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"Network of the future"

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D6.6 Socio-economic Studies Report-2

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Abstract:
This document describes the work done in the second year of the EFIPSANS project towards Socio-Economic Studies. The report particularly highlights the market indicators based on the data collected through survey and interviews, and identifies the technology-push and demand-pull factors influencing the adoption of IPv6 networks running with autonomic capabilities.

Keywords: WP6, Socio-Economic Studies.

[1] Security Class: PU- Public, PP – Restricted to other programme participants (including the Commission), RE – Restricted to a group defined by the consortium (including the Commission), CO – Confidential, only for members of the consortium (including the Commission)

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1. Introduction

1.1. Purpose and Scope

Innovative technologies and socio-economic needs have formed a symbiotic relationship that pose a challenge to determine which one is the primary change agent. Uncertain market conditions calls for revolutionary innovation (Assink, 2006) over evolutionary or continuous innovation in order to create novel solutions to customer needs (Hamel, 2000). However, the degree of influence of technology-push and demand-pull forces on the development of technological paradigms is still debatable in evolutionary economics (Chau and Tam, 2000; Ende and Dolfsma, 2004).

The objective of the EFIPSANS socio-economic Report-2 is to develop an understanding of the supply and demand side needs relating IPv6 and autonomic technologies leading to the identification of the wider social and economic impacts. The main goal of this report is to identify the socio-economic challenges being addressed by the research and technology development of the EFIPSANS project.

1.2. Overview from the Work Plan

Task 6.4 socio-economic Studies of the EFIPSANS project is an evolution of the work producing one deliverable for each year of the project. The first year deliverable (D6.3) concluded that the area of autonomics and IPv6 is still at its early stages of development and suffers from the lack of contributions to standards and industry scale exploitation. These factors to a large extent restrain the demonstration of socio-economic implications. For this reason, EFIPSANS took the initiative to establish an Industry Specification Group (ISG) within a well established standardization body (ETSI), called Autonomic Future Internet (AFI).

Based on the observations made in the first year of the study, the initial survey questionnaire was modified and more questions were added to seek further information regarding autonomics and network management problems. An interview track with experts was also incorporated into the work plan to augment the results of the survey.

1.3. Approach and Methodology

Over the past several years there has been a manifold increase in the complexity of the data networks. The societal need for access to information and communication anytime anywhere through myriad devices is continuously pushing the limits of existing network management systems. Based on the central proposition that advanced network management technologies are not only driven by technological requirements but also by socio-economic needs, this study aims to investigate and categorise the triggers responsible for driving the shift towards IPv6 networks running with autonomic network management capabilities.

Hair et al. (2003) recommends exploratory research for highly dynamic and innovative industries with an emphasis on discovery orientation. Consequently, the research design in such cases is usually not intended to test specific research hypotheses. Furthermore, Patton (2002) suggests an exploratory work with a qualitative approach in areas where few studies have been conducted before in order to generate new fields of inquiry. Therefore, an exploratory research like this study is conducted to clarify and analyse a situation with the expectation that subsequent research will be required to provide conclusive evidence to

determine a particular course of action (Saunders et al., 2007; Sekaran, 2000; Zikmund, 2000).

Figure 1: Data Collection and Analysis Procedure

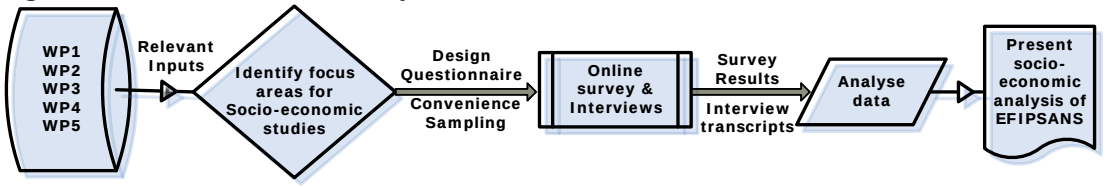
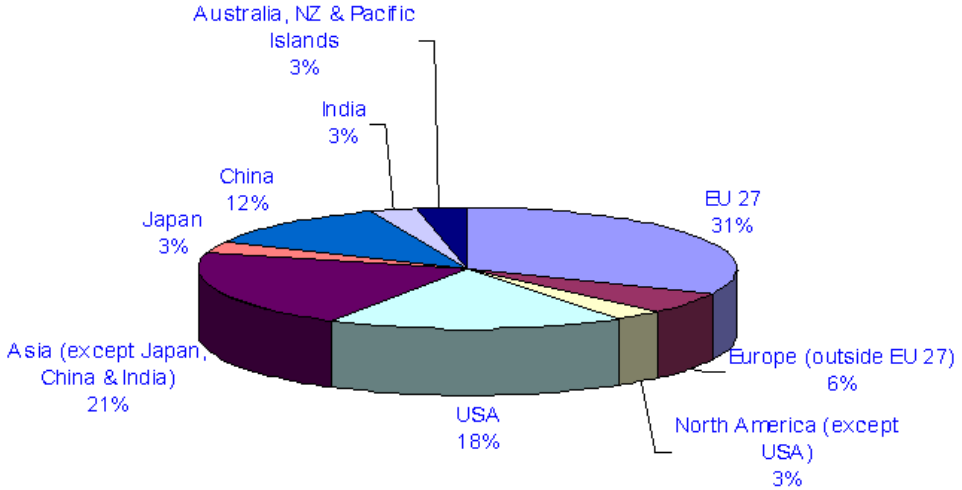


Figure 1 illustrates the data collection and analysis procedure for this study. Relevant inputs from the research and technology development work-packages (WPs) of the EFIPSANS project were distilled to identify the focus areas for socio-economic investigation. The population of interest for data collection through online survey and interviews was selected on the basis of convenience sampling. Convenience sampling is a non-probability sampling technique in which the researcher selects the subjects who are accessible and most conveniently available (Bryman and Bell, 2003; Zikmund, 2000). This represents a compromise between the extent of generalisability desired within constrains of time and other resources (Bryman and Bell, 2003; Saunders et al., 2007; Sekaran, 2000).

Information technology (IT) professionals and researchers were targeted as the populations of interest for this study taking into consideration the low maturity level of this topic that inhibits the involvement of a larger stakeholder group at this stage. Invitation for participation to the survey was sent to target industry contacts and researchers resulting in a 25 percent response rate. As Saunders et al. (2007) suggest that for internet mediated survey the response rate varies from 30 percent if conducted within an organisation to 11 percent or even lower when conducted with a geographically distant sample. In response to our survey, overall 35 expert responses were received from network engineers and administrators, researchers and senior management located around the world as shown in Figure 2.

Figure 2: Survey Demographics



The survey questionnaire was structured based on the topics: network management issues, autonomics and IPv6 including question types such as multiple-choice, short answer and matrix (see Appendix E). The comment from one of the respondents on Table 1 further explains the organisation of the questions and the limitations of this survey.

Table 1: Feedback on Survey Design

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	response	date
21	I have to appreciate the exhaustive attribute of this survey and the organization of questions is quite coherent. But however, i suggest trying to include a couple of questions to seek data on one or two particularly popular applications. The reason being autonomous technology is not still very popular today and a few candidates partiipcating in this survey might not be even aware that they had indeed used this autonomous product unless you point it out. Hope my inputs adds some value to your study! Good Luck!	8/11/09

On the other hand, the interviews were kept open and unstructured to capture the opinion of the experts. The interviews were recorded and transcribed to control bias and increase the reliability of the analysis (Bryman and Bell, 2003; Saunders et al., 2007). The five interviews were held individually and in private. The topic lists varied according to the expertise of the interviewee but at the same time thematic consistency was maintained to develop some comparability and aggregation of the information (see Appendix D). Each interview lasted for 30 to 60 minutes and the interviewees names are not displayed in this report for privacy reasons (Table 2). The interviewees hold key positions like Senior Researcher, Head of Software Development, Deputy Principal Staff (Mobile Internet), Assistant Manager (IT Infrastructure) and Research Director in their respective organisations. In total five interviews were conducted as a result of the availability and interest of the experts to participate in this study, the time and resources available along with the theme saturation due to the lack of industry scale exploitation of autonomic solutions.

Table 2: Interview Details

Interviewee	Company	Position	Location	Data Collection Technique
A	A: Telecom Research and Consultancy	Senior Management	EU	Telephone Interview
B	B: Telecom Operator	Senior Management	EU	Telephone Interview
C	C: Telecom Operator	Senior Management	Asia	Telephone Interview
D	D: Customer (MNC Bank)	Middle Management	Asia	Telephone Interview
E	E: National IPv6 Task Force	Senior Management	EU	Face-to-face Interview

1.4. Research Gap

EFIPSANS socio-economic study makes an attempt to evaluate the reasons driving the existing gap between the supply of advanced network management technologies and the market willingness to actually deploy such technologies based on primary data collected through online surveys and personal interviews. It also takes into consideration the related macroeconomic indicators and demand-pull factors to suitably map the technology development to the societal needs.

1.5. Contributions of this Study

This study makes an attempt to clarify the technology-push and demand-pull factors influencing the adoption of IPv6 networks with autonomic capabilities. Ende and Dolfsma (2004) analysed the different phases of Information and Communications Technology (ICT) and concluded that during the periods:

- 1900 to 1960: Demand-pull was the significant factor especially due to military requirements
- 1960 to 1990: It was the knowledge development in the field of microelectronics that played a major role
- After 1990s: The significant factor is the development of technological knowledge towards convergence of computing and telecommunications technology.

Ende and Dolfsma (2004) research suggests knowledge development has played a more significant role in the growth of ICT technologies, but it is not the only instigator. On similar lines the results from our analysis for IPv6 and autonomic technologies indicate that technology-push is the main impetus for creating new possibilities while the demand-pull is better poised to determine the actual application of this knowledge. The existing limits are being stretched by research and technology development however its final adoption will most likely be influenced by the economic, societal and political forces. Therefore the demand-pull factors are going to play a pivotal role in shaping the intelligent network management technologies to suit the socio-economic needs. In doing so, they will exhibit an equally important role as the technology-push factors over the technology transition phase. In that respect, this study lists the technology-push factors and demand-pull factors and presents the synergisms between them towards the adoption of IPv6 and autonomic technologies.

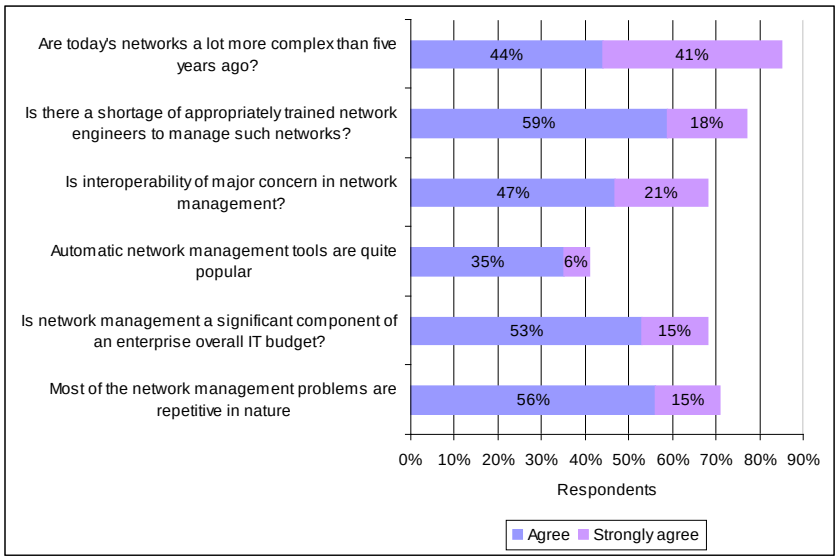
2. Microeconomic Indicators

2.1. Trade-off between Resource Cost and Network Quality

The balance between quality and cost is an ongoing consideration for all industry sectors. It mainly depends on the type of product and service being delivered. In network management the increased complexity in the management of the networks along with the lack of intelligent tools has contributed to the greater dependency on human resources to ensure the network quality. For example, the complexities of today's network are so enormous that the network management costs are predominantly devoted towards running the networks rather than investing in new initiatives, as confirmed by 82 percent of our survey respondents.

Network management costs are a significant component of an enterprise overall IT budget (Figure 3), and continue to rise year-over-year steadily at slightly above five percent according to the Aberdeen Group (2008). AOTMP, a telecom consultancy backs this increase in technology spend and further states that developing a strategy to manage network expenses remains one of the top telecom network initiatives for companies[2]. Moreover, most of the network management problems are repetitive in nature and few automatic processes exist to prevent them from recurring multiple times (Figure 3).

Figure 3: Growing complexity



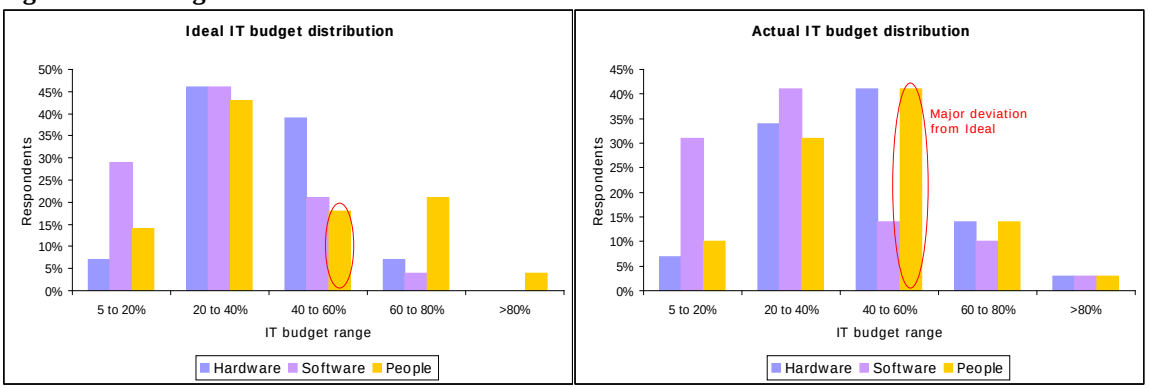
Interviewee B believes that we still think that networks behave as they did in legacy technologies and says 'complexity is a problem (today) and with complexity what I mean is that people must learn more, so everybody that operates on the network must be more aware of what they are doing, they need special training- it is more demanding'. According to Interviewee A an increase in the number of people becomes necessary not only to improve the service quality but also for better communication and coordination of the problem to the internal or external customer, which is more of an administrative or internal process. On the other hand, Interviewee D says that they have a luxurious budget for IT hardware and software to ensure seamless operations but the budget for people is always tight.

Another major implication of the growing complexity of today's network is the availability of appropriately trained human resources as indicated in Figure 3. The deployment of human

[2] http://www.networkworld.com/news/2008/082608-network-management-tips-for-managing.html

resources for network management varies from one company to another and is subject to changes depending on the organisation's IT strategy. In our survey, we asked the respondents about their opinion on the ideal and actual IT budget distribution between hardware, software and people in their company. Clearly, the allocation of human resources stands out showing a major deviation form the ideal to the actual distribution (Figure 4). This implies that the respondents are of the opinion that the people costs either needs to be reduced or increased depending on whether the organisation's IT strategy is to control network management costs or ensure seamless operation with additional human resources.

Figure 4: IT Budget Distribution



The issues surrounding human resources requirement for network management is also highlighted in 'The 2009 Handbook of Application Delivery' (Metzler, 2009), which identified the 'lack of personnel resources' as the number one factor that prevents organisations from improving the Network Operations Center (NOC), based on a survey involving 300 IT professionals. The survey also identifies the lack of adequate software tools as the other main reason for the existing inefficiency. Therefore the traditional trade-off between quality and cost is still evident in network management (Table 3).

Table 3: Reasons for the Trade-off

Interviewee	Reasons to increase people	Reasons to decrease people
A	• Better perceived service to your customers • This is part of the administrative (process)	• People who are operating the network naturally want to get rid of as many people as possible • You are basically able to get rid of some of the less skilled ones (with some sort of automation)
B	• There are new (trends) appearing • Complexity is a problem • More steps are needed (to solve the problem)	N/A
C	• To improve our network quality • Human resources are not that expensive (in the particular operating country)	• Under consideration..to balance the human resources and network quality..for the radio devices deployment (wireless)
D	• Complexity involved in the management of the network	• We try to have less number of IT people and more number of (people contributing to company's core business)

Consequently increasing the efficiency of the human resources to manage the growing complexity of the networks is seen as the most dominant solution to this trade-off between human resources cost and network quality. As Interview A summarises 'If you ask people you basically always get the answer yes we need to get down on the (human) resource cost but

realistically what happens is you are just able to do more with the same amount of people'. However, the efficiency of the human resources closely relates to the availability of the enabling technology and is discussed in detail in the next section 2.2: Network Technologies Supply and Demand Gap.

At present, training the workforce with the necessary expertise is seen as a way to increase their output and the quality of work. Interviewees B and D highlight the importance of special trainings and say that the nature, frequency and duration of the training depends on the type of technology and what is being managed as per the business needs and accordingly the personal skills and knowledge of the people are upgraded, which is an ongoing activity of their respective organisation. Additionally, Interviewee B with an example asserts that since there are no intelligent systems, scripts are used where possible to manage specific situations in a simple way. Even with that, a certain level of expertise is needed because not everybody can write or change the scripts. As a result, regular training of the human resources is needed to increase the network management efficiency (Interviewees A, B and C), which adds to the operational costs as well.

In order to address the aforementioned issues, the benefits described in EFIPSANS Deliverable 1.3 and 1.4 include the gains in flexibility in service or behaviour composition, provisioning and maintenance; OPEX reduction; and Performance; Reliability and Robustness. Moreover, the Task 4.2: Teachable and Learning IPv6 networks focus on minimising the repetitive problems in the networks by developing self-diagnosis capabilities. The goal of the EFIPSANS project is to make networks easy to manage with reduced human intervention and better operational efficiency.

2.2. Network Technologies Supply and Demand Gap

The gap between supply and demand for network management technologies exists because economically unsustainable problems like over-provisioning, time taken to solve repetitive problems and high costs for support services continue to exist. 71 percent of our survey respondents agree that most of the network management problems are repetitive in nature. For example, routine change and configuration management takes high to very high effort level for 70 percent of our survey respondents. Similarly 63 percent of the respondents also put high to very high level of efforts in dealing with fault management problems. Interviewee A says 'from a business perspective (fault management is) really the big problem'. Interviewee B further explains that a lot of effort is spent in the planning and development stage in providing the fault tolerance mechanisms to telecom networks. The problem Interviewee C emphasis is the inability of the network optimisation tools to cover cross-layer or the lack of management tool coordination for network operation. A similar situation is also seen in the enterprise IP network where Interviewee D attributes the time spent on repetitive configuration changes to the lack of more reliable functionalities from the management tools.

Due to the nature of their business it is not acceptable for Company D to have any downtime or failure. Interviewee D says that the company has a very clear policy 'that actually tells us that this kind of task is classified as critical and this cannot be carried out at this particular time'. The company also sets aside reserve hardware or backups to take care of critical times and hence the faults are not avoided because of the technology available but by following the company's contingency plans, according to Interviewee D. Interviewee A thinks that it more of a fundamental deployment or implementation problem and says 'people doing the buying decision of IT network equipment do not care too much about the management part so it is a low priority decision point'. This has lead to the practice of reserving the resources (Table 4) and the increased dependency on support services to ensure the desired network performance. The ongoing support cost is a significant component of the operational expenses as Interviewee D says 'the amount of money we spend on the support and service (over a period

of time) from the vendor is quite high compared to what we buy (hardware or software) from them'. On the other hand Company C is satisfied with the specialised services offered by the product vendors and consultancy firms as it helps them to overcome the issues relating to the availability of specific expertise for a particular task (Interviewee C).

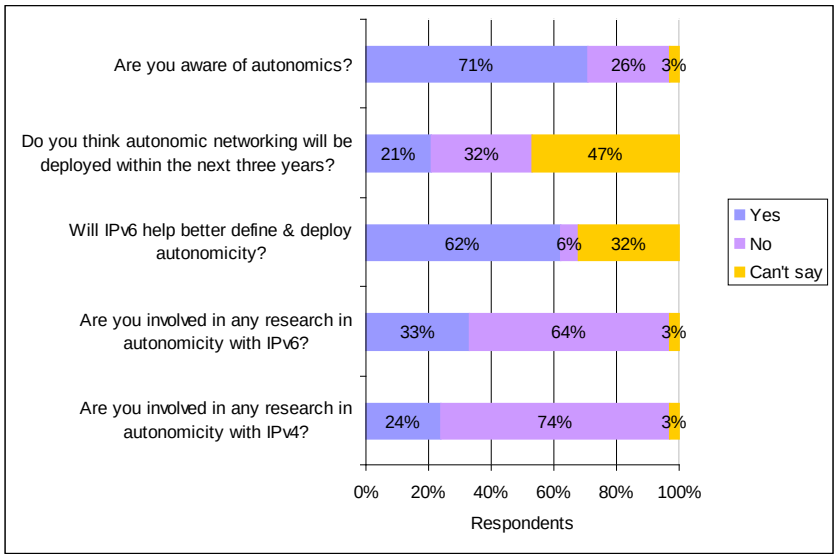
Table 4: Reserving the Resources

Interviewee	Over-provisioning
B	A big part of our bandwidth is spent on protection part – on securing data path so you see the importance of this we reserve plenty many resources for protection, to back-up systems and back-up links.
D	We have separate lines running for data and separate lines running for real-time voice or video (data-split)..though I would say we have been bit conservative in the way..it has helped us a lot.

In order to overcome the above problems, Interviewee A suggests incorporating built-in management functionalities while building a service or network function and explains 'one of the problem today is that somebody designs a system and then somebody else needs to design the management of that system, so there is a lot of things going lost in between in terms of know-how and the exact knowledge of how a system works and so on'. Interviewee D also sees this as a fundamental problem and questions, 'when we have the design very well structured in terms of logic why cannot we have physical infrastructure in terms of logic?' Furthermore, Interviewee D questions why cannot we have a disruptive innovation like virtualisation to reduce the number of devices managed on the network side? 'Five years ago..nobody wanted to see a number of servers running on a single physical hardware (and was considered to be) a single point of failure..now we have such reliability on virtualisation technology that everybody wants to move towards virtualisation' says Interviewee D. On the mobile side, Interviewee C explains that it will be good to 'understand more details of each packet..because the operator is more concerned to become a pipe of the internet traffic'.

Clearly, the lack of desired level of intelligence in today's networks is a major inhibiting factor increasing this gap between the supply and demand sides of network management technologies. Interviewees A, B and D highlight the issues with trust to move in this direction of more intelligent networks. Interviewee B comments 'people must obtain some trust on this new paradigm and that is a big issue: how to move from fully deterministic system to a system where you trust that machines are doing this job for you'. In terms of developing the necessary trust, Interviewee A thinks 'people operating the network they must start trusting in the autonomy and that is a lengthy process, so it is a gradual process getting more and more autonomy into the system, I think it is possible but it is not advanced'. On trying a new intelligent network management tool Interviewee D says 'talking about my company I would definitely not buy it..because I don't have any substantial proof telling that you use this and you don't have any operational risks..trying to embrace a new technology is a kind of challenge and is a very slow process for industries like ours'. The response from our survey also indicates similar trends where although the survey respondents are aware of autonomics, their interest and involvement with autonomic technologies is limited (Figure 5). Moreover, only 21 percent of the respondents are optimistic about the deployment of autonomic networking technologies within the next three years.

Figure 5: Autonomics Awareness and Deployment



Autonomic networking is still seen as something that is at the research level far away from being realistically deployed on a large scale (Interviewees A, B and D). Interviewee A is of the opinion that self-management is not realisable practically at depth, so the question is about the degree to which it is possible. Interviewee B points out the scalability issues and suggests 'we are already facing some scalability problems for the centralised approaches, we can move towards something more hierarchical for instance'. However, Interviewee D would like to have a single interface or device to manage routing, firewall, IDS, switching etc. A good result of autonomic networking research according to Interviewee A is that 'in the long term it is sort of a teaching of designers on how to build systems such that they are more easy to manage..if that is achievable..then we already have gained quite a bit'. For example, there is some initial traction to recovery solutions using autonomic network management features in 3GPP according to Interviewee C, who is optimistic that we will see more autonomic functionalities incorporated in the networks in the medium term. The other advantages of autonomics rated according to the percentage response from our survey are listed starting from the most significant benefit in Table 5. Interviewees C and D also give example scenarios of possible autonomic management solution in the telecom and enterprise networks respectively (see Appendix A and B). The above requirements highlight the need for more efficient network management solutions to narrow the supply and demand gap as evident with network management technologies. EFIPSANS is addressing this gap by developing and integrating built-in network management features into the current IPv6 protocol suites.

Table 5: Benefits of Autonomic Networking

Ranking	Benefits to the Internet Service providers	Benefits to the Users
1 (High)	• Easy to manage networks	• No need to know about network (infrastructure agnostic)
2	• Easy to maintain remote networks	• Improves the performance of applications
3	• Reduces downtime	• Saves time lost due to network problems
4	• Reduces operating costs • Easy to install networks	• Reduces downtime • Ease of use
5 (Low)	• Saves time spent on network management • Ensures quality of service • Easy to upgrade networks	

2.3.Key drivers and inhibitors to IPv6 adoption

IPv6 avoids NAT (Network Address Translation) and this, according to Interviewee C, is the fundamental benefit of IPv6. However, Interviewees A, B and D believe that NAT will stay even in IPv6 space as it is seen as a security mechanisms with its ability to hide the end-users from possible external attacks. Interviewee E points out that by doing so an implicit assumption is made that everybody on the private side of the firewall is trustworthy that is not necessarily true, and the 'reality is that anything important should be protected by a firewall and that will continue to be the case with IPv6'. Interviewee C agrees with Interviewee E and asserts that security features can be enabled by management, IPv6 firewalls etc., and having a similar solution as NAT is not a big problem with IPv6. Moreover, it will be possible to have closer auditing of the attacks at the node level, which makes IPv6 networks more reliable from a security point of view. Our survey respondents are also more affirmative about the IPv6 security features as 45 percent in total 'Agree' to 'Strongly Agree' as being the trigger for moving to IPv6 as opposed to 19 percent who disagree, the rest remaining neutral. Furthermore making a counter-argument to the advantages of NAT, Interviewee C with an example says 'agreed for enterprise the NAT is really efficient..(it is) the issue with the operators..because NAT can support mostly like 70 million subscribers but right now for us we have 700 million subscribers'.

The main trigger for moving to IPv6 is due to the lack of IPv4 addresses as confirmed by an impressive 85 percent of our survey respondents. According to the IPv4 exhaustion counter provided by Potaroo[3], the world will run out of IPv4 addresses by 2012 as per their latest predictions. 'Probably the best benefit of the IPv6 is that it will create a level playing field in the world..more fundamental in terms of the geopolitics is the allocation of addresses such that all the large address blocks are with the North American multi-nationals and institutions where there is very few addresses available for the Chinese and Indians of course who make up the majority of the world's population..so politically I think it has a social advantage' says Interviewee E.

Table 6: Perception on IPv6 Adoption

Interviewee	Comments on IPv6 adoption
A	• I don't see any economical benefit of IPv6
B	• Appears like a delayed promise never to be done
C	• It could simplify the network architecture to reduce the Capex and Opex • Possible solutions for end-to-end arguments
D	• (Could be a)Risk generating migration • (Need) substantial proof and success stories
E	• The key migration cost is the education of the staffs • We are going to hit that cliff within the next 8 to 12 months and then people will know that we should have moved two years ago

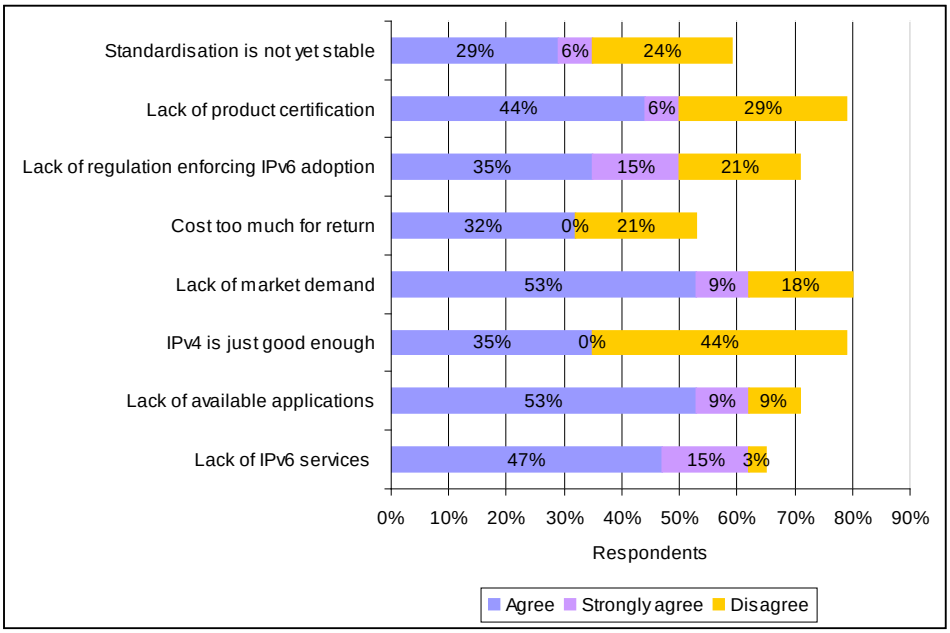
In North America itself as per the latest October 2009 statistics from ARIN (American Registry for Internet Numbers), the first nine months of 2009 has seen a larger increase in the demand for IPv6 than ever before and up to 20 percent year over year drop in the request for IPv4 addresses[4]. 72 percent of our survey respondents have 5 to 20 percent of their total internet traffic running on IPv6 that also indicates IPv6 adoption is picking up at present. 'I would say that particular tipping point is just about to happen but we are a long way from the tipping point which will be the crucial one where there will be more v6 nodes active on the internet than v4 nodes..that will be very hard to predict..but as soon as we hit..maybe 30 percent it will become much easier to persuade people to move to v6 because so many people have already moved, it is the initial movers that are harder to persuade' says Interviewee E.

[3] http://www.potaroo.net/tools/ipv4/

[4] http://www.infoworld.com/d/networking/ipv6-addresses-north-american-isps-are-now-grabbing-them-over-ipv4-582

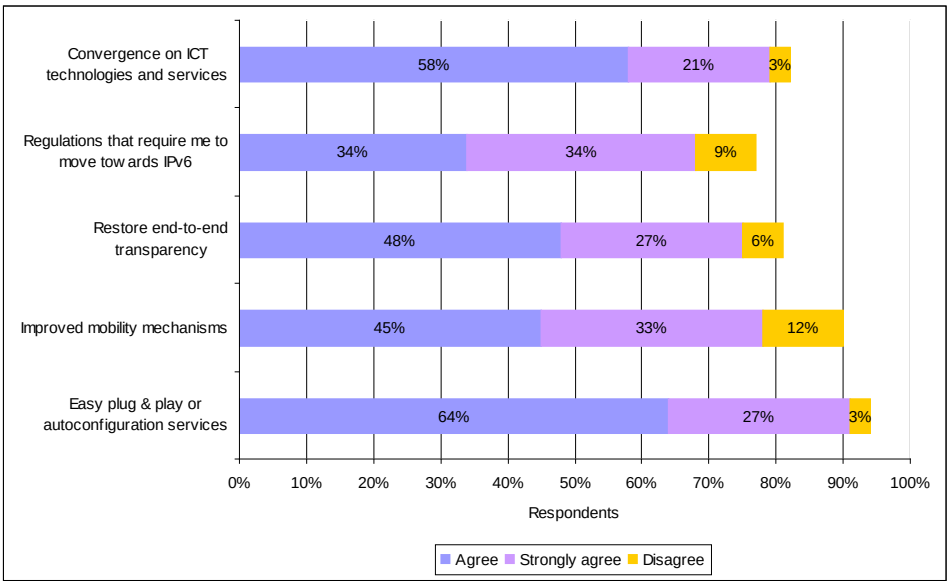
On the other hand, Interviewee B thinks the problem of address shortage with IPv4 'can be solved adding complexity (IPv4+NAT), so it is a balance between disruptive or evolutionary change- it will be political in the end probably'. However, Interviewee E explains that for certain types of application like for videoconferencing, involving multiple layers of NAT introduces huge amount of latency and degrades the quality of the real-time applications. Furthermore, Interviewee E adds that moving to IPv6 is like the need to move to any new technology that involves some complexity, cost and mainly learning. Moreover, there is no special advantage to the early movers except that they will develop an early knowledge to be ready to exploit some real economic benefits as the interconnectivity increases with IPv6, according to Interviewee E. Our survey results also show that the market driven factors like the market demand, availability of applications and lack of services running on IPv6 are the major inhibitors to the adoption of IPv6 (Figure 6). Interestingly there is no clear winner between IPv4 and IPv6 from our survey as 35 percent of the respondents agree that IPv4 is good enough against 44 percent who disagree.

Figure 6: Inhibitors to IPv6 Adoption



The main economic benefit of IPv6 as agreed by Interviewees B, C and D is that numerous devices (like mobile phones) will need IP addresses in the future for mobility and ubiquity, which cannot be satisfied by IPv4. IPv6 validates the end-to-end principle and reduces the barriers to entry for all services offerings over the internet. As Interviewee E emphasises 'everybody behind the NAT gateway has great difficulty in offering a service to anybody else because they do not have a public IP of their own..therefore it is like a huge dead hand on the innovative capabilities of the internet..the thing that makes the internet is its innovativeness with services'. Our survey respondents also support the above views and indicate convergence of ICT technologies and services along with the auto-configuration services as the other accelerators towards IPv6 adoption (Figure 7). IPv6 promises to provide solutions to some of the configuration problems as mentioned in Section 2.2, and the trend towards convergence to all-IP network is further discussed in Section 3.2 of this report.

Figure 7: Accelerators to IPv6 Adoption



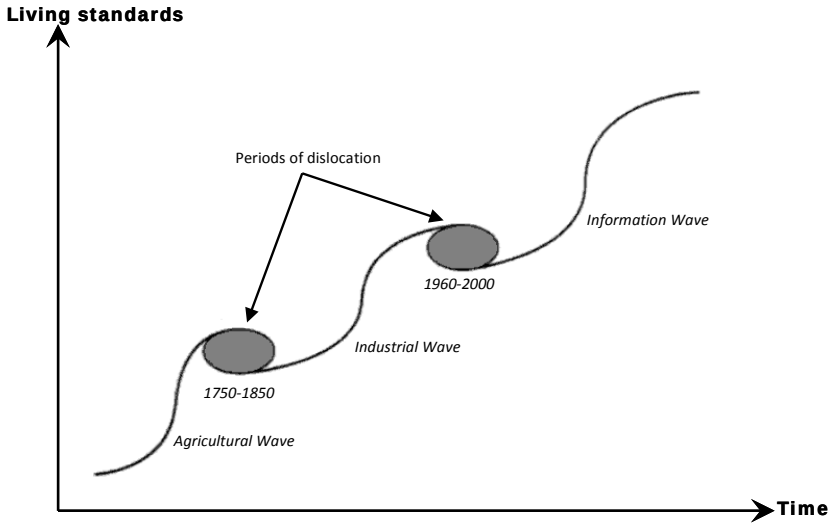
Despite the advantages, the reason why IPv6 adoption is not picking up according to Interviewee D is because the vendors continue to support IPv4 and customers continue to buy IPv4 and both try to stay away from making a hard decision of adopting IPv6, which has now become more of a political decision. In response to the suggestion of having a political mandate on IPv6 adoption, Interviewee E highlights that the internet is not driven by national regulations and says 'it is much more likely that the public sectors in different countries will set procurement standards that are based on v6 and through that process..will encourage the vendors to bring out v6 complaint products and then that will lower the cost of the products for everybody across the market'. Therefore it is likely that the public sector will lead the way in terms of IPv6 adoption as seen already in few countries rather than make it mandatory or offer incentives for migration governed by new regulations.

3. Macroeconomic indicators

3.1. Waves of Economic Change

Communications technologies continue to play an important role in driving globalisation, benefiting many economies around the world. In general, this resulted in higher productivity, creation of new jobs, increased wages and improved standard of living. The internet played a pivotal role in driving this change leading to the 'information wave' of economic change. However, the information wave seems to be approaching a period of dislocation where new trends are likely to take over, not necessarily by replacing the existing one completely. Similar patterns were observed with the previous agricultural and industrial waves of economic change (Hope and Hope, 1997). The periods of dislocations as shown in Figure 8 occurs during such transformations as the waves of economic change mature. In this sense it appears that the information wave is maturing and new trends are likely to take priority going forward. However, the degree and the nature of its maturity along with the pace at which other paradigms will supersede are still unpredictable.

Figure 8: The Waves of Economic Change

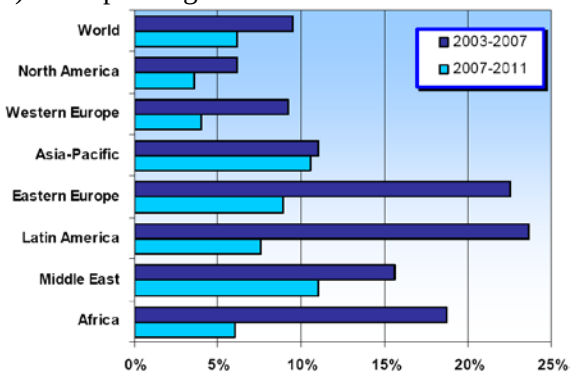


Source: Hope and Hope (1997), p.2.

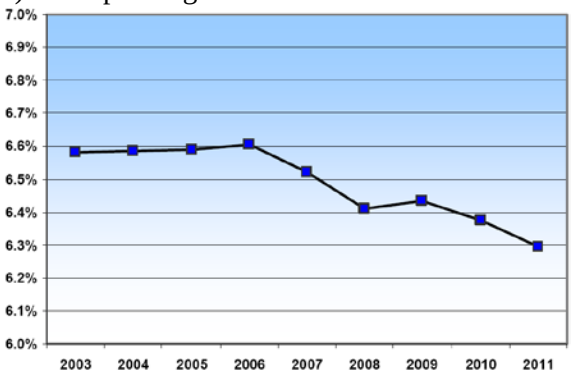
The World Information Technology and Services Alliance (WITSA) in their Digital Planet 2008 report (WITSA, 2008) forecast that the ICT spending growth across all regions has slightly retarded due to the present economic downturn. ICT spending growth in the Eastern Europe and Latin America will be outpaced by Middle East and Asia-Pacific region (Figure 9). North America and Western Europe with saturated markets will continue to show much slower growth rates than the other regions. The effect on this together with the on-going recession implies that the ICT spending as a percent of world GDP (Gross Domestic Product) is expected to drop from the peak of 7.3 percent in 2000 to 6.3 percent by 2011 (Figure 9). Moreover, with the socio-political swing towards climate change issues many are predicting that the next wave of economic change will be driven by the adoption of eco-friendly technologies and practices. However, ICT is expected to play a major role in enabling green solutions and hence its significance will remain even in light of changed socio-political priorities in the future.

Figure 9: ICT Spending

a) ICT Spending Growth



b) ICT Spending as a Percent of World GDP



Source: WITSA (2008) [online]

In the European Union (EU) sales of products and services from the IT, Telecommunications and Consumer Electronics sector were down by 2.2 per cent to € 718 billion in 2009 according to the European Information Technology Observatory (EITO)[5]. For 2010, EITO is quite optimistic and forecast only 0.5 percent further drop leading to some stabilisation ahead. It suggests that the demand for information technology is on its path to recovery, and the telecommunications industry is the least affected of the three sectors by the present economic crisis. This optimisation is further reflected by the stock market, which is considered as one of the dynamic indicator of economic growth. Leading stock market index DJIA (Dow Jones Industrial Average) shows sinusoidal fluctuations with overall positive change (+29 %) for the past one year period (Figure 10).

Figure 10: Stock Market Performance

Source: DJIA[6] [online] As on 19.11.2009

3.2. The Internet Economy

A large part of the ICT industry is driven by the internet and is popularly known as the 'Internet Economy'. The internet penetration and user-growth continues to increase at a phenomenal rate around the world as broadband and wireless connections replace the dial-up internet connections. For example, the number of internet users increased by 227 percent in the European Union with a population penetration of 63.1 percent for the period 2000-2009 (Table 7). According to MarketResearch.com[7], the total global revenues generated by Internet Service Providers (ISPs) from the provision of narrowband and broadband internet connections to the internet subscribers grew by 13 percent in 2008 to reach a value of US$ 184.8 billion. This is expected to grow at a CAGR (Compound Annual Growth rate) of 10 percent reaching US$ 298.8 billion in 2013.

5 http://www.eito.com/pressinformation_20091112.htm

6 http://www.google.com/finance?q=INDEXDJX:.DJI

7 http://www.marketresearch.com/map/prod/2405080.html

Table 7: Internet Penetration and Growth

World Region	Population (2009 Estimate)	% Population of world	Internet users, latest data	Penetration (% Population)	User Growth (2000-2009)	% Users of world
European Union	489.6 million	7.2%	308.97 million	63.1%	227%	18.5%
Rest of world	6.28 billion	92.8%	1.36 billion	21.7%	410%	81.5%
Total world	6.77 billion	100.0%	1.67 billion	24.7%	362%	100.0%

Source: Internet World Stats[8] (cited 12 November 2009)

Such is the importance of the internet that one week internet blackout can result in more than the estimated one percent GDP drop (calculated for Switzerland), according to the Swiss Federal Institute of Technology (ETH)[9]. A greater part of this loss is due to liability, customer loss and disaster recovery. It is also impacted by the downtime loss (degraded productivity + loss of revenue). Similarly, for enterprise networks, Infonetics Research[10] found that medium-sized businesses (101 to 1,000 employees) lost one percent of their annual revenue in network downtime. Therefore the Internet Economy has a positive relationship with economic performance and GDP growth while having a major influence on increasing the business productivity and employment levels.

Arguably one of the major transformations of all times that is taking place in the telecommunications network is the convergence of voice, video and data traffic over IP network. Interviewees A, B and C agree that this convergence is driven by the market need to reduce the cost of data transport while opening the way to enhanced and new services. Although technology maturity has helped in this process Interviewee B feels the data traffic provided the impetus to move towards this as it exceeded the other types of operator's traffic. However, Interviewee A is doubtful about the commercial benefits of convergence to the operators from the large amount of data they will transfer. Interviewee B also agrees that the revenue from the traffic is getting lower but at the same time convergence offers 'more earnings on investments on Capex than Opex' because only one network type is being managed in contrast to the legacy networks. Moreover, Interviewee C asserts that with convergence the operators will continue to have full knowledge of their subscribers' behaviour as to what they are doing and where money can be made. Hence the convergence to an all-IP network is influenced by the market and offers potential benefits not only to the users but also to the operators as listed in Table 8.

Table 8: Converged Networks

Interviewee	Advantages of convergence to all-IP network
A	• Reduces complexities • (Able to handle) the growth of the data • Cheaper (data and services)
B	• You can use the same network..same technology..(for)different services • Easier to manage (for operators) • Allows (operators) to reduce what (they) spend and increase the (profit) margin

[8] http://www.internetworldstats.com/stats9.htm

[9] http://www.mi2g.com/cgi/mi2g/frameset.php?pageid=http%3A//www.mi2g.com/cgi/mi2g/press/220705.php

[10] Infonetics Research. *The Costs of Downtime: North American Medium Businesses*. March, 2006.

4. Social Implications

In terms of the potential social benefits of the future services over the IP network, the Interviewees predicted possible applications in the areas ranging from health, entertainment to internet of things. Interviewees A and B complemented the internet for the contributions already made like e-shopping, e-banking, teleconference, videoconference, social networking etc that is likely to see more advancements going forward. Furthermore, Interviewee A points out the health sectors and says it appears to be one of the potential sectors that is underdeveloped when it comes to ICT usage and adds that ICT can bring 'about higher productivity in health sector through exchange of data'. Both Interviewees A and B agree that the technology already exists to increase the efficiency through ICT technologies in the health sector and it is only a matter of wide scale implementation. For example, Interviewee B mentions a high quality video system they had developed to transmit the medical image to a specialist doctor for paediatric care way back in 1998.

Furthermore, Interviewee C believes that the internet of people is much more powerful than the internet of things because it creates additional value in the life of the people. Interviewee A agrees to this view and gives examples of technologies like RFID (Radio Frequency Identification) that are more suitable for increasing operational efficiency and only have an indirect positive effect on society. On similar lines, Interviewee C comments that when machines or sensors connect to the internet they contribute extra data or information but when people connect they communicate, express their feelings and build relationships with other people, which adds value to their life.

As a result, communications and entertainment are seen as the common services over the internet that benefit both businesses and people. With the increase in bandwidth capacity, the screen size for video chatting is expected to be further increased and more ways of expressing emotions incorporated to enhance the communication experience of the people (Interviewee C). Similarly Interview B thinks that virtual reality has a lot of scope for further development and says 'I see the big industry as entertainment, everything that is to do with entertainment for me is profit guaranteed'. Therefore, the challenges and ongoing transformations in the telecommunications sector (as discussed in Chapter 2 and 3 of this document) reflect the societal need for better health care system, enhanced communication and greater entertainment experience. EFIPSANS technology development provides the enabling technology to meet such demands in the future.

Apart from the service delivery, the role of the IP network has also become very important to deal with the existing problems like crime and climate change that concerns the society at large. As discussed in section 3.1 of this document, the probable movement towards the next wave of economic revolution is being driven by the depleting energy supplies and raising temperatures due to global warming. In our online survey, overall 51 percent of the respondents either 'Agree' to 'Strongly Agree' when asked whether IPv6 adoption can lead to novel green technology solutions or provide energy savings. One of the major reasons for this affirmation is the fact that NAT (Network Address Translation) can be removed with IPv6, which provides some energy savings. NAT devices are 'always on' and consuming energy as they enable a single internet connection with a single IP address to be shared across a large number of user devices. Furthermore, 65 percent of the respondents said Yes in response to the question: Do you think the power of autonomics can drive us toward novel green technology solutions or provide energy savings for telecom and enterprise networks?

In this regard, we evaluate the potential of intelligent network management technologies to reduce carbon emissions originating from the IP networks. Therefore, the following sections discuss the various challenges and emerging solutions towards green communications and its significance to the society.

4.1. Green Communications

The concept of sleeping or zero-idle power that calls for deactivating the under-utilised components in a network is gradually picking up now with the goal to achieve energy savings in the ICT networks. In a seminal study, Gupta and Singh (2003) identified the problem of excessive energy consumption in the internet and suggested changes to the network protocols and the internet architecture in order to put network interfaces and components to sleep as needed. This is an interesting direction especially as we reach the limits of semiconductor technology to improve the energy efficiency of the devices. On similar lines Allmany et al. (2007) also suggested an initial architectural construct to support selective connectivity. Interviewees A and B believe that such energy management mechanisms although slightly overrated are realisable going forward. Taking forward this concept Chabarek et al. (2008) recognised that increases in power consumption are directly related to increases in bandwidth, and advocate making power-awareness a primary objective in the design and configuration of networks and network protocols.

Additionally Das et al. (2008) demonstrated the ability of an autonomic multi-agent approach to manage power and performance objectives in server clusters through a prototype. However, according to Qureshi et al. (2009) achieving zero-idle power without performance degradation is still an open challenge. Interviewee C further points out the difficultly with developing such solutions and says 'this is more of a long term dream right now because most of the routers on the network are for backup or reliability purpose (and are) running (all time) so.. principally, it is really hard..to do such kind of intelligence'.

The European Commission emphasises the role of **ICTs as an enabler of energy efficiency** across the economy in its communication 'Addressing the challenge of energy efficiency through Information and Communication Technologies' dated 13.5.2008. This states[11]: "*To put ICTs at the core of the energy efficiency effort and to enable them to reach their full potential, the following needs to be done:*

- *Firstly, it is necessary to foster research into novel ICT-based solutions and strengthen their take-up - so that the energy intensity of the economy can be further reduced by adding intelligence to components, equipment and services;*
- *Secondly, efforts should be made so that ICT leads by example and reduces the energy it uses - ICT industry accounts for approximately 2% of global CO_2 emissions, but is pervasive throughout all kinds of economic and social activities, and increasing its use will result in energy savings from the other industries;*
- *Thirdly and mainly, it is crucial to encourage structural changes aimed at realising the potential of ICT to enable energy efficiency across the economy, e.g. in business processes through the use of ICTs, e.g. substituting physical products by on-line services ('dematerialisation'), moving business to the internet (e.g. banking, real estate) and adopting new ways of working (videoconferencing, teleconferencing)".*

EFIPSANS introduces a holistic Generic Autonomic Network Architecture (GANA) i.e. the Architectural Reference Model of an autonomic node and network that serves the following purposes:

- To answer the question of how Self-Management or Autonomicity can be introduced into the fundamental architecture of Future Internet devices (GANA conformant devices).
- To use the GANA as a guide to examining and exploiting the strengths and features of IPv6 protocols in order to have the 'big picture' on where extensions to IPv6 protocols can be introduced and for what purposes.

11

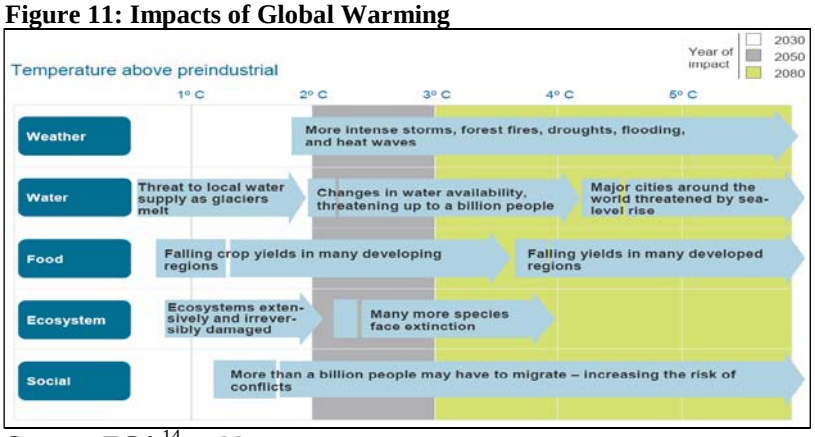
http://ec.europa.eu/information_society/activities/sustainable_growth/docs/com_2008_241_1_en.pdf

Therefore, GANA enhances the self-management and self-learning aspect of the IPv6 network, which can be further expanded and exploited to improve the energy efficiencies. It improves the interface into the systems so the engineers can push the policies for energy management, performance management etc. EFIPSANS is developing a framework that can be extended to include features like energy management in the ICT networks; however it is outside the scope of the EFIPSANS project to validate functionalities relating to energy management.

4.2. ICT Contributions to Emissions

Global warming aggravates natural calamities that concern the economic well being and social life of the people. It is seen as one of the biggest challenges facing mankind today. In light of the climate change, countries around the world are setting up new polices and exploring measures to control the rising temperatures that are expected to increase by 5^0C by the end of this century (Figure 11). For example, EU "20-20-20 goal" envisions reducing greenhouse gases by 20 percent below 1990 levels, making 20 percent improvement in energy efficiency, and using 20 percent renewable energy by 2020[12]. Latest data from the European Environmental Agency[13] for EU-27 confirms that buildings, transport and industry sectors are the three major contributors to emissions within the European Union. The internet already plays a role in reducing the energy used in these sectors by encouraging teleconferencing, teleshopping, e-magazines, increasing resource utilisation through various enterprise systems and enabling internet based energy management of buildings. Therefore ICT has the ability to not only reduce its own global footprint but also to help achieve energy savings in other areas by steering novel technological solutions.

Figure 11: Impacts of Global Warming



Source: ECA[14], p.22.

Interviewee A is of the opinion that the internet increases carbon emissions, for example, the increase in the number of routers and chips needed to transport the growing traffic. This, according to the Interviewee A, is a problem because it will easily eat-up any amount of energy saved through an intelligent network energy management mechanism. Gartner (2007) estimated for the first time that the ICT industry was responsible for 2 percent of global carbon emissions. This included the embodied carbon from the design, manufacturing and distribution of the various ICT devices; and the carbon footprint from use of personal computers, servers, cooling, fixed and mobile telephony, local area network, office telecommunications and printers. Subsequently The Climate Group (2008) further categorised

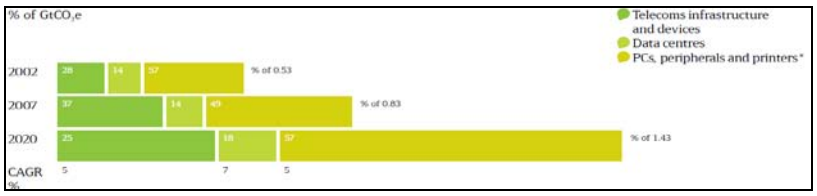
12 http://ec.europa.eu/environment/climat/climate_action.htm

13 http://dataservice.eea.europa.eu/atlas/viewdata/viewpub.asp?id=4038

14 http://www.mckinsey.com/App_Media/Images/Page_Images/Offices/SocialSector/PDF/ECA_Shaping_Climate%20Resilent_Development.pdf

the ICT global footprint by sub-sector (Figure 12). It is interesting to note from this study conducted as part of the Global e-Sustainability Initiative that the Telecoms Infrastructure and Devices sector alone will be responsible for 25 percent of the estimated 1.43 Gt carbon emissions for the ICT industry or 360 million tonnes of CO_2 equivalent by 2020.

Figure 12: Global Footprint by ICT Sub-Sector



Source: The Climate Group (2008)

Interviewees C and E indicate that IPv6 will enable some energy savings. Interviewee C thinks IPv6 could provide energy efficiencies for mobile phone batteries by avoiding NAT traversing. Interviewee E explains in order to keep alive their network connections the battery operated devices have to keep sending packets at regular intervals even when they are not in active use. This results in electricity wastage from the batteries, which can be avoided using peer end-to-end, as IPv6 is capable of providing a private IP address to each device. In this way the battery operated network devices 'do not need to wake up every few hours to reserve mapping between local address and some public address on some middle box' says Interviewee E.

4.3.New Regulations for Energy Management

In December 2008, the European Parliament approved a new EU climate change package applicable to all its 27 member states. The revised EU Emission Trading System (ETS) will apply from 2013 to 2020 and sets a target of 21 percent reduction in greenhouse gas emissions compared to reported 2005 levels (European Parliament, 2008). The ETS allows firms in one EU country to buy allowances in any other and is basically a "cap and trade system". The non-ETS sources like buildings and transport are also required to reduce the overall emissions by 10 percent and contribute towards the aim to cap the global temperature increase at 2^0C.

Similar initiatives are also seen in other parts of the world as the issues surrounding climate change take high political priority. For example, carbon emissions target levels set by Kyoto Protocol (signed up by 34 countries), countries like UK, Norway, China, etc, have their own target levels, and so does the state of California in the United States. In order to drive the eco-friendly measures, the Environmental Protection Agency (EPA) in the US even proposed a system of imposing carbon tax. Such initiatives will soon become a reality as energy prices and demand continue to go up everyday. McKinsey supports this as 82 percent of the 2,192 executives surveyed expect some form of climate change regulation in their companies' home country within five years from 2008 (McKinsey, 2008). For example, Republic of Ireland has already introduced carbon tax. Interviewee D comments that the gap between the other critical factors of the business and the need for energy savings is quite high and it can only be reduced either through government intervention (in the form of incentives, tax credits etc.) or pushed by the scarce energy supply itself.

The green regulations in place for the IT industry are mostly voluntary at present but are likely to become mandatory and more stringent in the future. For example, the EPA has proposed that large data centres use energy meters as a first step toward creating operating-efficiency standards while the European Union has issued a voluntary code of conduct laying out best practices for running data centres at higher levels of efficiency (Forrest et al, 2008).

Consequently, companies are getting ready to incorporate energy efficiency capabilities into their business so that they are able to meet the future energy regulations.

4.4. Towards Green Branding

Green marketing is not a new concept but in light of global warming companies are setting up aggressive goals to improve their Corporate Social Responsibility (CSR) image. Grant (2008) defines "A green brand is one that offers a significant eco-advantage over the incumbents and which hence appeals to those who are willing to making green a high priority". Green branding stems from the belief that customers have CSR problems, and they will reward the companies able to meet their requirements while addressing the environment at the same time. This consumer segment is popularly known as the 'green consumer' (Pedersen and Neergaard, 2005). However, Rex and Baumann (2006) argue that the market share of such consumers is low and hence there is a greater need to increase awareness and attract a wider range of customers to green products and services.

McKinsey (2008) identified the motivations by industry sector that encourage companies to take actions regarding climate change where corporate reputation clearly stands out as the most significant factor across all industry sectors. Moreover, companies anticipate that a reputation for eco-friendliness will attract talented people to come and work for them and provide a competitive edge. Therefore, they are embracing more sustainable business practices as we enter into an era of environmental revolution. Green initiatives will not only provide the opportunity for brand capitalisation but also real economic benefits to the companies. For example:

- Operational efficiencies through energy savings is the biggest economic motivation as it cuts energy costs and directly contributes to the Return on Investment.
- Reduced carbon tax and energy footprint of the company
- Carbon credits
- Conforms to the regulations and avoids related penalties
- Often there are incentives from the government for adopting eco-friendly practices.

On the demand side, it is argued that the benefits of using an eco-friendly product are not conveyed effectively to the customers as they are often unable to differentiate them from others. Only a few eco-friendly products are able to attract the customer's attention while others remain in obscurity (Pedersen and Neergaard, 2005). In order to overcome this limitation, Hartmann et al. (2005) suggest that adverts or visual stimuli of such products must convey the emotional benefits alongside the functional benefits to enable customers to perceive their real environmental benefits. For example, car adverts showing a family trip to a picturesque place on an eco-friendly family car. This helps consumers relate closely to the products and develop a more favourable perception of the product and the brand.

Right market positioning is very important as it helps create a unique identity of the company and its products and services in the minds of the target customers. However, the conventional factors like availability and price continue to play the most important role in driving the purchase decisions towards green products and services (Bhate, 2006). On the other hand Pedersen and Neergaard, (2005) argue that the preferences of the green consumer market is not clearly understood. First and Khetriwal (2008) support this view and confirm that there is no conclusive evidence whether consumers reward eco-friendly companies and punish the laggards. On similar lines, Interviewee D comments that at present there is no market evidence or data that suggests customers prefer to do business with energy efficient companies.

According to Rex and Baumann (2006) most companies have resorted to only eco-labelling in their pursuit to green positioning. Furthermore, Peattie and Crane (2005) argue that firms

have compartmentalised their green strategies instead of applying them holistically to the entire value chain. In order to measure a company's commitment to the environment, First and Khetriwal (2008) suggest examining how deep the eco-friendly policies and practices are embedded and reflected through every activity of the organisation. As Hatch and Schultz (2001) emphasise, corporate branding is an interplay between the strategic vision, organisational culture and corporate image, that needs a shift of focus from:

- Product to the company
- Customers to multiple stakeholders
- Short (life of the product) to long (life of the company) time horizon
- Functional to strategic importance to the company

Most importantly, public support and government policy implementation in this direction is expected to influence and favour the decision of the customers to purchase environmentally friendly products (Bhate, 2006; Peattie and Crane, 2005). It will be difficult for companies to balance sustainable business practices while meeting the competition at the same time without the public awareness and the right policies in place.

4.5. Current Approaches to Green IT

Network-connected elements and devices offer a challenging and rewarding opportunity to recognise and reduce carbon footprint. To this effect, a number of complementary Green ICT initiatives being developed internationally by consortia are aspirational and only at early stages, such as GeSI , Climatesavers and GreenGrid. A number of measures ranging from increasing the use of alternative energy, applying innovative designs, virtualisation and consolidation are being explored to reduce the ICT energy consumption.

Data centre operators and computing equipment vendors such as Microsoft, Dell, HP, Intel Corporation and NEC Corporation have come together to suggest de facto standardised interfaces to server equipment in the Intelligent Platform Management Interface (IPMI) initiative[15]. Also, controllers that provide the interface between servers and disk drives are being developed with intelligent power management capabilities to save power consumption[16]. This approach to storage power management is not integrated into existing telecom Network Management Systems.

It is estimated that radio base stations are the highest contributors of CO_2 emissions[17]. On the wireline side including for backhaul, the power reduction requirements and reducing truck rolls play an equally important role. Telecom equipment vendors are currently experimenting with ways to increase the capacity of the base stations while intelligently shutting down the systems during periods of low traffic. These are very specific to radio networks, are non-interoperable and are not coordinated with total IP system traffic.

Other equipment vendors such as router manufacturers, air conditioning suppliers and others have bespoke technology all addressing the issue of energy savings. However, these initiatives are also piecemeal and leave network operators with even more costly data integration and application synchronisation problems. Moreover, successful centralised network energy management is difficult to achieve because it is not easy to set policies for all possible events and actions[18]. Cisco Energy Wise and IBM Tivoli solutions have come together in an attempt to achieve this goal. At present, Interviewee D (like most customers)

[15] http://www.intel.com/design/servers/ipmi/index.htm

[16] http://www.aberdeen.com/c/report/market_alert/5471-MA-adaptec-implementing-green-storage.pdf

[17] http://www.wirelessweek.com/Article-Going_Green.aspx

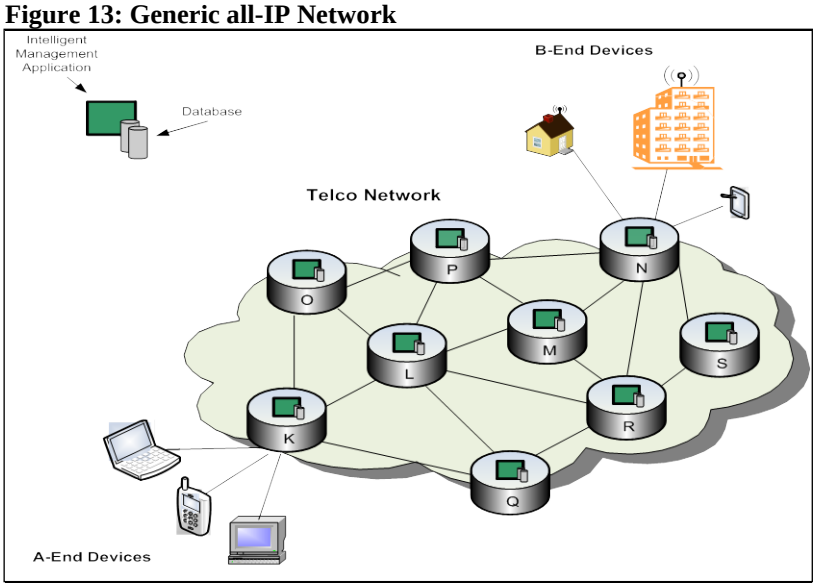
[18] http://www.verdiem.com/docs/Solution%20Comparison.External.pdf

does not see any notable improvements from the vendor's side and is of the opinion that the data centres are still operating in the same way. Therefore, users and vendors of ICT alike will need to innovate to improve energy efficiency of devices, components, other equipments, and data centres.

4.6. Green Communications Scenario

A scenario utilising an Intelligent Management Application (IMA) to reduce the energy consumed by the network(s) of the Telecommunications Network Operators (TNOs) is presented below. TNOs normally design their networks based on the maximum amount of traffic that may flow through the network. Once set up, the entire network is operational at all times- even when the traffic is at a minimum. The IP routing algorithms of such networks are designed to spread the current traffic load evenly throughout the system. This may leave many of the trunks operating at 10-20 percent capacity at low traffic times such as from midnight to early morning resulting in energy wastage

Figure 13: Generic all-IP Network



In the Figure 13, consider a generic all-IP network where traffic flowing from the A-End Devices to the B-End devices would be balanced across the different paths {KLMN}, {KOPN}, {KLPN}, {KLRN} etc. This traffic is directed either by static routing algorithms defined in the Routing table of each router or by proportional routing using parameters available to the router (failure rates transmitting to adjacent routers, etc.). A great deal of human intervention is needed in managing such networks using various monitoring tools.

The novel approach and goal of this scenario is to process IP traffic using the minimum number of resources while still maintaining the operator's defined quality targets. To determine the "best" route to send traffic from ingress node K to egress node N the IMA measures the available bandwidth and effective bandwidth figures for each path through the system from K to N (KLMN, KLPN, KOPN, KQRN, etc.). The IMA then scores each path between node K and node N where the highest score identifies the busiest path that still has sufficient capacity to carry traffic, without reducing the quality of service below a threshold set by the Operator.

In order to achieve this, it is important to be able to extract key traffic data from the network and correlate it to the power management decisions accordingly. Additionally, network management mechanisms developed should allow network elements to be switched on and off as needed in a controlled fashion, thus minimising energy consumption of the network as

a whole. Over time, through traffic profiling, data mining, feedback analysis and monitoring of usage patterns, the self-learning component of an IMA can observe and learn the behaviour of the network and understand its characteristics so that, in the future, it can optimise the use of network resource and minimise energy wastage, particularly in off-peak periods.

This scenario highlights the approach to initiate a controlled shutdown and report on the potential energy savings made. Similarly when the traffic ramps up and QoS levels start to be under pressure, the IMA will turn those resources back on to meet the traffic demand using prearranged methods. Interviewee B gives an example (see Appendix C) emphasising that one important aspect of autonomic networks is its ability to adapt to change and if the patterns of usage can be accurately identified then such intelligent re-routing can be realisable.

4.7. Supporting Business Strategy

Aberdeen Group identified the rising cost of energy in 2008 as the number one factor influencing organisations to adopt a green initiative[19]. Additionally, Forrestor asserts that companies will use green products and green corporate behaviour as a way to appeal to the growing segment of 'green consumers'[20]. However, there is a cost associated with these benefits. According to analyst and research firm S2 Intelligence, most big businesses will collectively spend at least US$ 595 billion, three times more than they spent on Y2K, to support systems for carbon accounting and sustainability reporting[21].

In line with the above trends, major telecommunications providers have set goals to reduce their carbon footprint. For example, France Telecom is planning to reduce the greenhouse emissions per customer by 20 percent between 2006 and 2020, and British Telecom claims to have reduced its carbon footprint by 60 percent since 1996, and has an objective to reach 80 percent by 2016[22].

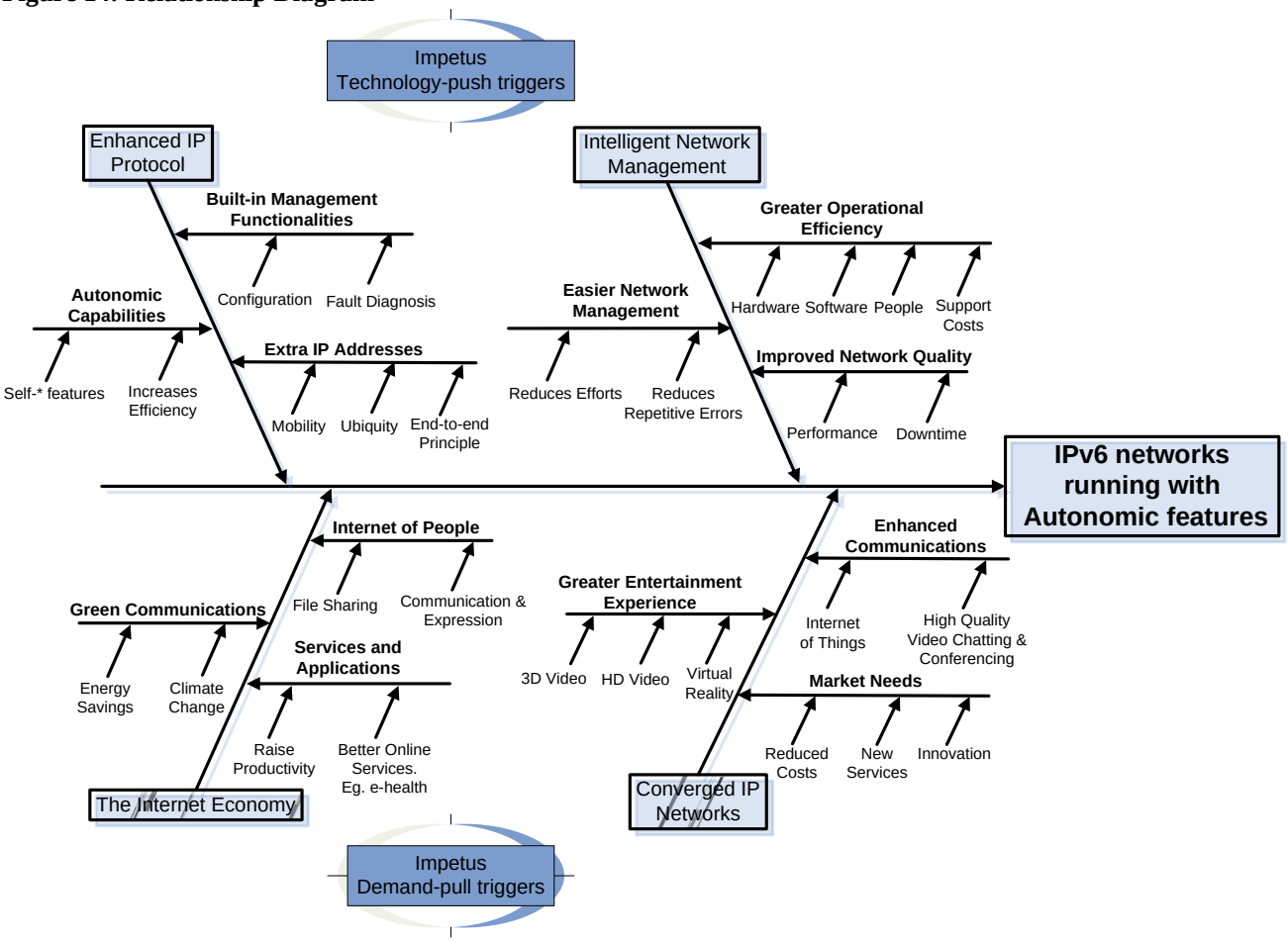
Deloitte (2007) analysis report highlights that competitive advantage firmly lies with companies who choose to be among the Early Adopters and Early Majority of Green solutions. The forecast suggest that there will be more regulatory influence in the future along with the increased costs and risks towards compliance. As a result the companies those delay adapting to the new changes risk eroding their competitiveness in the marketplace. Therefore, sustainable business practices are becoming a key competitive differentiator and are likely to provide the much needed post-recession trump card to survive and excel in the highly competitive business environment.

19 http://www.aberdeen.com/c/report/research_briefs/4941-RB-green-strategies-help-costs.pdf
20 http://www.forrester.com/Research/PDF/0,5110,43494,00.pdf
21 http://www.networkworld.com/news/2008/031208-green-it-spend-to-outstrip.html
22 http://www.emersonnetworkpower.com/energysystems/pdf/ES-113_EnergyLogic.pdf

5. Conclusions and Future Work

A systematic review of the social and economic factors that influence the adoption of IPv6 networks running with autonomic features was conducted in this study. The resulting technology-push and the demand-pull triggers based on our primary data are identified and represented in the form of a relationship diagram as shown below. Additionally, each trigger is also linked to its primary and secondary causes. In this way, the cause and effect diagram presents an effective classification of the various factors as identified from this study that are likely to result in the single effect – IPv6 networks with autonomic capabilities.

Figure 14: Relationship Diagram



5.1. Technology-Push Triggers

Intelligent Network Management and Enhanced IP Protocols are seen as the two main technology-push triggers towards IPv6 networks with autonomic features. Additionally, each trigger is influenced by three primary causes. The movement towards intelligent network management technologies is mainly driven by the need for:

- Greater operational efficiency of the networks
- Better network quality
- Easier network management.

Growing network complexity due to the increase in the number of devices and technologies being managed affects the operational efficiency of the networks. Additional network management tools or applications, hardware devices along with well trained staff are needed

to manage such networks, which add to the operational costs. Apart from that a large percentage of the operational budget is also spent on maintenance and support costs to the software and hardware vendors. Any compromise on the present operational aspects of network management has implications on the network quality due to network downtime or performance degradation. Such is the significance of network quality to the businesses that they resort to over-provisioning and reserve back-up resources to avoid any critical failure.

These economically unsustainable network management problems are further amplified by the reoccurrences of the same problems giving rise to multiple error alarms making it more difficult for the network engineers to assess the root-cause for precise diagnosis. As a result, managing the networks with higher levels of efficiency still remains a challenge, and this indicates an existing gap between the supply and demand of network management technologies. This gap is expected to be reduced by introducing some level of intelligence into the networks for various purposes like self-configuration, fault diagnosis, application performance etc. Consequently, the self-* features are likely to ease the management of the networks by providing more functionality and performance at lower cost.

On similar lines, having built-in management functionalities in the IP protocol itself will further facilitate the progressive increase in the level of autonomy of the networks. Moreover, the IPv4 protocol is running out of the addresses and the shift to another protocol appears inevitable considering the raising demand for IP addresses, especially for mobility and ubiquity purposes. Additional IP addresses are also required for the validity of the end-to-end principle that reduces the barriers to entry for all services, which is necessary to continue encourage innovation over the internet. In this regard, IPv6 overcomes the limitations of the current IPv4 along with the latency issues that multiple NAT layers introduce. Therefore, the movement towards IPv6 adoption is mainly driven by the need for:

- Built-in management functionalities for more efficient network management
- Incorporating autonomic capabilities in to the networks
- Make available large number of IP addresses.

5.2. Demand-Pull Triggers

The internet has become an integral part of the lives of 1.67 billion people or 25 percent of the world's population (see Table 7). Therefore the internet by itself is one of the major economies in the world. The network infrastructure has evolved a long way to support high quality voice and video over the internet, and is moving towards converged IP networks in order to satisfy the societal demands for such services at a cheaper price. Therefore, the convergence to an all-IP network (transformation) and the need for innovative services (demand) over the internet are primarily being driven by the market and the people that push the technological advancements to suit their needs. As a result, the primary causes for demand-pull factor (Converged IP Networks) are:

- Greater entertainment experience
- Enhanced communications
- Market needs.

In addition to this, internet-based applications enable numerous online services to the benefit of the people as well as the businesses making the overall process transparent and more efficient. Furthermore, Internet of Things that utilises sensor networks, RFID etc is expected to provide important data for various purposes including logistics management and environmental monitoring. On the other hand, social networks, emails, chatting (text, voice and video), blogs, interactive wikis, sharing photos and video clips have become an indispensable part of our lives In this way, the internet economy influences many aspects of our lives and businesses, exhibiting a correlation with GDP growth, productivity and

employment levels that have major implications on the standard of living as discussed in Section 3 of this report. Therefore, the primary causes shaping the internet economy are:

- Internet of people
- Green Communications
- Services and applications

Internet-based applications underlie major advances in education, e-government, science and technology, business management and environmental management. However, the health sector still appears to be under-developed in terms of ICT usage compared to others, but this is likely to change in order to address the concerns of the ageing societies and dispersed population. On the other hand, the world leaders are currently in the process of negotiating a global climate change deal, and the internet is also gearing up to meet the sustainable demands of the future. In this regard, the socio-political impacts of green communications were discussed in detail to highlight the need and the potential of intelligent network management technologies. The message that green practices do not really provide a competitive edge to the companies is comparable to 'ethical trading' a few years ago. Originally ethical trading was very much the preserve of a small minority prepared to trade-off gain and ethics but now ethical trading is big mainstream business. On similar lines it is possible for green credentials to gain the same foothold in the next few years. Additionally, new developments like smart electricity grid networks call for new internet standards as different networks and technologies need to work together, the present internet was not built for such requirements. Intelligent network management capabilities on IPv6 networks offer the enabling technology to meet the above socio-political and business needs.

5.3. Future Work

Socio-economic Report-2 of the EFIPSANS project adds to the debate regarding the adoption of IPv6 networks and autonomic network management technologies. This study indicates that there is a noticeable resistance to change primarily because of the apprehension that it may undermine the existing network management practices giving rise to new problems in the future. For example, NAT is not easily dispensed with for similar reasons. Such apprehensions are further augmented by the lack of realistic deployments of autonomic technologies and wide scale IPv6 adoption. As a result, the first movers are hard to persuade as they wait and watch for more proofs and success stories in order to make the move. This in turn slows down the diffusion and maturity process of the new technology. Therefore, it is important that the benefits and reliability of the EFIPSANS approach are proved under realistic conditions. In order to support this goal, the final year of the EFIPSANS socio-economic study will focus on:

- Factors contributing to the individual and organisational resistance to change
- Characteristics of this innovation and its disruptive nature
- Technical survey to develop a deeper understating of the technology-push factors
- Consolidated final report presenting a summary of the key results for the entire duration of this study.

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Appendix A- Problem Description (a)

Interviewee C Scenario: Telecom Network

‘(Regarding the) major difficulty factor for organisation of networks..what we are considering is if we can really make the IP network intelligent enough..then the future generation base station (can be) connected through the Ethernet cable, (and) then all the base station configuration or management coordination (will be) automatically downloaded from network side but today (it is) still impossible even (though) we already have the Ethernet cable connection, there are other reason we cannot do that. I think (it is because of) the technical driven or problems (with the understanding) of the requirements’.

Appendix B- Problem Description (b)

Interviewee D Scenario: Enterprise Network

‘There is lot of things that can be pointed out in a particular data centre or in a particular network. But based on my experience we had a situation wherein it was quite a simple operation but the criticality of the service involved was quite high because it was a production server..(for the) website that had e-commerce running at the backend.

Now we had a simple situation where we were trying to move this particular application into a de-militarised zone (DMZ) and it was done quite a lot of times by myself in a lot of locations. (The task was scheduled off-market hours) and the task was just a simple thing to change the IP of a particular interface, which is purely a networking task though the changes were required from the operating systems side, the overall task was the responsibility of the network team.

So there we had an issue because we has to physically remove the cable and plug-in a new cable which was actually connected to the new DMZ network. Now this is not acceptable in such kind of situation and once it was done the configuration was changed in the operating system level and physical cable of the switch was down and we started and it wouldn’t start and there was no way we would know what was the issue because we were completely blank we didn’t have any kind of messages coming up from either the switch or from the operating system level because for the operating system everything was fine. The interface was up and the right IP was allocated but from the network side we could not figure out what went wrong.

This actually happened because we had to physically switch now if we had a logical switch this wouldn’t have occurred. The rollback was a big problem because we went beyond the schedule, got in to the market time and we had to switch the traffic for that particular service from one cluster to another cluster. This is a typical example how things can go wrong. We don’t have efficient network management tools to manage this’.

Appendix C- Intelligent Energy Management

Interviewee B Scenario: Intelligent re-routing

'I think that's one of the interesting things that has been discussed in autonomic networks. Because inside autonomic related projects one of the examples is about adapting to changes and a change is not necessarily a bad thing. What is a change is something like to said you have seasonal traffic shapes you have winter and summer time and we have for instance small towns that during the summer are full of tourists so you need special or more bandwidth than usual. It's a sociological problem the way cities are growing. Of course if we can identify those patterns then we can use them for re-routing more intelligently using more optimised way of resources and shutting down a system..is a possibility. I think there are good possibilities for that it is not just a fantasy.'

Appendix D- High Level Interview Questions

1) Most of the network management problems are repetitive in nature and few automatic processes exist to prevent them from recurring multiple times (from our online survey) leading to a more evident trade-off between personnel resources and network quality. What is your outlook on the operational efficiency of today's networks?

2) What solutions are emerging to solve economically unsustainable network management problems?

3) In what way will IPv6 will be economically beneficial?

4) Will the internet play an important role in reducing the carbon footprints within and outside the ICT sector?

5) What societal needs are likely to be addressed in the future by the internet based technologies and services?

Appendix E- Survey Questionnaire

IPv6 and Autonomics Survey

2) Network Management

	strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
Are today's networks a lot more complex than five years ago?	○	○	○	○	○
Is interoperability of major concern in network management?	○	○	○	○	○
Automatic network management tools are quite popular	○	○	○	○	○
Is there a shortage of appropriately trained network engineers to manage such networks?	○	○	○	○	○
Is network management a significant component of an enterprise overall IT budget?	○	○	○	○	○
Most of the network management problems are repetitive in nature	○	○	○	○	○

3) What percentage of effort is spent on routine network management tasks?

	very low	low	medium	high	very high
Fault management	○	○	○	○	○
Configuration and change management	○	○	○	○	○
Performance management	○	○	○	○	○
Security management	○	○	○	○	○

4) The network management costs are predominantly devoted towards:

○ Running the business (maintain)
○ Changing the business (new initiatives)

5) What % (approximate) of your IT budget is spent on the following?

	5%-20%	20%-40%	40%-60%	60%-80%	>80%
Hardware	○	○	○	○	○
Software	○	○	○	○	○
People	○	○	○	○	○

6) An ideal IT budget distribution would be

	5%-20%	20%-40%	40%-60%	60%-80%	>80%
Hardware	○	○	○	○	○
Software	○	○	○	○	○
People	○	○	○	○	○

7) What percentage of your total traffic is IPv6?

○ None
○ <5%
○ 5%-20%
○ 20%-50%
○ 50%-80%
○ >80%

8) Autonomics awareness

	yes	no
Are you aware of autonomics?	○	○
Are you involved in any research in autonomicity with IPv4?	○	○
Are you involved in any research in autonomicity with IPv6?	○	○
Do you make any difference between autonomic and autonomous?	○	○
Is autonomicty similar to auto configuration?	○	○
Did you use any autonomic network or applications?	○	○
Do you think autonomic networking will be deployed within the next three years?	○	○
Have you heard about the ETSI AFI group (Autonomic Future Internet)?	○	○
Do you wish to participate in the standardisation work done by AFI?	○	○

9) Are you aware of any autonomic application, if so what?

Do you use any autonomic application, if so what?

Are you considering any autonomic application, if so what?

10) What will be the likely benefits of autonomics to ISPs? Click one or more

- ☐ Easy to install networks
- ☐ Easy to manage networks
- ☐ Easy to maintain remote networks
- ☐ Easy to upgrade networks
- ☐ Reduces OPEX
- ☐ Reduces CAPEX
- ☐ Infrastructure becomes highly exploitable
- ☐ Saves me time
- ☐ Reduces down time
- ☐ Ensures Quality of Service

11) What will be the likely benefits of autonomics to users? Click one or more

- ☐ Ease of use
- ☐ No need to know about network (Infrastructure agnostic)
- ☐ Saves me time
- ☐ Reduces my down time
- ☐ Improves performance of applications

12) What are the triggers for moving toward IPv6?

	strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
Convergence on ICT technologies and services that needs such protocol	○	○	○	○	○
Regulation that requires me to move towards IPv6	○	○	○	○	○
There is a market demand	○	○	○	○	○
Because of IPv6 security features	○	○	○	○	○
Lack of IPv4 addresses	○	○	○	○	○
Low operational expenses (Opex)	○	○	○	○	○
I am running applications requiring IPv6 features	○	○	○	○	○
Allows permanent addresses	○	○	○	○	○
Restore end-to-end transparency	○	○	○	○	○
Pave the way to triple play (data voice & video) model	○	○	○	○	○
Allows push services	○	○	○	○	○
Better handling of multicasting	○	○	○	○	○
Enhanced QoS	○	○	○	○	○
Improved mobility mechanisms	○	○	○	○	○
Easy plug and play/Autoconfiguration services	○	○	○	○	○

13) What are the inhibitors to IPv6 adoption?

	strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
Standardisation is not yet stable	○	○	○	○	○
Lack of product certification	○	○	○	○	○
It is not a mature enough technology	○	○	○	○	○
Lack of regulation enforcing IPv6 adoption	○	○	○	○	○
Cost too much for return	○	○	○	○	○
Lack of market demand	○	○	○	○	○
IPv4 is just good enough	○	○	○	○	○
Lack of security features	○	○	○	○	○
Lack of available applications	○	○	○	○	○
Lack of available hardware solutions	○	○	○	○	○
Lack of IPv6 services	○	○	○	○	○

14)Would you consider moving to a self-managed network?

- ○ No
- ○ Unlikely
- ○ Would trial
- ○ Would test
- ○ Yes

Please forward this survey to your contacts who can provide us valuable inputs for this study or provide us their name and company. Thank you for your help and any feedback on this survey will be much appreciated.