8 Comms of the Future

8.1 Overview

Today, the movement from basic fixed telephony to wireless mobile connectivity is changing the way we communicate, work and entertain ourselves. Singapore has one of the world's highest mobile penetration rates, indicating a trend that has implications for the future development of applications and services.

In the recent past, we witnessed the birth of two formidable smartphone platforms, namely iOS and Android, from non-traditional mobile makers, Apple and Google. These two platforms have revolutionised the world and to date, have cornered more than 80% of the smartphone market.

The popularity of smartphones, tablets and other Web-enabled, connected devices further fuels social media and networking activities. Currently, 82% of the world's online population, representing 1.2 billion users around the world, visit social networking sites. The amount of time people spend on social networking activity has more than tripled in the past few years.

This "always on" connectivity has given rise to a world where the Internet of Things (IOT) captures the essence of the digital lifestyle. We can expect more new machine-to-machine (M2M)/IOT applications to crowd the landscape. To cope with the scale and elastic demand, cloud-based infrastructure that offers more flexibility will become an attractive proposition.

The confluence of these three domains - mobile, social, and cloud technologies – has created something the industry describes as the "perfect storm", an unusual convergence of forces that creates an exciting impact of unusual magnitude. We can expect new waves of applications enabling even more info-gratification for users on the go in the near future. The Internet and the underlying infrastructures that power our communication networks (fixed and mobile) will experience dramatic changes to support and adapt to ever increasing demand.

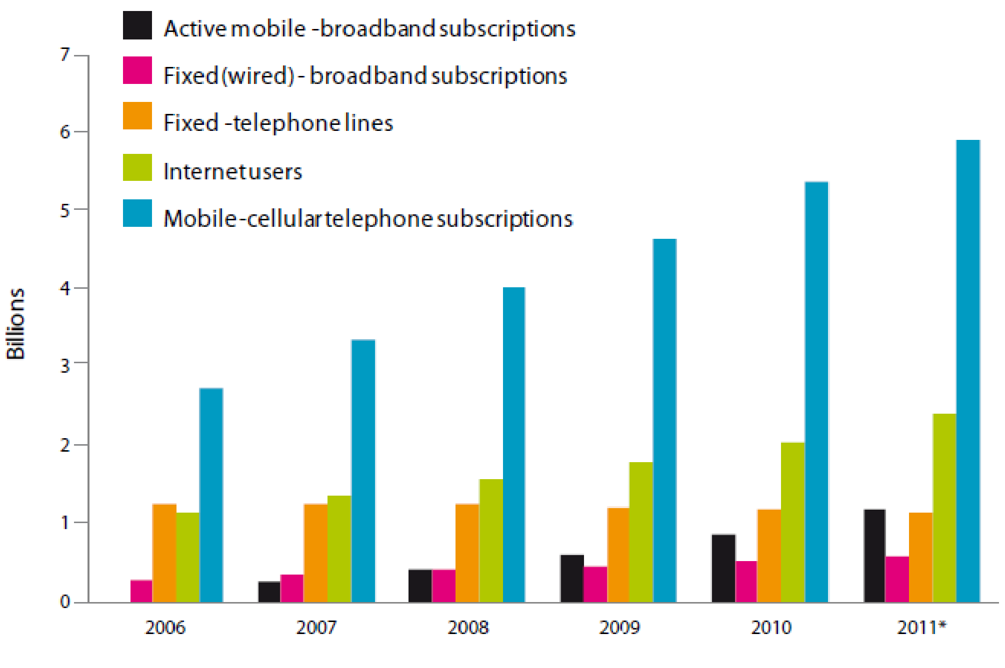
8.2 Market Trends

This section highlights some key global and local telecommunications and usage trends, and explores how they are changing the telecommunications landscape.

8.2.1 Telecommunications Trends

On 25 October 2011, on the occasion of the International Telecommunication Union (ITU) Telecom, ITU published[1] end 2011 estimates for ITU's key telecommunications/ICT indicators. The publication highlighted the latest global ICT facts and figures, charting the path for telecommunications trends of the future.

With 5.9 billion mobile subscriptions registered worldwide, global mobile penetration reached 87% and 79% in the developing world. This reflects dramatically on the declining fixed lines uptake, which, at 14%, is currently hovering around 1 billion lines worldwide (Figure 1).



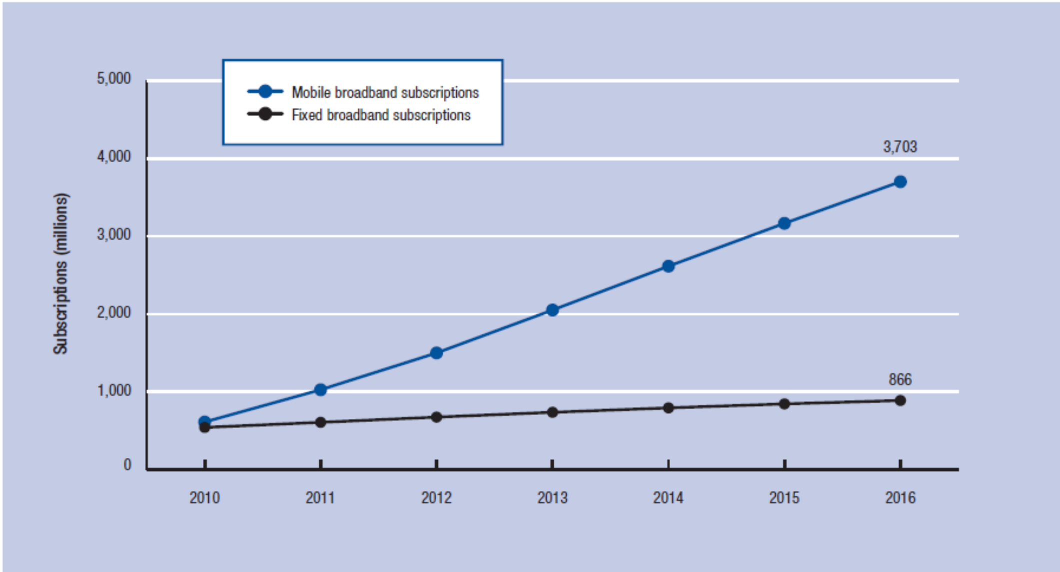
Note: * Estimate
Source: ITU World Telecommunication/ICT Indicators database

Figure 1: Global telecommunications subscriptions[1]

ITU also reported that mobile broadband subscriptions had grown 45% annually over the past four years. Today there are twice as many mobile broadband as fixed broadband subscriptions. The Global Information Technology Report[2], published by the World Economic Forum (WEF), projected that the number of mobile broadband subscriptions would hit 80%, exceeding that of fixed subscriptions by fourfold in 2016 (Figure 2).

[1] International Telecommunication Union. The World in 2011: ICT Facts and Figures. [Online] Available from: http://www.itu.int/ITU-D/ict/facts/2011/material/ICTFactsFigures2011.pdf [Accessed 9th July 2012].

[2] INSEAD. The Global Information Technology Report 2012: Living in a Hyperconnected World. [Online] Available from: http://www3.weforum.org/docs/Global_IT_Report_2012.pdf [Accessed 9th July 2012].



Sources: Industry analyst firm forecasts. For mobile broadband subscriptions: HSPA, EV-DO, TD-SCDMA, and LTE subscribers: Wireless Intelligence Database, February 2012; for WiMax: ABI Database, February 2012; for fixed broadband subscriptions: Informa Telecoms & Media (WBIS) Database, February 2012.
Note: Mobile broadband technologies include EV-DO, HSPA, TD-SCDMA, LTE, WiMax, and their respective evolutions.

Figure 2: Global broadband subscriptions: Mobile at 80% by 2016[2]

Figure 3 and Figure 4 illustrate the breakdown of worldwide subscriber numbers according to the broadband technologies used for both fixed and mobile access respectively.

In the fixed domain, Digital Subscriber Line (DSL) remained the most popular technology overall, with over 314.6 million subscribers (63.18%). Cable modem was next with 108.8 million users (20%) and fibre to the x (FTTx) was third with over 76 million subscribers (14%)[3].

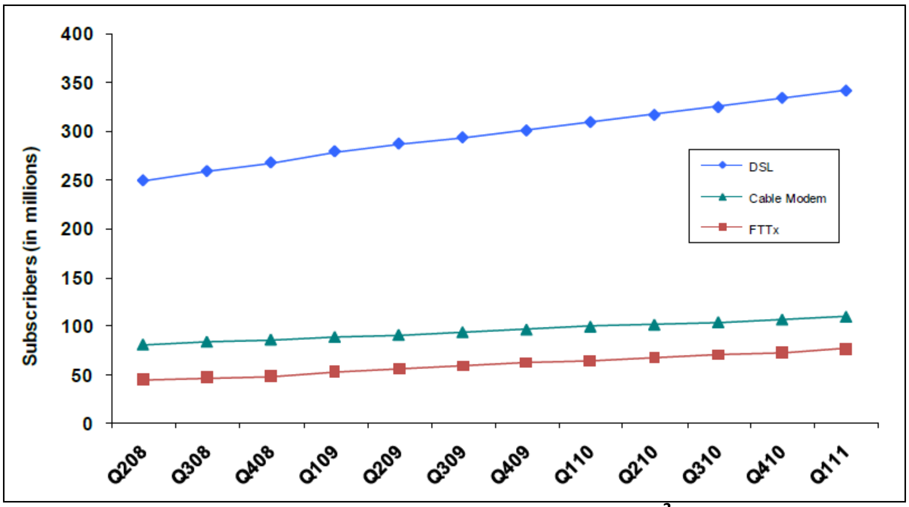


Figure 3: Technology trends in Q1 2011[3]

FTTx, a generic term for any broadband network architecture using optical fibre for last-mile telecommunications, is the most recent technology of the three but is often used for Next Generation Networks. This is also the most popular technology in Asia, with almost 31.8 million (41.71%) FTTx subscribers in Asia Pacific and 29.7 million (38.96%) in South and East Asia. These regions are home to some of the most technologically advanced countries in the world[3].

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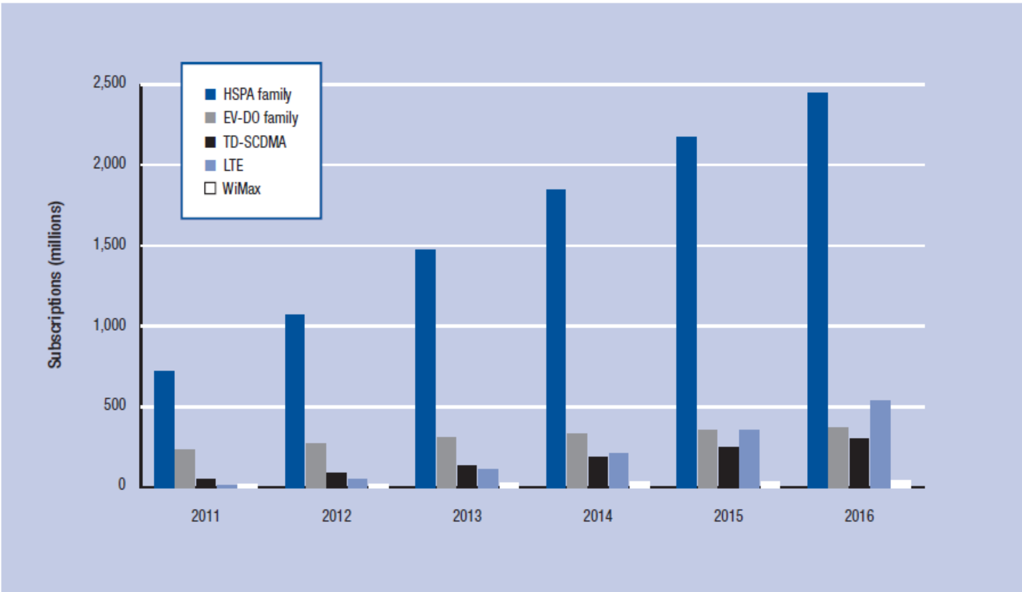
[3] Fiona Vanier. World Broadband Statistics: Q1 2011. [Online] Available from: http://point-topic.com/dslanalysis.php [Accessed 9th July 2012].

Asia Pacific was the only region whose DSL market experienced quarterly negative growth. This could be an indication that the key DSL markets in this region have reached saturation and are experiencing churn[4]. In addition, many of these countries could be looking to transfer their DSL subscribers to next generation services and as such, are no longer aggressively marketing these types of services[3].

In the mobile segment, a majority of mobile operators have launched 3G services while a significant number are launching 4G services. As of June 2012, more than 457 operators (100% of 3G operators) had launched commercial High Speed Packet Access (HSPA) networks, 270 had launched Evolution Data Optimised (EV-DO) networks, and 80 had launched Long Term Evolution (LTE) networks. The Global mobile Suppliers Association (GSA) forecast a total of 144 LTE networks in 59 countries that would be deployed by end 2012[5,6]. GSA also previously confirmed LTE as the fastest developing mobile system technology ever. Figure 4 shows the projection of mobile subscriptions across various technologies till 2016.



Sources: Subscriptions for HSPA, EV-DO, TD-SCDMA, and LTE technologies: Wireless Intelligence Database, February 2012; subscriptions for WiMax: ABI Database, February 2012.
Note: Mobile broadband subscriptions are expected to grow at approximately 29 percent CAGR from 2011 to 2016, led by 3G and its evolution.

Figure 4: Growth in mobile broadband subscriptions fuelled by 3G[2]

Singapore enjoys a registered mobile penetration of 150.4% and fixed line penetration of 38.9%[7]. As for Singapore mobile and fixed broadband penetration, they currently stand at 69.7% and 24.9% respectively (mobile surpass fixed by 2.8 times)[1].

Singapore launched its Next Gen Nationwide Broadband Network (NGNBN) back in July 2009 and is on track to achieve its target of 95% coverage by mid 2012. As of end January 2012, more than 86%

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[4] Churn rate refers to the annual percentage rate at which customers discontinue using a service, in particular cable and satellite television.

[5] CDMA Development Group. CDMA Statistics. [Online] Available from: http://www.cdg.org/resources/cdma_stats.asp [Accessed 9th July 2012].

[6] Global Mobile Suppliers Association. Fast Facts. [Online] Available from: http://www.gsacom.com/news/gsa_fastfacts.php4 [Accessed 9th July 2012].

[7] Infocomm Development Authority of Singapore. Statistics on Telecom Services for 2012 (Jan - Jun). [Online] Available from: http://www.ida.gov.sg/Publications/20120402113400.aspx [Accessed 9th July 2012].

nationwide deployment has been completed[8]. The NGNBN infrastructure will put Singapore on par with other global economic players. Singapore's DSL and cable market have reached saturation and are currently experiencing churn, as indicated by the declining subscription numbers[7]. This is most likely due to transfer of subscribers to NGNBN or mobile broadband.

8.2.2 Internet Trends

Any discussion about current telecommunication trends is never complete without addressing Internet trends. This world is now home to 7 billion people, of which one third of which are now using the Internet (Figure 5). Over the past five years, developing countries have increased their share of the world's total number of Internet users from 44% in 2006 to 62% in 2011. Today, Internet users in China represent almost 25% of the world's total Internet users and 37% of the developing countries' Internet users.

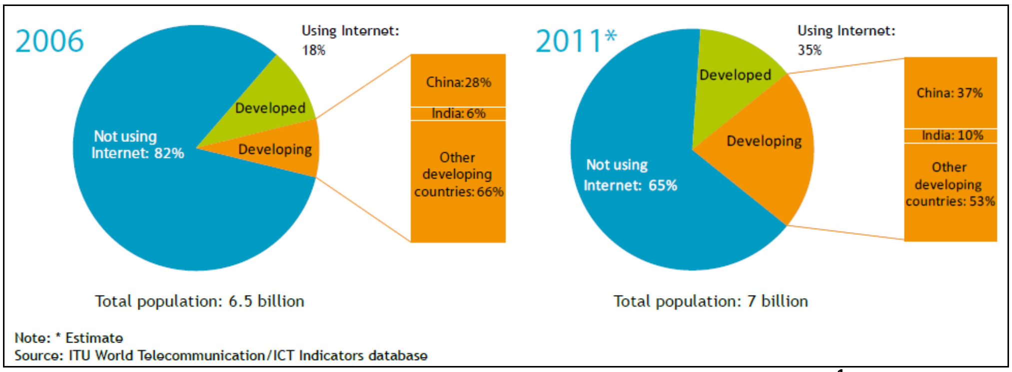


Figure 5: Share of Internet users in the total global population[1]

Today, 45% of the world's Internet users are below the age of 25. Younger people tend to be more online than older people. In developing countries, 30% of those under the age of 25 use the Internet, compared to 23% of those 25 years and older (Figure 6).

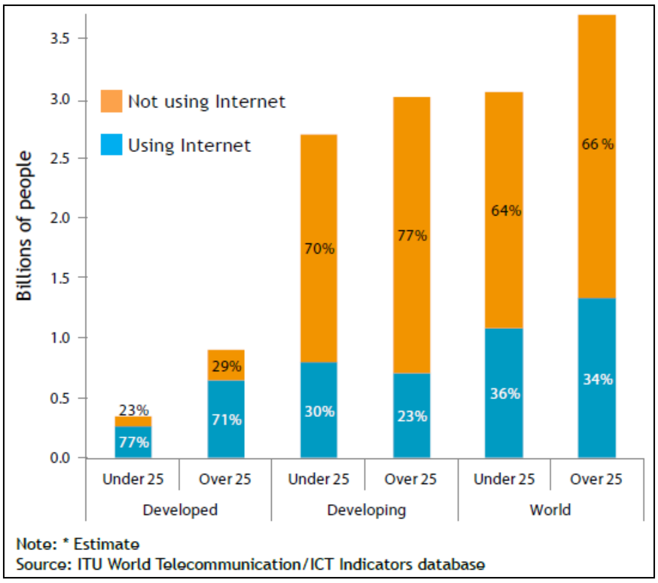
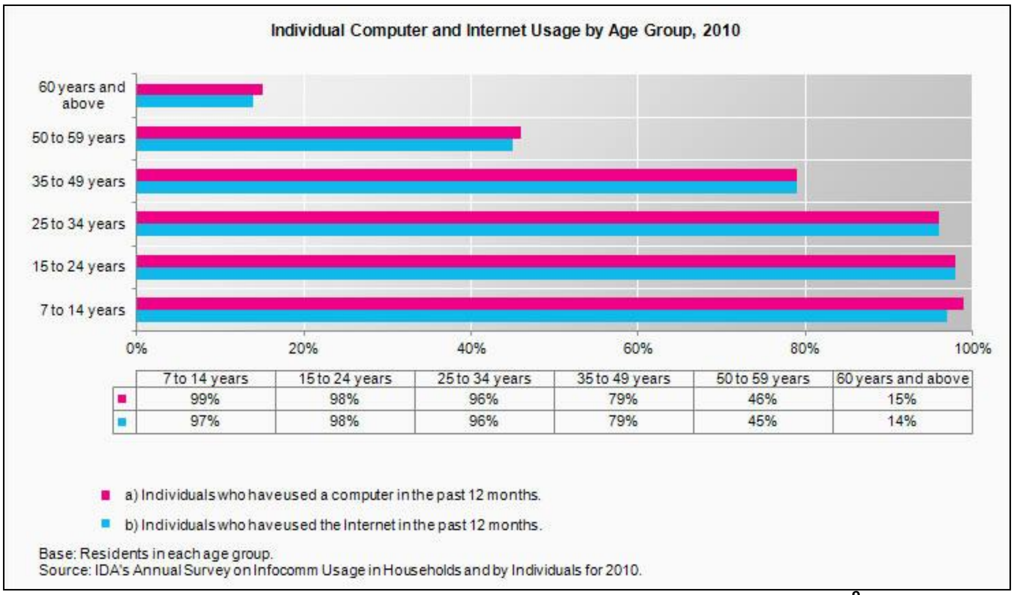


Figure 6: Estimate of global Internet users by age and by development level, 2011[1]

[8] Infocomm Development Authority of Singapore. Key Milestones. [Online] Available from: http://www.ida.gov.sg/infrastructure/20090731131156.aspx [Accessed 9th July 2012].

Singapore's Internet penetration rate has been hovering around the 70% mark for the past couple of years[9] and the demographic profile of these users (Figure 7) also exhibits features of a developed nation, as illustrated in the ITU report[1].



	7 to 14 years	15 to 24 years	25 to 34 years	35 to 49 years	50 to 59 years	60 years and above
a)	99%	98%	96%	79%	46%	15%
b)	97%	98%	96%	79%	45%	14%

Figure 7: IDA Survey On Individual Computer and Internet Usage[9]

8.2.3 International Internet Bandwidth Trends

International Internet bandwidth, a key factor in providing high-speed Internet access to a growing number of Internet users, has grown exponentially over the past five years, from 11'000 Gbit/s in 2006 to close to 80'000 Gbit/s in 2011 (Figure 8). However disparities between regions in terms of available Internet bandwidth per Internet user remain. According to ITU, on average almost 90'000 bit/s of bandwidth per user is provisioned in Europe compared with 2'000 bit/s per user in Africa[1].

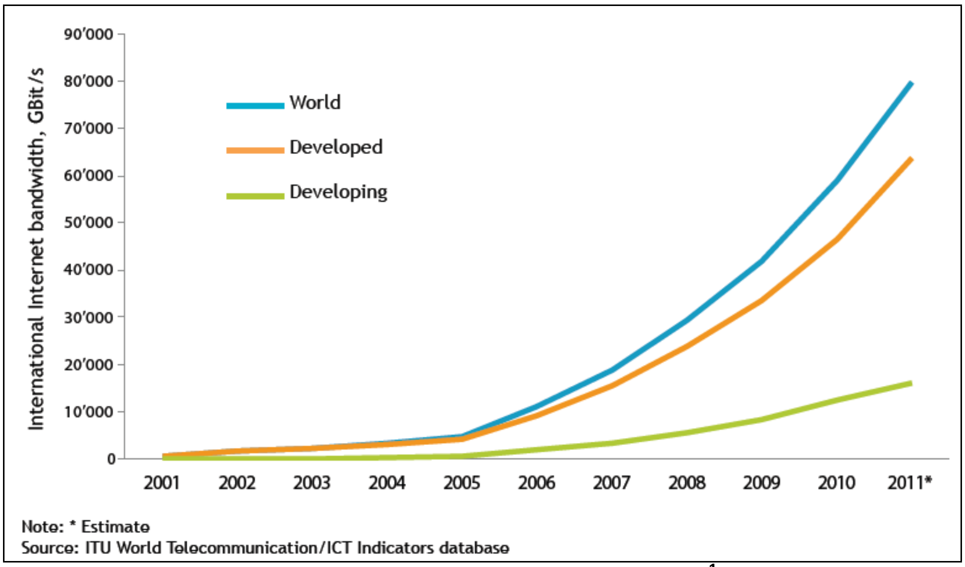


Figure 8: International Internet Bandwidth[1]

9 Infocomm Development Authority of Singapore. Infocomm Usage – Households and Individuals. [Online] Available from: http://www.ida.gov.sg/Publications/20070822125451.aspx [Accessed 9th July 2012].

To cope with the rise in Internet usage among domestic users, Singapore's total international Internet capacity (owned by operators licensed in Singapore to carry Internet traffic) also increased by almost 2.8 times over past two years[10].

8.2.4 Usage Trends

Several key ICT trends have been identified as the driving forces for the changes in the telecommunications landscape. In this section we highlight some key technological advancements which have enabled new capabilities and are, in turn, giving rise to new ICT trends.

8.2.4.1 Variety of Devices and Connections

The notion of mobile computing came about in the early 1990s when the appearance of full-function laptop computers and wireless local area networks (LANs) led researchers to confront the problems arising from building a distributed system with mobile clients. The field of mobile computing was thus born[11].

Today we have taken mobile computing almost for granted, applying it in almost every aspect of our lives, and thus driving ICT penetration ahead at a significant rate. This can be clearly demonstrated by the number of computing devices shipped over the years as illustrated in Figure 9.

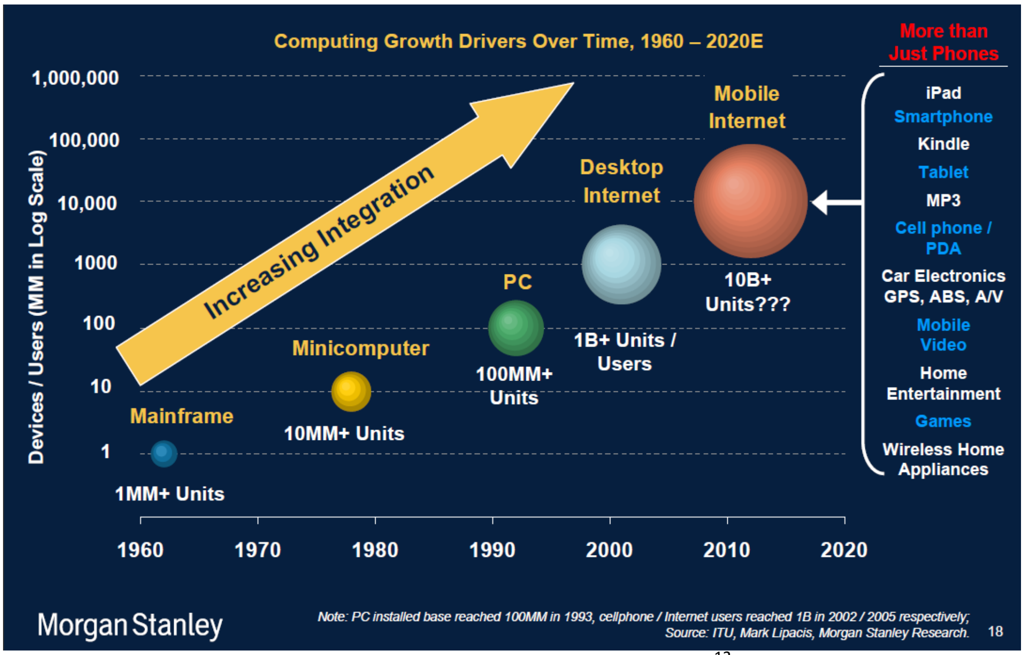


Figure 9: ICT device shipment numbers[12]

[10] Infocomm Development Authority of Singapore. Statistics on Capacity/Bandwidth Services. [Online] Available from: http://www.ida.gov.sg/Publications/20061207175622.aspx [Accessed 9th July 2012].

[11] IEEE. Pervasive Computing: Vision and Challenges. [Online] Available from: http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=943998&url=http%3A%2F%2Fieeexplore.ieee.org%2Fxpls%2Fabs_all.jsp%3Farnumber%3D943998 [Accessed 9th July 2012].

[12] Morgan Stanley. Internet Trends. [Online] Available from: http://www.morganstanley.com/institutional/techresearch/pdfs/Internet_Trends_041210.pdf [Accessed 9th July 2012].

2011 was a pivotal year for the mobile industry, marked by the dramatic rise of smartphones in the mainstream, the burgeoning of tablets and other Web-enabled connected devices. According to International Data Corporation (IDC), mobile devices have finally exceeded PCs in shipments and spending. Last year, unit shipments of both smartphones and media tablets exceeded PC shipments. This year, that gap will widen dramatically as 895 million of these mobile devices ship, compared with less than 400 million PCs. At least as important, 2012 will be the first year in which spending from these devices (US$277 billion) exceeds that for PCs (US$257 billion), growing at 23% - almost 5 times - PC spending growth[13].

The rapid adoption of smartphones, coupled with the growth of connected device usage, ushered in a period of expansion for mobile Internet use, introducing the shift in digital connectivity, away from the "classic" use on desktop and laptop computers to mobile platforms. According to a survey[14] conducted by Pew Internet Project, just over a third of American adults own a smartphone of some kind, with many preferring to use it as their primary connection to the Internet.

By December 2011, mobile and connected devices were driving approximately 11.5% of observed Internet traffic in Singapore. Mobile phones drove the majority of the wireless data traffic while tablets grew in significance as a channel of delivery, accounting for nearly one-third of Internet traffic (Figure 10)[15].

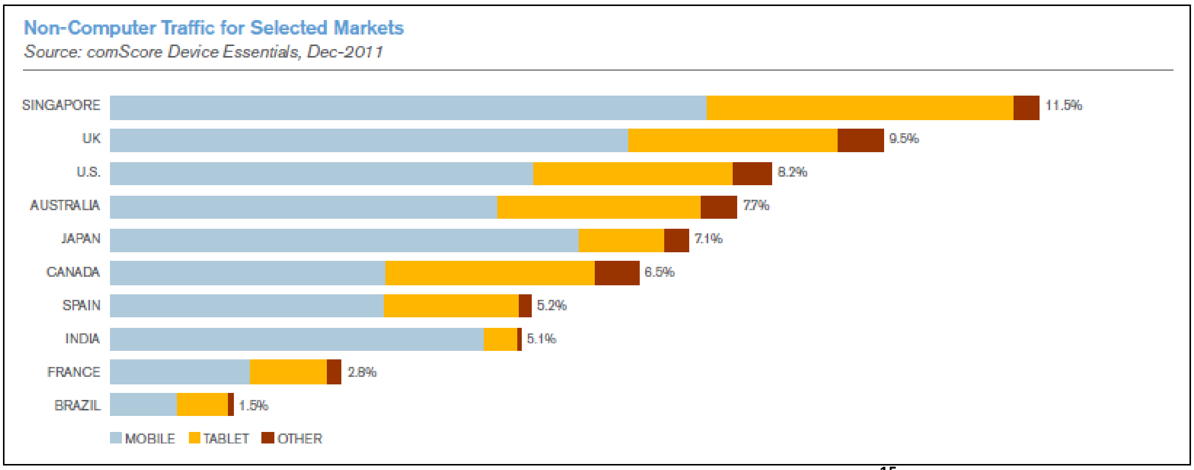


Figure 10: Non-Computer Traffic for Selected Markets[15]

These connected devices are designed to be portable and typically access data content on the Internet via WiFi or mobile data networks. Ericsson's latest market report (Figure 11) highlighted the spread of different kinds of Internet connectivity for mobile PCs and tablets. An online survey conducted by Blackbox, an independent research company based in Singapore, also shows similar connection behaviour among local users. On the average, 45% of network connectivity on smartphones takes place via WiFi[16].

[13] IDC. IDC Predictions 2012 : Competing for 2020. [Online] Available from: http://cdn.idc.com/research/Predictions12/Main/downloads/IDCTOP10Predictions2012.pdf [Accessed 9th July 2012].

[14] Pew Research Center. Smartphone Adoption and Usage. [Online] Available from: http://pewinternet.org/Reports/2011/Smartphones.aspx [Accessed 9th July 2012].

[15] ComScore. 2012 Mobile Future In Focus. [Online] Available from: http://www.comscore.com/Press_Events/Presentations_Whitepapers/2012/2012_Mobile_Future_in_Focus [Accessed 9th July 2012].

[16] Blackbox Research Pte Ltd. Smartphones in Singapore: A Whitepaper Release. [Online] Available from: http://www.blackbox.com.sg/wp/wp-content/uploads/2012/05/Blackbox-YKA-Whitepaper-Smartphones.pdf [Accessed 9th July 2012].

Today, the convergence of device networking, machine-to-machine (M2M) communication, and the Internet has brought the world several steps closer to the vision of a "smart world", consisting of an "Internet of things (IOT)", enabled by an intelligent infrastructure linking objects, processes, information, and people. There is an increasing use of comparatively low-connected-rate but ubiquitous, mostly wireless, systems that play a vital role in our digital present and future. These range from Radio Frequency Identification (RFID) tags, smart cards and wireless controllers that are networked through sensor systems. This new wave of M2M communications will enable the growth of IOT. Analysts predict that there will be 25 billion connected IP devices by 2015, with M2M traffic expected to grow by 258% and the managed mobile M2M services market to be worth US$20 billion by 2014[17].

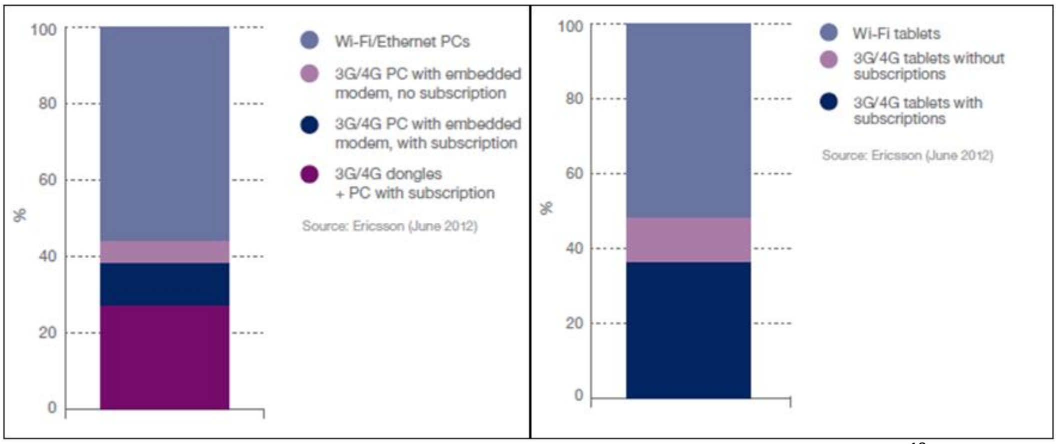


Figure 11: Mobile PCs and tablets with their share of subscriptions 2012[18]

8.2.4.2 Mobility-Enabled Applications

The connected devices revolution has brought about a new wave of mobility-enabled applications. This is evident from various developments within the ICT ecosystem.

Mobile media usage – defined as browsing the mobile Web, accessing applications, or downloading content – saw a surge in activity and surpassed 50% penetration in many markets. This is supported by the proliferation of high-speed networks and increased public WiFi availability. Cisco's Visual Networking Index (VNI) Mobile report even predicted that mobile video would generate over 70% of mobile traffic by 2016[19] (Figure 12).

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[17] Steve Wexler. Cisco Jumps into The M2M Market. [Online] Available from: http://www.networkcomputing.com/wireless/231600077 [Accessed 9th July 2012].

[18] Ericsson. Traffic and Market Report. [Online] Available from: http://www.ericsson.com/res/docs/2012/traffic_and_market_report_june_2012.pdf [Accessed 9th July 2012].

[19] Cisco. Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2011–2016. [Online] Available from: http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html [Accessed 9th July 2012].

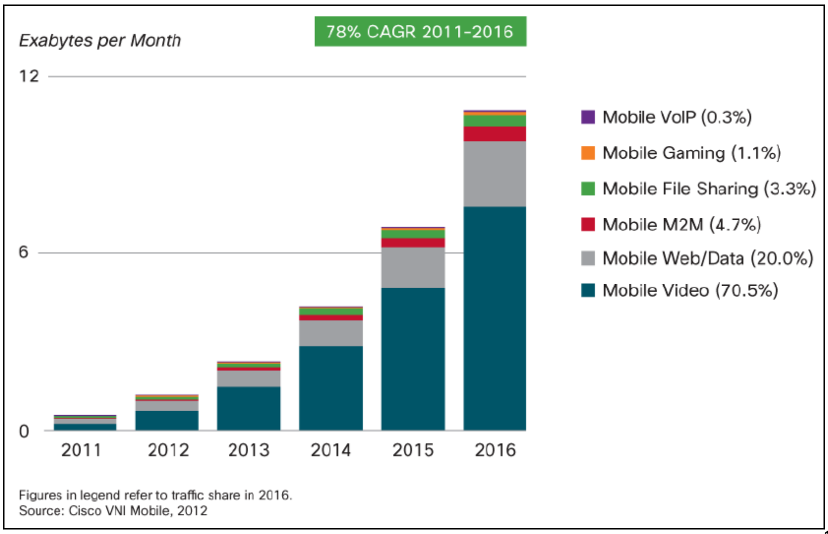

Figure 12: Mobile video will generate over 70% of mobile data traffic by 2016[19]

Along with the growth in smartphone adoption, investment in mobile applications by publishers has fuelled increasing app usage among total mobile users. Mobile app downloads are forecast to soar from 10.7 billion in 2010 to 182.7 billion in 2015, according to a new forecast from IDC[20]. Both Apple and Google are each seeing 1 billion apps downloaded per month and Apple has already had 14 billion cumulative apps downloaded since the App Store opened.

Mobile devices also fuel social networking on the go, driving real-time online interaction. With the means to connect on-the-go, mobile users have not only adopted real-time social networking on their devices at a growing rate but they are doing so with increasing frequency. The on-the-go and constantly connected usage trend is clearly shown in Discover Mobile Life[21] by TNS as shown in Figure 13. The graph presents a snapshot of current mobile-related activity levels across different time zones of the day.

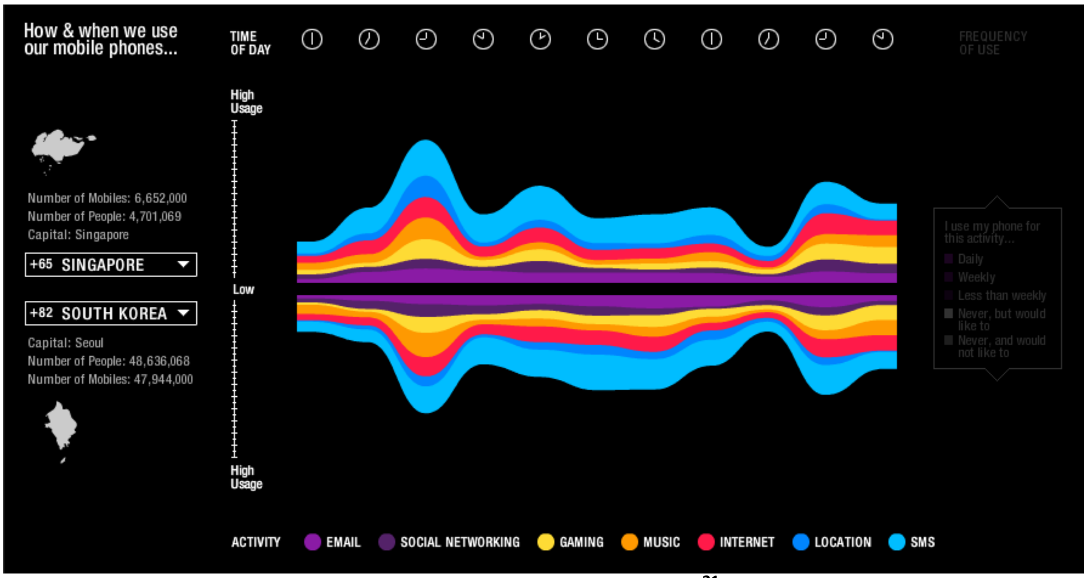

Figure 13: Discover Mobile Life[21]

[20] IDC. IDC Forecasts Nearly 183 Billion Annual Mobile App Downloads by 2015: Monetization Challenges Driving Business Model Evolution. [Online] Available from: http://www.idc.com/getdoc.jsp?containerId=prUS22917111 [Accessed 9th July 2012].

[21] TNS. Discover Mobile Life. [Online] Available from: http://discovermobilelife.com/ [Accessed 9th July 2012].

IDC believes the advancement in M2M and convergence in ICT services will lead to the next wave of computing evolution known as context-aware services. This is a new computing paradigm that describes services which utilise contextual information to predict and act on behalf of, or in accordance with, a user's profile and predetermined requirements.

8.2.4.3 Variety of Services and Content Types

Our ever-increasing reliance and constant connectivity to the Internet has given rise to many opportunities. The open Internet has spurred innovation and given rise to a whole new category of service providers, collectively known as Over-The-Top (OTT) players. who innovate on their product and business models, delivering freemium or paid offerings via the Internet. A major fixed access Internet Service Provider (ISP) in North America has identified OTT providers as a significant segment accounting for 60% real-time traffic plying through their network in a Sandvine report[22].

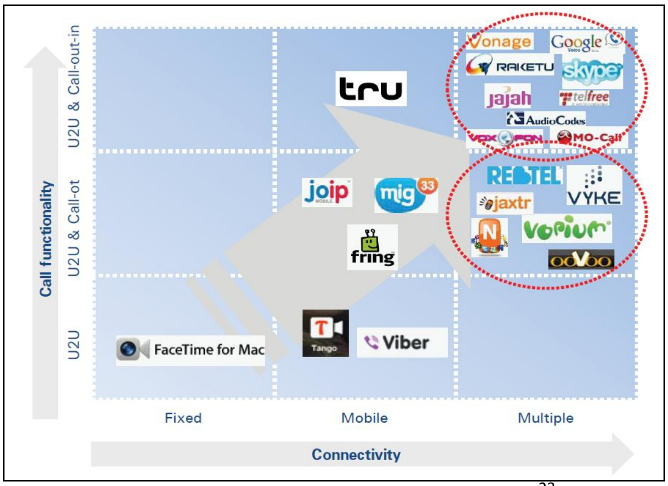

Figure 14: Landscape view of voice OTT[23]

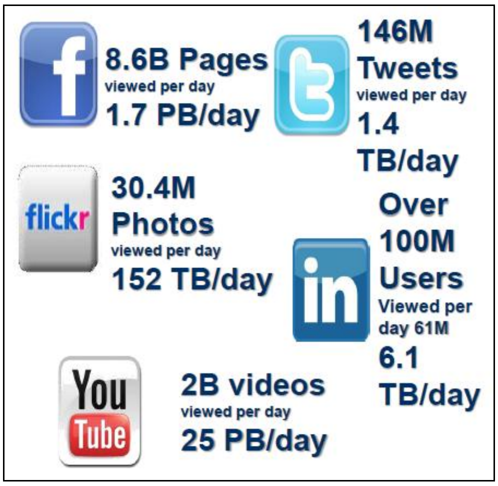

Figure 15: Example of popular social driven applications[24]

These OTT players come in many forms and compete aggressively on multiple fronts with traditional telcos or ISPs. One example is a group of voice OTT players that have adopted Session Initiation Protocol (SIP) to deliver voice services over an Internet connection. Figure 14 presents a landscape view of some of these voice OTT players.

Social media is the next new category of content that has generated interest. Social media also takes on many forms in terms of text, pictures and even videos. The volume of traffic generated by these platforms is also very significant. Figure 15 highlights some examples of popular social media-driven applications and the corresponding amount of data generated per day.

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22 Sandvine. Global Internet Phenomena Report, Fall 2011. [Online] Available from: http://www.sandvine.com/downloads/documents/10-26-2011_phenomena/Sandvine%20Global%20Internet%20Phenomena%20Report%20-%20Fall%202011.PDF [Accessed 9th July 2012].

23 Arthur D. Little Analysis. Disruptive Threat or Innovative Opportunity? [Online] Available from: http://www.adlittle.com/downloads/tx_adlreports/ADL_OTT_Disruptive_threat_or_innovative_opportunity_v2_01.pdf [Assessed 9th July 2012].

24 IDC. The Next Generation of Computing: Intelligent Systems. [Online] Available from: http://www.idc.com/getdoc.jsp?containerId=234027 [Assessed 9th July 2012].

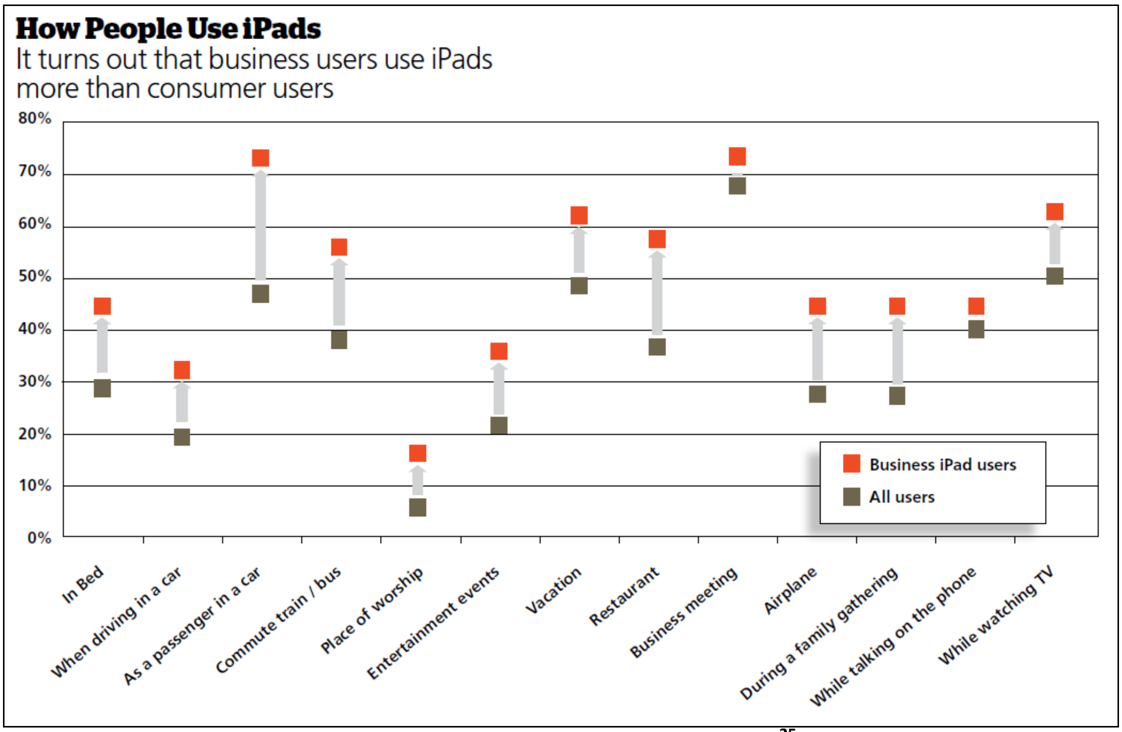

Figure 16: Results of survey on iPad usage[25]

As we become accustomed to these more portable and user-friendly devices, we enter the era of 'Bring Your Own Device' (BYOD) where such consumer ICT devices are brought into enterprise environments for daily work. BYOD reflects the increasing enterprise adoption of the use of personally-owned devices, and simultaneously the use of social media, through these devices, for business usage. In May 2011, IDC conducted the "Consumerization of IT Study" and found that employees owned 40% of the devices used to access business applications, compared to 30% in 2010[25]. The study also provided clear evidence of how and where the iPad was used for both personal and business purposes (Figure 16).

Businesses have long valued the notion of empowering its workforce with up-to-date information to make timely business decisions without compromising security. This has always been the value proposition of traditional enterprise-centric solutions such as Blackberry. Advancements in consumer device capabilities have now enabled a granularity of security similar to that of traditional enterprise solutions. This has further extended mobility solutions to a much wider audience.

8.3 Implications for our Infrastructure and Resources

In the previous sections we have highlighted a cultural shift toward cross-platform, digital media consumption fuelled by the availability of devices and various network connections. Data traffic generated by these connected devices will take centre stage in years to come. With mobility becoming an increasing part of our digital landscape, it becomes more important than ever to understand how current trends are shaping the future environment.

[25] IDC. 2011 Consumerization of IT Study: Closing the "Consumerization Gap" sponsored by Unisys, July 2011. [Online] Available from: http://www.unisys.com/unisys/ri/report/detail.jsp?id=1120000970016710178 [Accessed 9th July 2012].

The proliferation of high-end handsets, tablets, and laptops on WiFi and mobile networks is a major generator of traffic. These devices offer consumers content and applications not supported by previous generations of mobile devices. As shown in **Error! Reference source not found.**, a single smartphone can generate as much traffic as 35 basic-feature phones, a tablet as much traffic as 121 basic-feature phones, and a single laptop as much traffic as 498 basic-feature phones[19].

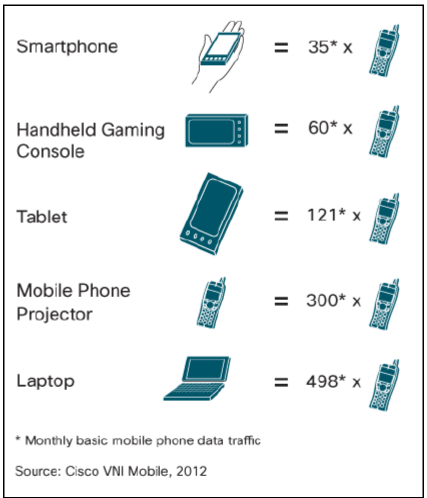

Figure 17: High-End Devices Significantly Multiply Traffic[19]

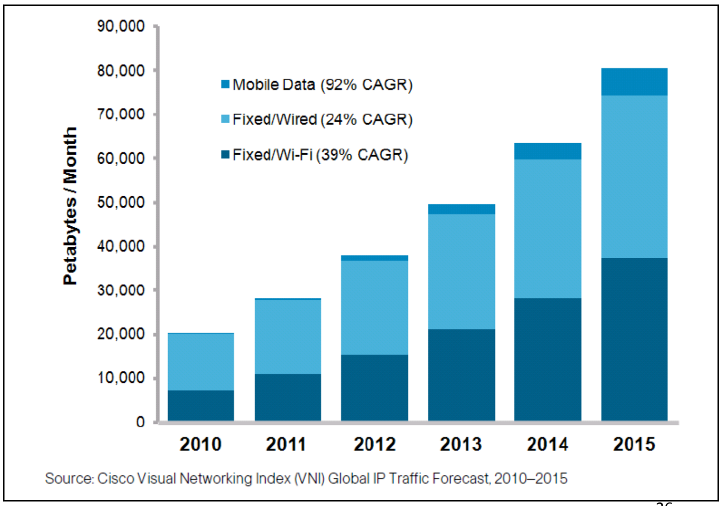

Figure 18: Projected Global IP Traffic by Access Network[26]

Cisco VNI predicts that by 2015, WiFi traffic will represent 46% of total Internet Protocol (IP) traffic while mobile data will still constitute only 8% (Figure 18). This clearly indicates that our access networks, especially WiFi and mobile networks, will be further strained to satisfy our hunger for more content.

Our mobile networks will need to go through a technology "refresh" to bring in new technologies that deliver much higher network throughput and lower latency. For licensed spectrum use, heterogeneous networks will be a key feature of our future mobile infrastructure.

As spectrum is a scarce resource, WiFi, which utilises unlicensed spectrum, has already been gaining interest in recent years and might continue to play a significant role in the near future. We would expect the industry to take more interest in exploring newer wireless technologies to further drive mobility.

The content consumed by these connected devices is typically hosted online on the Internet. This demand is also changing our core networks and data centres. In order to cope with the scale and elastic demand, cloud-based infrastructure is being deployed as it is more cost-efficient and has the flexibility to scale on demand, depending on business needs.

8.4 Challenges

Services and applications have always been the driving wheel for the development of new technologies in both wired and wireless networks. Requirements for fast and reliable Internet access

[26] Cisco. A New Chapter for Mobile? [Online] Available from: http://www.cisco.com/web/about/ac79/docs/sp/New-Chapter-for-Mobile.pdf [Accessed 9th July].

connections and high data rates for wired networks have led to small home and office-initiated development of Asymmetric Digital Subscriber Line (ADSL), wireless, optical, and hybrid versions of access networks. Similarly, the demand for fast connections and high data rates for mobility have initiated the development of 3G, HSPA, LTE and finally, 4G networks in recent years.

Looking ahead, we expect the increasing demand for bandwidth-hungry services such as high-definition TV (HDTV) and access to data files of rapidly increasing size to continue. As increasing network speed rates are made available from fixed networks, users who are used to cross-platform digital media consumption will expect wireless to match. This is especially evident in the industry's push for converged broadband services offering "triple-play" services for users in any environment. Multiple networks with different technologies and access protocols need to work with each other to provide a platform catering to a wide range of services and applications in a heterogeneous configuration. Networking all these technologies requires sophisticated topologies, protocols and management techniques to achieve the best out of the collective capabilities of the available technologies.

These developments pose a number of challenges for our communication networks:

- Maintaining good Quality of Service (QoS) to ensure good user experience in a mixed traffic environment;
- Coping with new and heterogeneous system architectures to deliver the same service and user experience;
- Efficient resource management in a converged multi-service network environment;
- Good user profile management across heterogeneous systems.

8.5 Technology Trends

8.5.1 Wireless Infrastructure - Licensed spectrum

8.5.1.1 New Mobile Capabilities: Higher Speed Wireless Systems – LTE (2-4 years)

The 3rd Generation Partnership Project (3GPP)[27] body began its initial investigation of the LTE standard as a viable technology in 2004. In March 2005, 3GPP embarked on a a feasibility study whose key goals were to agree on network architecture and a multiple access method, in terms of the functional split between the radio access and the core network. The study concluded in September 2006 when 3GPP finalised selection of the multiple access and basic radio access network architecture. 3GPP decided to use Orthogonal Frequency Division Multiple Access (OFDMA) in the downlink direction and use Single Carrier Frequency Division Multiple Access (SC-FDMA) in the uplink direction. The specification for the LTE Release 8 was approved by the 3GPP body in late 2008.

Once fully deployed, LTE technology offers a number of distinct advantages over other wireless technologies. These advantages include increased performance attributes such as high peak data rates and low latency, and greater efficiencies in using the wireless spectrum. Improved performance and increased spectral efficiency will allow wireless carriers using LTE as their 4G technology to offer higher quality services and products to their customers. Figure 19 provides a quick glance at LTE's technical specifications and attributes.

Peak performance downlink	Power-efficient uplink	Scalable and compatible with 3G networks	Flat all-IP architecture for performance and efficiency
• Efficiency OFDM/OFDMA in the downlink – Spectral efficiency (2-5 times, Rel.6) – Resistant to multi-path interference • MIMO antennas – Doubles the throughput – Deployment simplicity	• SC-FDMA – Lower peak-to-average ratio – Longer mobile battery life – Larger cell coverage • Collaborative (multi-user or virtual) MIMO – Simplifies mobile implementation – Increases uplink capacity	• Scalable spectrum allocation (1.4, 3, 5, 10, 15, 20 MHz) – Great for in-band deployment • Mobility with 3GPP and non-3GPP access – Smooth network migration to LTE and beyond • Global roaming with other 3GPP networks	• High performance network – Efficient IP routing reduces latency – Increased throughput – Fast state transition time (enhanced always-on) – Less than 50 ms transition from dormant to active

Figure 19: A summary of LTE capabilities[28]

Operators are in the process of deploying LTE. However LTE devices are still quite limited in the marketplace. Currently, the spectrum allocation for LTE deployment is still quite fragmented. Large-scale deployment with full interoperability and harmonised spectrum for effective worldwide roaming will be expected to take centre stage in the coming years as chipset developers put multiband chipsets in place.

[27] The 3GPP unites 6 telecommunications standards bodies (ARIB, ATIS, CCSA, ETSI, TTA and TTC), known as "Organizational Partners"and provides their members with a stable environment to produce the highly successful Reports and Specifications that define 3GPP technologies.

[28] Verizon. LTE: The Future of Mobile Broadband Technology. [Online] Available from: http://opennetwork.verizonwireless.com/pdfs/VZW_LTE_White_Paper_12-10.pdf [Accessed 9th July 2012].

8.5.1.2 New Mobile Capabilities: Small Cell Wireless Systems (2-5 years)

Increase mobile data usage is transforming the design of networks from coverage constraint to capacity constraint (Figure 20). To relieve the network loading constraints, smaller cells are required. This demand drives the development of smaller cells.

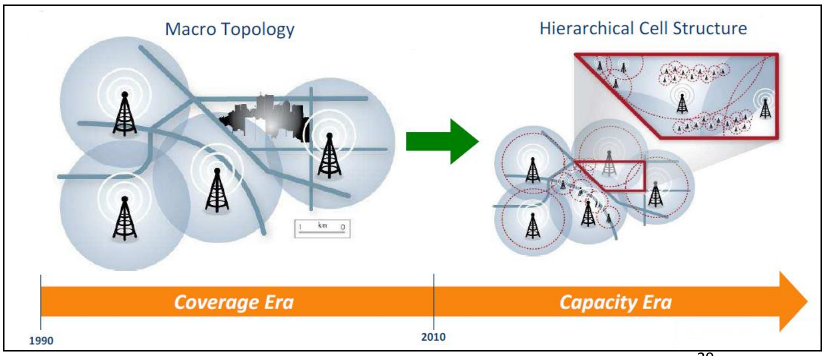

Figure 20: From coverage to capacity constraint networks[29]

Another development is the femtocell. Femtocells are a new tool that wireless carriers can use to supplement traditional network upgrades. Femtocells benefit wireless carriers as they improve coverage and offload the wireless macro-cells network. The test results of the current femtocells on the market reveal that femtocells can greatly improve coverage and the data throughput of mobile devices. While the performance of femtocells is impressive, some technical issues such as handoffs and restricted access still need to be resolved. The deployment motivation (**Error! Reference source not found.**) might be different for each operator; hence, these drivers might lead to variance in the model and rate of deployment.

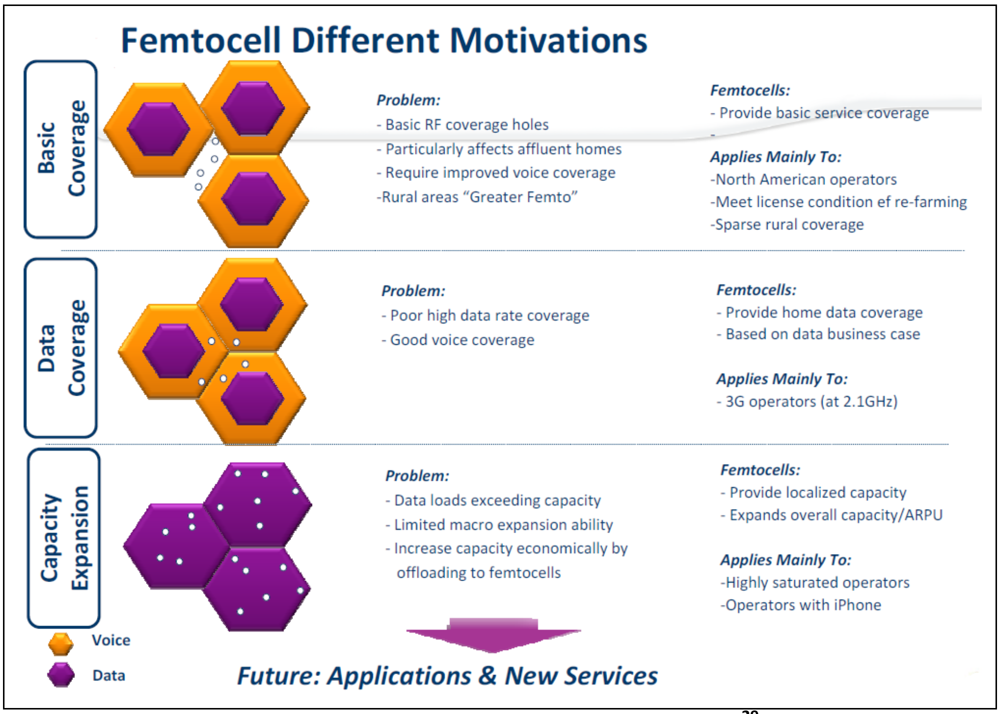

Figure 21: Motivations for femtocell deployments[29]

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29 Picochip. The disruptive future of femtocells. [Online] Available from: http://www.ict-befemto.eu/fileadmin/documents/publications/workshop_2011/Future_networks_June_2011.pdf [Assessed 9th July 2012].

Also LTE might also take on the femtocell deployment model to take on more demand as shown in Figure 22.

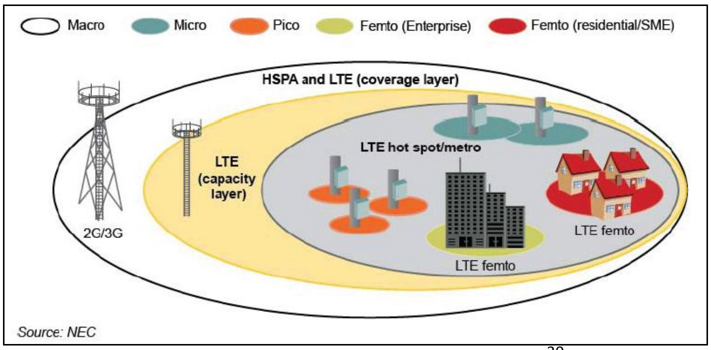

Figure 22: Small-cell architecture for LTE[30]

8.5.1.3 New Mobile Capabilities: Next Generation 4G Wireless Systems – LTE-A (>5 years)

The LTE-Advance, more commonly known as LTE-A, is the next generation 4G technology for the future. Our mobile networks will evolve along the scheme in the following 3GPP technology roadmap (Figure 23).

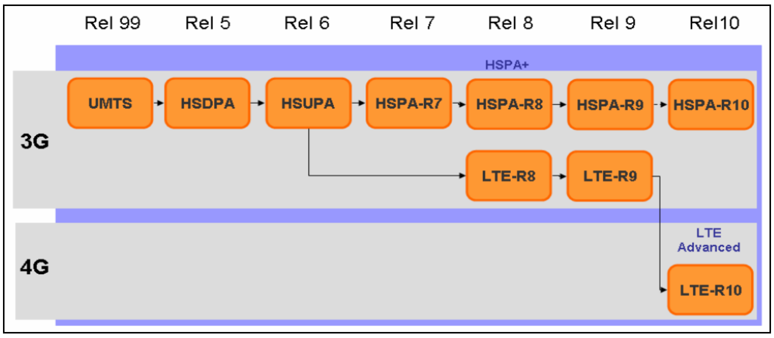

Figure 23: 3GPP Evolution Roadmap

LTE-A technical capabilities will inch us forward to the International Mobile Telecommunications-Advanced (IMT-Advanced) requirements target, shown below in Figure 24.

Item	Subcategory	LTE (3.9G) target [9]	LTE-Advanced (4G) target [10]	IMT-Advanced (4G) target [11]
Peak spectral efficiency (b/s/Hz)	Downlink	16.3 (4x4 MIMO)	30 (up to 8x8 MIMO)	15 (4x4 MIMO)
	Uplink	4.32 (64 QAM SISO)	15 (up to 4x4 MIMO)	6.75 (2x4 MIMO)
Downlink cell spectral efficiency (b/s/Hz), 3 km/h, 500 m ISD	2x2 MIMO	1.69	2.4	
	4.2 MIMO	1.87	2.6	2.6
	4x4 MIMO	2.67	3.7	
Downlink cell-edge user spectral efficiency (b/s/Hz) 5 percentile, 10 users, 500 m ISD	2x2 MIMO	0.05	0.07	
	4x2 MIMO	0.06	0.09	0.075
	4x4 MIMO	0.08	0.12	

**Note: ISD = Inter-site distance*

Figure 24: Performance targets for LTE, Advanced-LTE and IMT-Advanced

30 NEC. Future Mobile Networks. [Online] Available from: http://www.informatandm.com/wp-content/uploads/2011/05/Future-Mobile-Networks-Sample.pdf [Assessed 9th July 2012].

8.5.2 Wireless Infrastructure - Unlicensed Spectrum

8.5.2.1 WiFi, Next Generation Hotspot and Hotspot 2.0/Passpoint (2-3 years)

Due to the prevalence of Bring Your Own Device (BYOD) and mobility, WiFi is expected to take centre stage in the coming years in the enterprise environment. For existing WiFi deployments, we would expecting a technology refresh to the 802.11n-based infrastructure.

In the context of operator-owned infrastructure, some providers are exploring a more seamless mobile data offloading mechanism onto WiFi to give a better user experience. This can be achieved by implementing a Subscriber Identification Module (SIM)-based, Extensible Authentication Protocol (EAP)-SIM/Authentication and Key Agreement (AKA) authentication to bridge users across mobile and WiFi networks.

IEEE proposed a new 802.11u standard for WiFi to address network discovery and selection. This allows your WiFi-enabled device to find, automatically select and connect to your preferred WiFi networks. So this standard works by letting your device automatically scan for networks, find out details about the networks, and based on a set of policies set by you or your provider, prioritise the network that it connects to. 802.11U, together with SIM-based, EAP-SIM/AKA authentication, has become the foundation of the next generation hotspot, commonly known as Hotspot 2.0 or Passpoint.

Hotspot 2.0/Passpoint and Next Generation Hotspot (NGH) are highly complementary initiatives but they are different in scope. Hotspot 2.0/Passpoint is the WiFi Alliance’s certification program that will include a technical specification defining the Hotspot 2.0/Passpoint technology. Following the WiFi Alliance’s core purpose, Hotspot 2.0/Passpoint will also be a device certification, based on product interoperability testing, that allows vendors to implement the protocols in a common way.

However the WBA’s mission for NGH is targeted at the whole scope of functionality and interoperability, including interoperability between network operators and service providers on the back-end. In 2011, the Wireless Broadband Alliance (WBA) conducted NGH trials, which are real-world functionality tests using equipment from the participating vendors. WiFi client and infrastructure participants were required to first pass the WiFi Alliance’s Hotspot 2.0/Passpoint test events. In the NGH trials, the approved Hotspot 2.0/Passpoint devices were tested with the various back-end systems and architectures. NGH trials included testing for different authentication setups, including direct authentication with the owner operator (e.g., SingTel SIM on SingTel networks), authentication through third-party hubs (e.g., using a third party’s authentication, authorisation and accounting (AAA) proxy to an operator’s servers), and through visited network operators (e.g., Singtel SIM on Starhub networks).

8.5.2.2 Next Generation Higher Speed WiFi (3-5 years)

Figure 25 shows the evolution of generation of Wi-Fi standards. Wi-Fi Alliance and WiGig Alliances have agreed to cooperate on the next generation Wi-Fi technology for networking in the 60 GHz band. The 60 GHz band, also known as a millimetre band for its wavelength, can allow up to 7 Gbps in short-range data transmission in the USA and many other countries, with multiple channel configurations allowed to operate in the same space. The short wavelength means short propagation, mostly in room. The IEEE has a 60 GHz task group (802.11ad) that is paired with the 5 GHz band 1 Gbps group (802.11ac) as part of two separate moves forward to faster Wireless Local

Area Networks (WLANs). The Wi-Fi Alliance would likely certify specific characteristics of 802.11ad for 60 GHz.

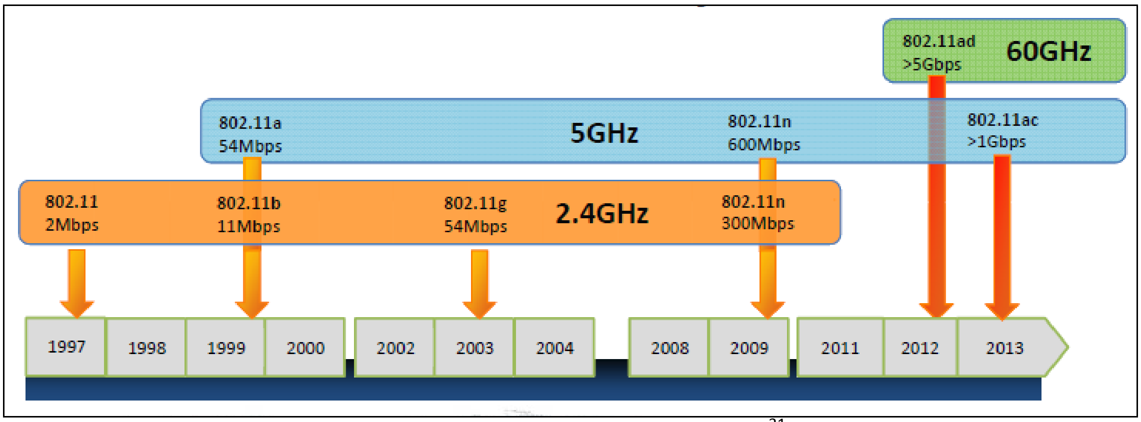

Figure 25: WiFi standards are evolving[31]

Broadcom said that products using the next-generation IEEE 802.11ac wireless technology would ship near the end of 2012, providing a roadmap to wireless technology above 1 Gbit/s[32].

8.5.2.3 TV Whitespace (TVWS) and Related Technologies (4-6 years)

To support the continuing growth of data traffic on mobile networks and offset the increasing strain all this traffic is placing on those networks, the US Federal Communications Commission (FCC) has made unused wireless TV spectrum (commonly referred to as “white spaces”) available for open, free and unlicensed use. TVWS relates to parts of the television broadcast radio spectrum which, in a given location or any given time, remains unused for broadcast television. This creates opportunities for the alternative use of such pockets of spectrum.

The TVWS spectrum is large and in the same prime range (50MHz-698MHz) as the 700 MHz spectrum that was auctioned to operators by the FCC for US$20 Billion in March 2008. Google views TVWS as “Wi-Fi on steroids” and, although it is difficult to attribute value to regulatory mandates, Microsoft estimates that the market is worth US$100 billion in equipment and application revenues.

As a result of the confluence of market trends, recent regulatory events and the strong demand for new wireless services, the TVWS wireless equipment market should see, in the not-too-distant future, increased volumes, pricing pressures, and rapid technological obsolescence similar to the Wi-Fi market. However, unlike the Wi-Fi market, the TVWS market will most likely expand the need for supplier expertise and services for new equipment support, distribution methodology, and customer billing and payment systems.

The free, unlicensed TVWS spectrum ranges from 50MHz to 698MHz and has extremely good propagation characteristics. White space radios will reach much further than current 3G/4G and Wi-Fi radios in the higher gigahertz bands and make this spectrum attractive for providing high bandwidth coverage at low costs. At the moment, (IEEE is creating 802.11af standard extensions for

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31 Xirrus, Inc. Cited by BICSI. The Changing Role of Wi-Fi – Are You Ready for the Wireless Explosion? [Online] Available from: http://www.bicsi.org/uploadedfiles/BICSI_Conferences/Canada/2012/presentations/GS_MON_6.pdf [Accessed 9th July 2012].

32 Mark Hachman. Broadcom Aims 802.11ac Gigabit Wireless at End of 2012. [Online] Available from: http://www.pcmag.com/article2/0,2817,2397420,00.asp [Accessed 9th July 2012].

Wi-Fi mobile white spaces use. Generally technologies operating in TVWS take on two basic classes of implementation:

1) Cognitive Radio utilises radio technology that is able to sense the environment and configure itself. The technology is heavily dependent upon Software Defined Radio (SDR) technology. ETSI's standards SDR Architecture Baseline will be finalised before 2015. A flexible control and signal processing environment with agile RF front-end and antennae will be available within a few years. However for TVWS, typically a fixed frequency range (e.g., UK's 470-790 MHz) should serve the purpose instead of having a fully flexible SDR.

Lack of spectrum drives the development of cognitive radio capabilities required in a majority of technologies. Global bands for cognitive radios have been identified and standards for some technologies exist. Devices with cognitive radio capabilities are available on the market. These solutions are band-specific, fixed RF-front ends which limit true implementation of cognitive radios. Figure 26 below shows the research roadmap direction for Carnegie Mellon University.

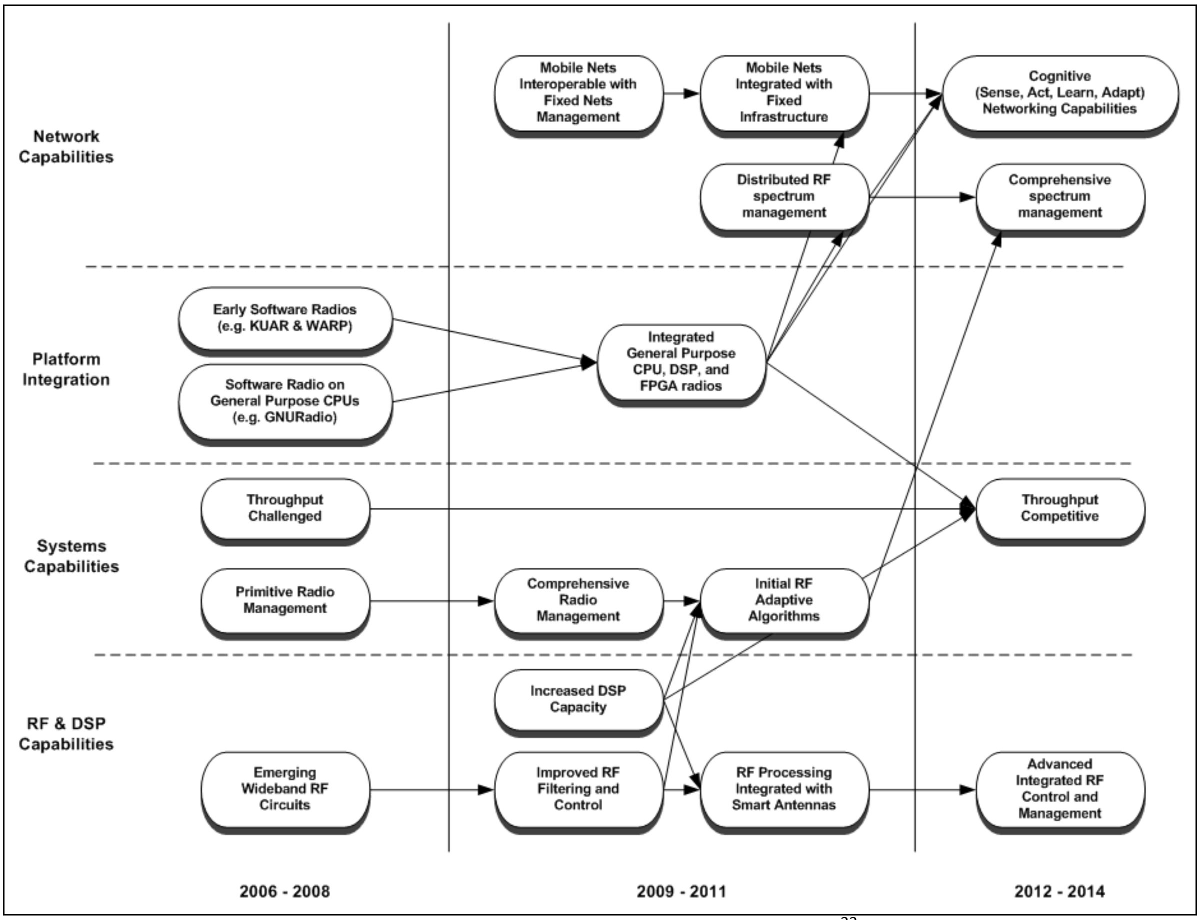

Figure 26: Cognitive Radio Research Roadmap[33]

2) Geographic sensing technology is another method that is favoured by many. It consists of a geographic database and knowledge of what channels are available so as to avoid using saturated channels.

[33] NSF. Future Directions in Cognitive Radio Network Research. [Online] Available from: at http://www.cs.cmu.edu/~prs/NSF_CRN_Report_Final.pdf [Assessed 9th July 2012].

The technology is proven and ready for production. However implementation and standardisation have yet to be harmonised. More digital switch over in the coming years will drive regulatory changes for the market to adopt in the near future.

8.5.3 Fixed Infrastructure

8.5.3.1 Much Higher Speed Optical Transport Network, 40Gbps and 100Gbps (2-5 years)

The major drivers for 10G and now 40G deployments was the need to connect core routers, high-capacity demanding users, better economics versus yesterday's high-end transmission capacity and network capacity exhaust. These have been the most cited factors observed when moving toward higher transmission speeds. Figure 27 charts the technology evolution optical communication has taken over the years.

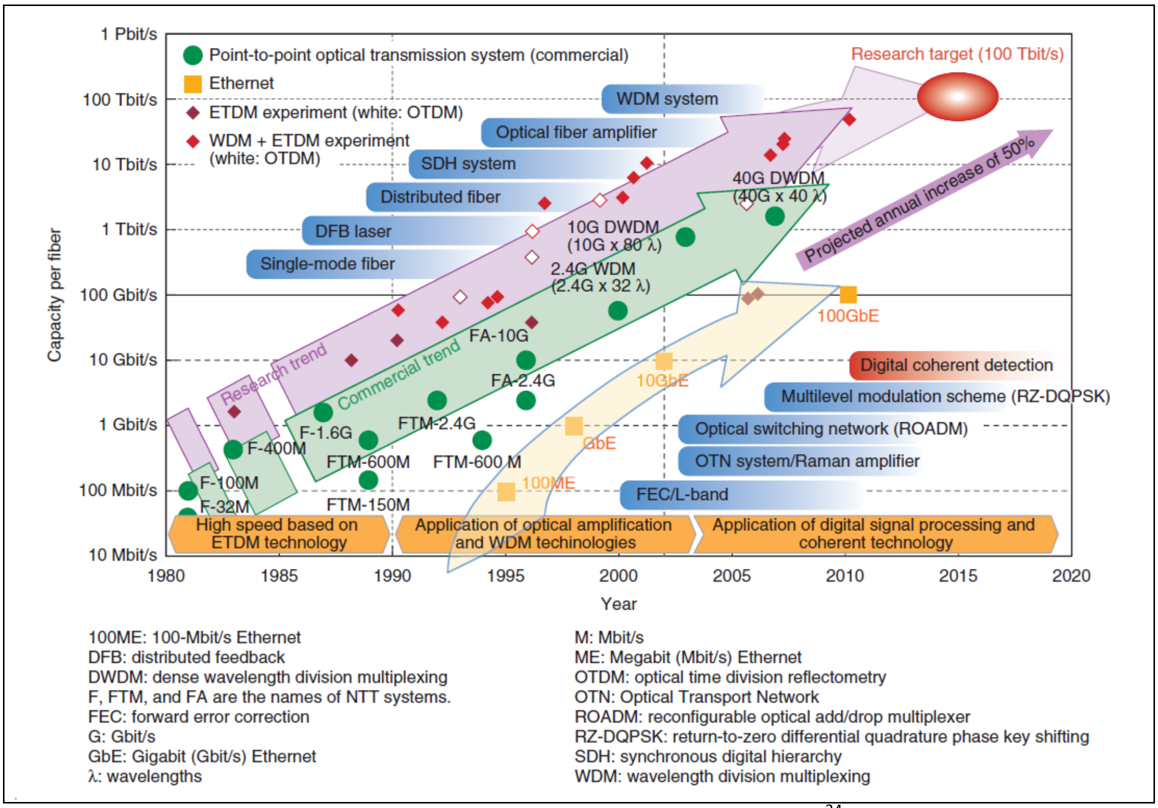

Figure 27: Trends in optical transport technologies[34]

In 2006, the IEEE 802.3 working group formed the High Speed Study Group (HSSG) and found that the Ethernet ecosystem needed something faster than 10 Gigabit Ethernet (GbE).

For the first time in the history of Ethernet, a HSSG determined that two new rates were needed:

- 40 Gbps for server, computing and switch interconnection
- 100 Gbps for LAN/WAN aggregation and interconnection

[34] NEC. Toward Well-timed Application of Advanced Technology. [Online] Available from: https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201108fr1.pdf&mode=show_pdf [Assessed 9th July 2012].

The IEEE P802.3ba 40 Gbps and 100 Gbps Task Force was formed in January 2008 to develop a 40 GbE and 100 GbE draft standard. At the June 2010 IEEE Standards Board meeting, approval of IEEE Std 802.3ba-2010 was obtained.

The major drivers for 100G transmission will be similar to the drivers for moving from 10G to 40G. The main difference is the focus on economic factors in the latter.

8.5.3.2 Passive Optical LAN (POL) for Enterprises (2-5 years)

It is evident that some believe Passive Optical Network (PON) technology is destined to migrate from being a residential-only technology toward low-cost connectivity known as Passive Optical LAN (POL) for enterprises. This approach collapses the entire active Ethernet infrastructure into passive optical fibre with active end points similar to the NGNBN we have in our homes today.

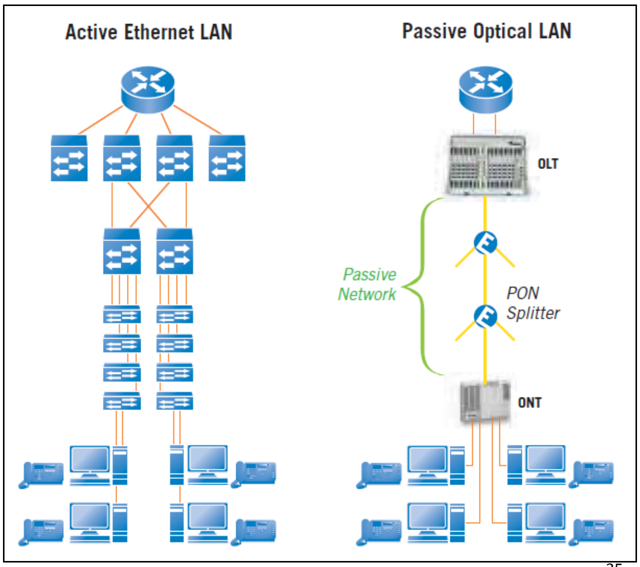

Figure 28: Active Ethernet LAN versus Passive Optical LAN[35]

8.5.3.3 Passive Optical Network Evolution (>5 years)

A passive optical network (PON) features a point-to-multi-point (P2MP) architecture to provide broadband access. The P2MP architecture has become the most popular solution for FTTx deployment among operators. PON-based FTTx has been widely deployed since 2004 when ITU-T Study Group 15 Q2 completed recommendations that defined the GPON system [ITU-T series G.984]. Our NGNBN is based upon GPON.

As full services are provisioned by the massive deployment of PON networks worldwide, operators expect more from PONs. These include improved bandwidth and service support capabilities, as well as enhanced performance of access nodes and supportive equipment over their existing PON networks. The direction of PON evolution is a key issue for the telecoms industry.

[35] Tellabs. Optical LANs Help Enterprises Go Green and Reduce Costs. [Online] Available from: http://www.tellabs.com/resources/papers/tlab_green-olan_wp.pdf [Assessed 9th July 2012].

Full Service Access Network (FSAN) and ITU-T refer to the PON interest group and standard organisation respectively. In their view, the next-generation PONs are divided into two phases: NG-PON1 and NG-PON2 (Figure 29). Mid-term upgrades in PON networks are defined as NG-PON1 while NG-PON2 is a long-term solution in PON evolution. Major requirements of NG-PON1 are the co-existence with the deployed GPON systems and the re-use of outside plants. NG-PON2 is a long-term solution in PON evolution that can be deployed over new optical distribution networks (ODNs), independent of GPON standards.

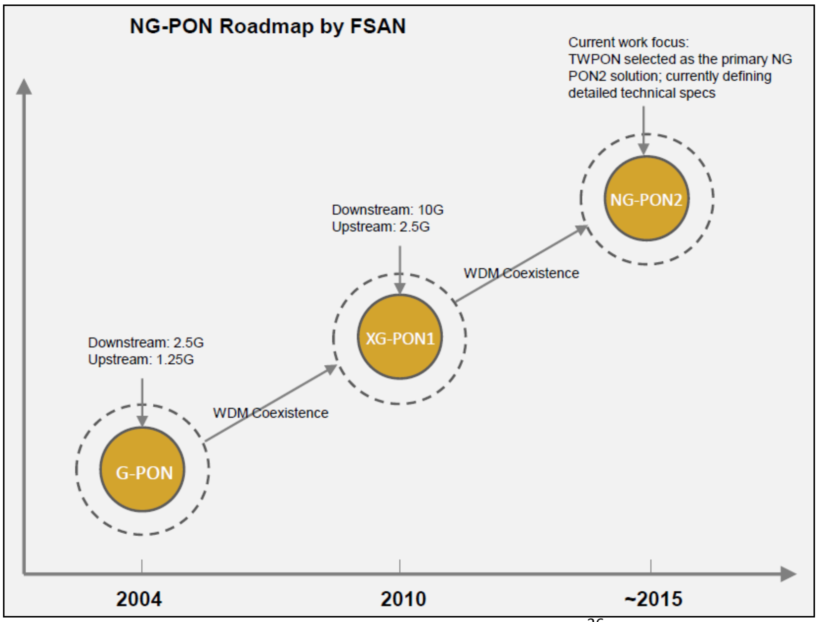

Figure 29: NG-PON Roadmap by FSAN[36]

8.5.4 Network Resources

8.5.4.1 IPv6 (2-5 years)

The IPv4 address pool is effectively exhausted, according to industry accepted indicators. The final allocations under the existing framework have now been made, triggering the processes for the Internet Assigned Numbers Authority (IANA) to assign the final five IPv4/8 blocks, one to each of the five regional registries. With the exhaustion of the IANA pool of IPv4 addresses, no further IPv4 addresses can be issued to the regional registries that provide addresses to organisations.

IPv4 address depletion is an important milestone that has been anticipated for more than a decade, and poses a real business threat to service providers. For example, service providers need to migrate users to IPv6 once there are no new IPv4 addresses to assign to new subscribers; however, there are overwhelming amounts of legacy IPv4 infrastructure, devices, services, applications and content.

The explosive trends highlighted above will drive more connectivity to our networks - hence the need for more IP addresses. The only viable long-term solution available is the adoption of IPv6.

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36 Huawei. Next Generation PON Evolution. [Online] Available From: http://www.huawei.com/ilink/en/download/HW_077443 [Assessed 9th July 2012].

8.6 Technology Radar

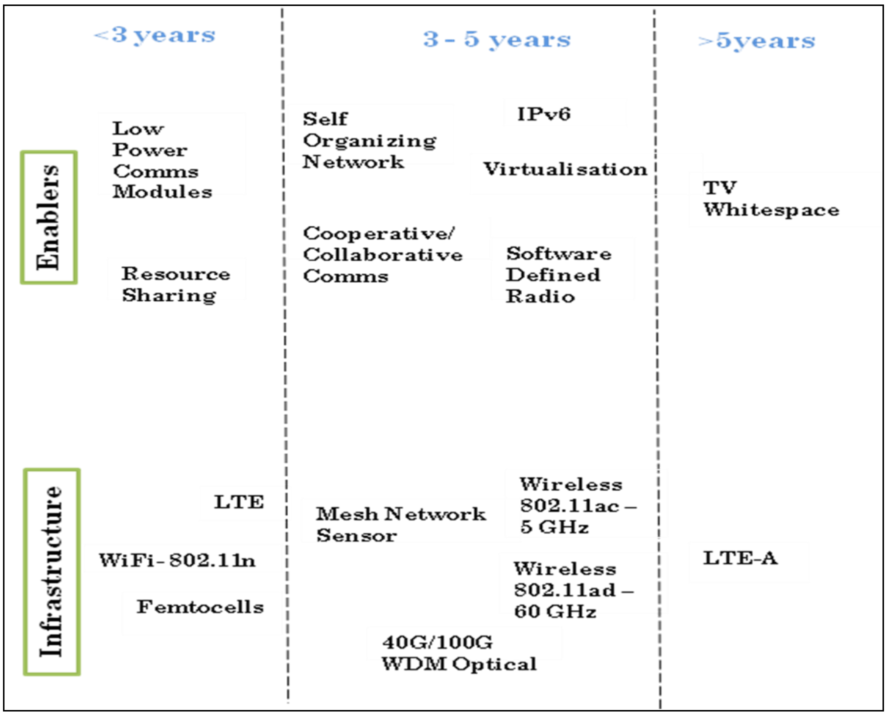

Figure 30: Technology Radar

8.7 Market Applications

Our infrastructures need to satisfy specific network requirements before digital services can be successfully delivered over the digital highways. Figure 31 illustrates the network bandwidth and latency requirements for some categories of services.

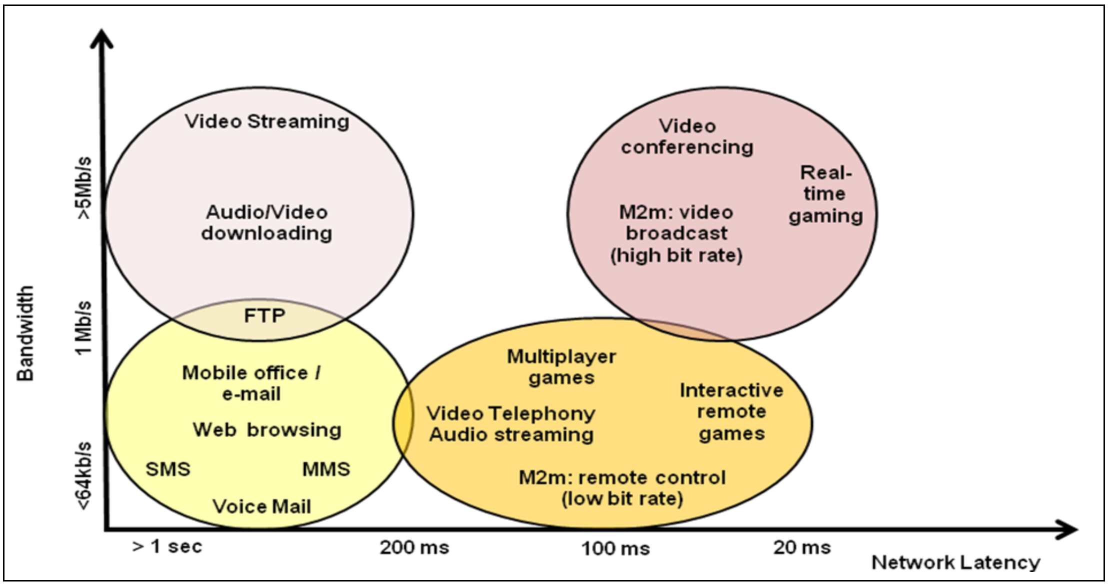

Figure 31: Network Requirements for Services

Upgraded new network capabilities for the future will bring about opportunities for new services to be delivered over our future networks to our homes, offices and our mobile phones while we are on the move. We would expect future services to be more interactive, real-time and perhaps require more bandwidth for delivering higher definition media. Figure 32 gives some examples of possible future services to be delivered using new technologies.

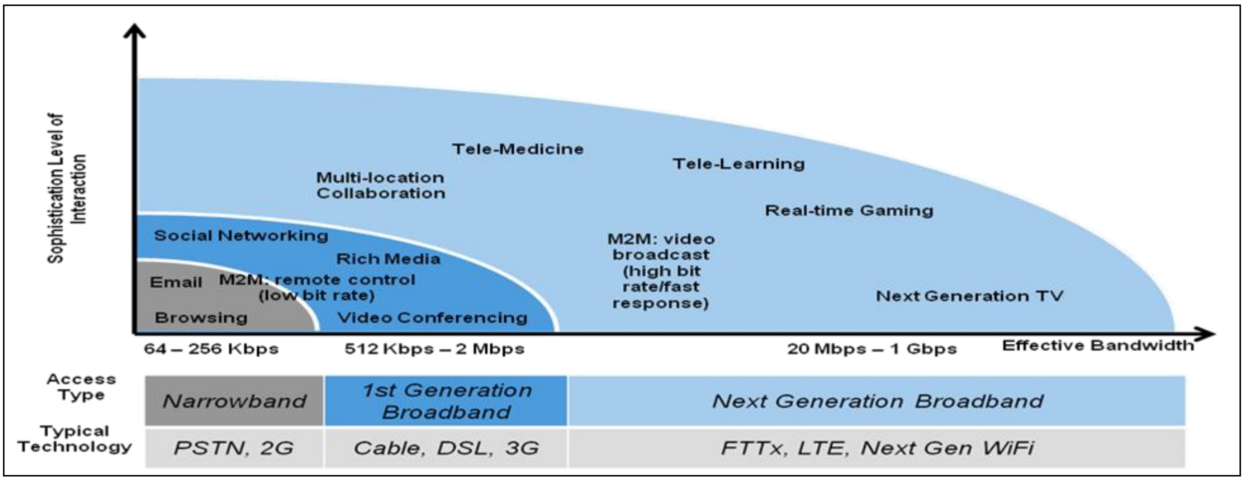

Figure 32. Opportunities for New Services

8.7.1 Government

High-speed wireless access from anywhere would allow government agencies greater ease in the deployment of systems and infrastructures to service the nation. This would allow remote site field officers to set up mobile offices in order to access common back-end systems so as extend better and more responsive services to our citizens.

M2M and location-aware capabilities would enable government agencies to be better equipped to tackle more sophisticated challenges. These technologies provide tracking capabilities that can be applied in managing security threats, monitoring health and resolving environment issues.

8.7.2 Healthcare

With an ageing population, our approach to healthcare is also evolving so as to relieve the strain on our healthcare providers. Through M2M communications, step-down care could be enhanced and home patients always connected to the hospitals for continuous monitoring of their vital health signs.

Higher bandwidth and better connectivity will allow telemedicine services to be more widely deployed to support our ageing population and the concept of ageing in place. Patients could receive the same standard of healthcare and potentially save on the travelling and waiting time at the clinics or hospitals.

8.7.3 Businesses/Citizens

M2M communications will enable more pervasive automation. Businesses could embrace such connectivity to automate and streamline certain business processes. This will reduce human error and increase productivity. One such example is smart metering.

Faster and lower latency infrastructure will open up more new opportunities for the use of M2M communications. For example, in areas of real-time control systems where latency is critical to the operations, new M2M capabilities would allow remote systems to operate as in near real time.

Higher connectivity and mobility adoption would also facilitate the growth of more personalised and innovative services such as context-aware services.

8.8 Summary

The telecommunications industry is on the cusp of another period of explosive growth. Over the next decade, billions of new devices will connect to the global internetwork and data volumes will expand geometrically. A host of players - from traditional telecommunications service providers to video and web service vendors - are both driving this growth and seeking to benefit from it.

In this environment, service providers have an unprecedented opportunity to expand operations with new scalable services. But to do so, they must build flexible infrastructures for a broad array of content and data services aimed at smarter end-user devices. A scalable, dependable and coherent architecture will help service providers to quickly and cost-effectively support service offerings that counter competitive threats and meet changing marketplace demands.

The notion of cloud computing is already influencing the network infrastructure of the future. The cloud environment enables functions that earlier were very much locked into specific hardware to be deployed in a much more flexible way across geographical domains, using functions of cloud technology. More functions will be available as open source services instead of being locked into specific hardware products. Intel envisions the future network to be more software-defined to allow flexible re-engineering of the network to cope with demand changes as illustrated in Figure 33.

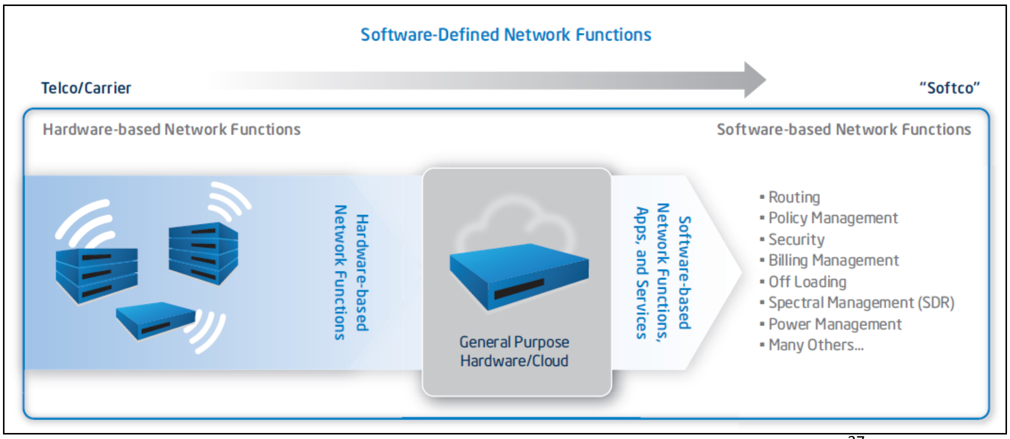

Figure 33: Transition to software-based network based functions[37]

This view is complemented with the vision of Future Networks (FN). The fundamental difference between FN and NGN (Next Generation Network) is the switch from "packet-based" systems such as those using IP with a separate transport and service strata in NGN to a service and management–aware, packet-based network which is based on shared virtualised resources in the form of processing and storage, smart objects and communication resources. These features of FN are shown in Figure 34 below.

[37] Intel. Endless Possibilities for the Future of Communications. [Online] Available from: http://www.intel.com/content/dam/doc/white-paper/325289.pdf [Assessed 9th July 2012].

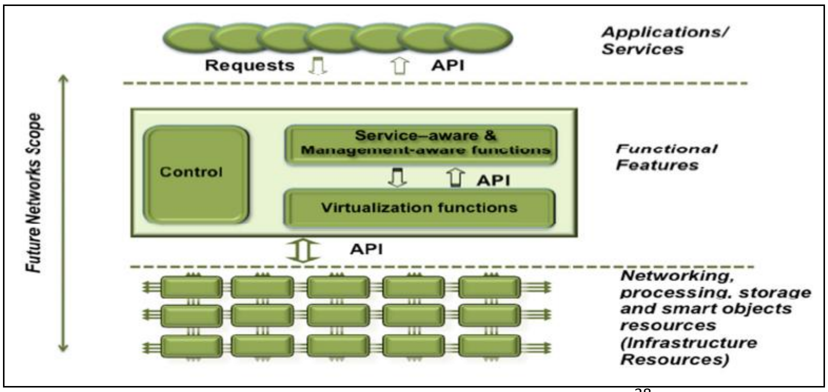

Figure 34: Key features in future networks[38]

On this note, we would expect the landscape of the future to still consist of heterogeneous networks. However, these networks would be working in a collaborative manner to ensure the efficient use of resources to deliver services. Use of communication services will be even more pervasive, powering the vision of IOT through M2M services.

[38] Net!Works European Technology Platform. Future Networks and Management. [Online] Available at http://www.networks-etp.eu/fileadmin/user_upload/Publications/Position_White_Papers/White_Paper_Future_Network_Management.pdf [Assessed 9th July 2012].