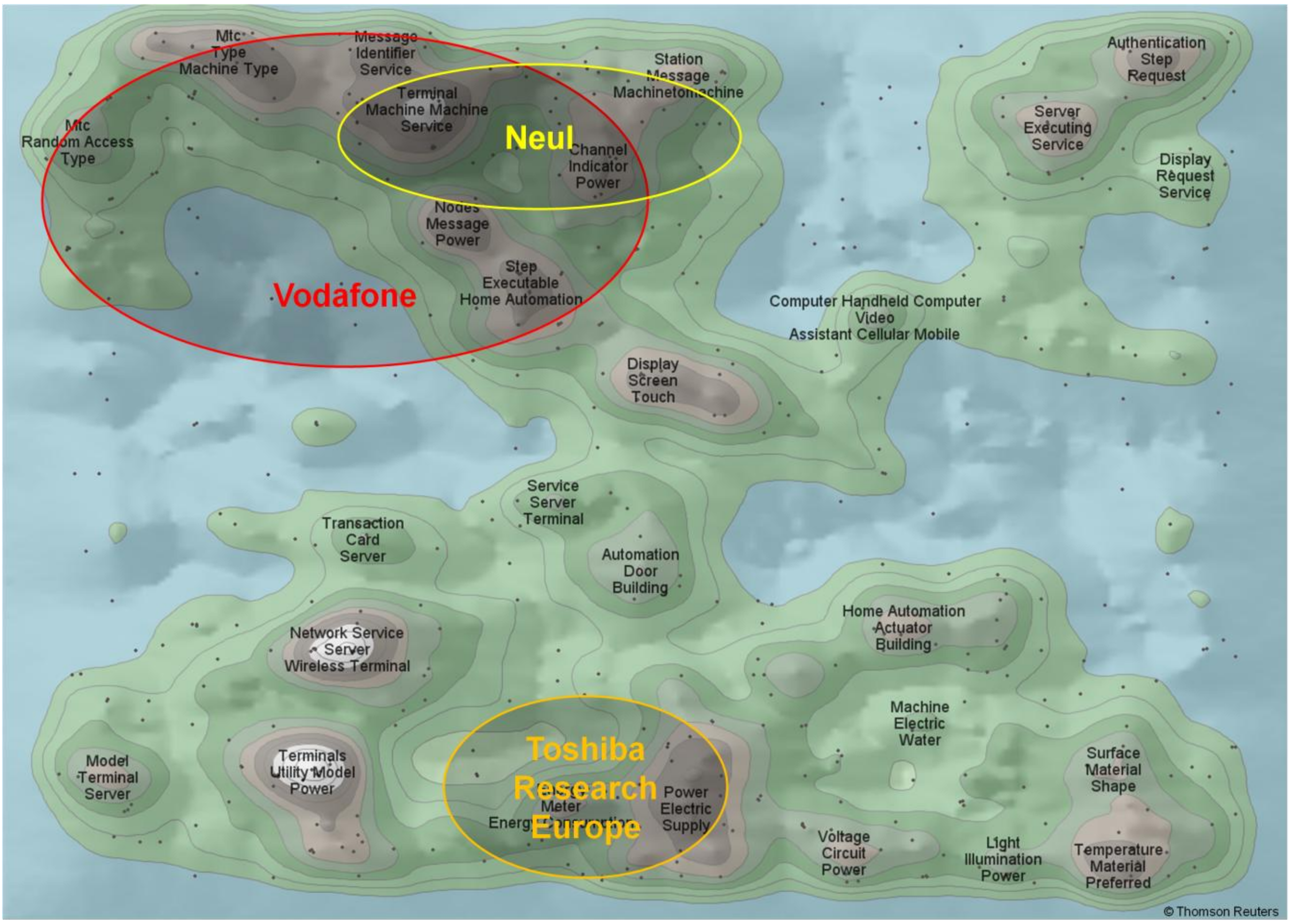

Figure 17: Patent landscape map of all patents relating to the internet of things with top three UK applicants highlighted

5 Conclusions

There are almost 22,000 published patent applications between 2004 and 2013 relating to the internet of things (IoT), resulting in almost 10,000 patent families (inventions). Not surprisingly patenting activity in this field has grown sharply and rapidly in recent years and in the last three years the annual increase in IoT patenting activity has been over eight times larger than the general worldwide increase in patenting.

The Chinese telecommunications company ZTE has the most patent families with several other well-known multinational companies appearing in the list of top applicants, including LG, Samsung, IBM and Sony. The leading UK applicant is Neul, a dedicated IoT company incorporated in 2010 to exploit the full potential of the IoT. Neul has been a major contributor to a new wide-area wireless networking technology designed specifically for the IoT with better coverage, battery life, module cost and efficiency than current mainstream wireless solutions[18]. In 2013 Neul produced the first single chip baseband implementation of this standard in the world and this technology is capable of delivering high coverage, low-power and low-cost wireless networks for the IoT[19]. Neul has recently worked alongside BT[20] and Google[21] to fast-track the development and push the boundaries of these technologies.

UK patenting activity in the IoT has significantly increased in recent years with a rise of over 150% in the number of published IoT patent applications between 2011 and 2012. In 2013 there were almost 250 IoT patents published from UK patenting activity compared to less than 50 in 2009. Although UK patenting activity in the IoT is relatively small, on a direct comparison it is on a par with the growth in patenting activity from several other countries including Germany, France, Korea, Japan and the USA.

There are an increasing number of internet-connected devices in modern life and a smart home environment that creates a framework for communication and control is on the cusp of being a mainstream consumer technology. For example Apple have recently announced[22] that their latest mobile operating system due for release in late 2014 will have the added functionality to allow manufacturers of smart home appliances to develop software that will allow their devices to interact with each other and be controlled using Apple's mobile devices. With an estimated[23] 75 billion connected devices by 2020, it appears that the IoT is likely to radically change the way we live our lives in a smarter digital world.

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18 http://www.neul.com/neul/?page_id=3614
19 http://www.weightless.org/silicon-neul and http://hexus.net/tech/news/network/51681-first-tv-white-space-network-chip-unveiled-uk-based-neul-ltd/
20 http://www.theregister.co.uk/2014/05/22/uk_government_bt_neul_milton_keynes_iot_m2m
21 http://www.businesswire.com/news/home/20130326005400/en/Carlson-Wireless-Neul-Ltd.-Join-Forces-Google
22 http://www.cnet.com/uk/news/apple-introduces-homekit-for-ios-8/
23 http://www.businessinsider.com/75-billion-devices-will-be-connected-to-the-internet-by-2020-2013-10

Appendix A Interpretation notes

A.1 Patent databases used

The *Thomson Reuters* World Patent Index (WPI) was interrogated using *Thomson Innovation*[24], a web-based patent analytics tool produced by *Thomson Reuters*. This database holds bibliographic and abstract data of published patents and patent applications derived from the majority of leading industrialised countries and patent organisations, *e.g.* the World Intellectual Property Organisation (WIPO), European Patent Office (EPO) and the African Regional Industry Property Organisation (ARIPO). It should be noted that patents are generally classified and published 18 months after the priority date. This should be borne in mind when considering recent patent trends (within the last 18 months).

The WPI database contains one record for each patent family. A patent family is defined as all documents directly or indirectly linked via a priority document. This provides an indication of the number of inventions an applicant may hold, as opposed to how many individual patent applications they might have filed in different countries for the same invention.

A.2 Priority date, application date and publication date

Priority date: The earliest date of an associated patent application containing information about the invention.

Publication date: The date when the patent application is published (normally 18 months after the priority date or the application date, whichever is earlier).

Analysis by priority year gives the earliest indication of invention.

A.3 WO and EP patent applications

International patent applications (WO) and European patent applications (EP) may be made through the World Intellectual Property Organization (WIPO) and the European Patent Office (EPO) respectively.

International patent applications may designate any signatory states or regions to the Patent Cooperation Treaty (PCT) and will have the same effect as national or regional patent applications in each designated state or region, leading to a granted patent in each state or region.

European patent applications are regional patent applications which may designate any signatory state to the European Patent Convention (EPC), and lead to granted patents having the same effect as a bundle of national patents for the designated states.

[24] *http://info.thomsoninnovation.com*

Figures for patent families with WO and EP as priority country have been included for completeness although no single attributable country is immediately apparent.

A.4 Patent documents analysed

The dataset for analysis was identified in conjunction with patent examiner technology-specific expertise. A search strategy was developed and the resulting dataset was extracted in July 2014 using keyword searching of titles and abstracts in the *Thomson Reuters* World Patent Index (WPI) and limited to patent families with publications from 2004 to 2013.

The applicant and inventor data was cleaned to remove duplicate entries arising from spelling errors, initialisation, international variation (Ltd, Pty, GmbH *etc*.), or equivalence (Ltd., Limited, *etc*.).

A.5 Analytics software used

The main computer software used for this report is a text mining and analytics package called *VantagePoint*[25] produced by *Search Technology* in the USA. The patent records exported from *Thomson Innovation* were imported into *VantagePoint* where the data is cleaned and analysed. The patent landscape maps used in this report were produced using *Thomson Innovation*.

[25] *http://www.thevantagepoint.com*

Appendix B Relative Specialisation Index

Relative Specialisation Index (RSI) was calculated as a correction to absolute numbers of patent families in order to account for the fact that some countries file more patent applications than others in all fields of technology. In particular, US and Japanese inventors are prolific patentees. RSI compares the fraction of technology area specific patents found in each country to the fraction of patents found in that country overall. A logarithm is applied to scale the fractions more suitably. The formula is given below:

$$\log_{10}\left(\frac{n_i/n_{total}}{N_i/N_{total}}\right)$$

where

n_i = number of technology area specific patents in country i
n_{total} = total number of technology area specific patents in dataset
N_i = total number of patents in country i
N_{total} = total number of patents in dataset

The effect of this is to highlight countries which have a greater level of patenting in the specific technology area than expected from their overall level of patenting, and which would otherwise languish much further down in the lists, unnoticed.

Appendix C Patent landscape maps

A patent landscape map is a visual representation of a dataset and is generated by applying a complex algorithm with four stages:

i) **Harvesting documents** – When the software harvests the documents it reads the text from each document (ranging from titles through to the full text). Non-relevant words, known as stopwords, (e.g. “a”, “an”, “able”, “about” etc) are then discounted and words with common stems are then associated together (e.g. “measure”, “measures”, “measuring”, “measurement” etc).

ii) **Analysing documents** – Words are then analysed to see how many times they appear in each document in comparison with the words’ frequency in the overall dataset. During analysis, very frequently and very infrequently used words (i.e. words above and below a threshold) are eliminated from consideration. A topic list of statistically significant words is then created.

iii) **Clustering documents** – A Naive Bayes classifier is used to assign document vectors and Vector Space Modelling is applied to plot documents in n-dimensional space (i.e. documents with similar topics are clustered around a central coordinate). The application of different vectors (i.e. topics) enables the relative positions of documents in n-dimensional space to be varied.

iv) **Creating the patent map** – The final n-dimensional model is then rendered into a two-dimensional map using a self-organising mapping algorithm. Contours are created to simulate a depth dimension. The final map can sometimes be misleading because it is important to interpret the map as if it were formed on a three-dimensional sphere.

Thus, in summary, patents are represented on the patent map by dots and the more intense the concentration of patents (*i.e.* the more closely related they are) the higher the topography as shown by contour lines. The patents are grouped according to the occurrence of keywords in the title and abstract and examples of the reoccurring keywords appear on the patent map. Please remember there is no relationship between the patent landscape maps and any geographical map.

Please note that the patent maps shown in this report are snapshots of the patent landscape, and that patent maps are best used an interactive tool where analysis of specific areas, patents, applicants, inventors *etc* can be undertaken ‘on-the-fly’.

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