NEXT GENERATION NETWORK PERFORMANCE MANAGEMENT: A BUSINESS PERSPECTIVE

C Harding

CSIR (DPSS)

CHarding@CSIR.co.za

B Naudé

CSIR (DPSS)

BNaude@CSIR.co.za

Abstract. This paper addresses a Next Generation Network (NGN) performance management model in a business context. The CSIR is currently in the process of the concept design for the new Next Generation Communications Network (NGCN) for a large South African organization. The objective for the NGCN is to provide an integrated access and transport platform that supports a suite of advanced, end-to-end managed, voice, data, and video services. A concept design for the NGCN was done using International Telecommunications Union standards and a NGN architectural framework was designed to support the objective and business of the customer. The primary focus of the NGN is the delivery of a service that satisfies the quality requirements of the customer/user across a multitude of transport and access technologies on almost any user device. The most important and integral component of the NGCN NGN Architectural Framework is the physical and logical management of the network elements and services to provide maximum utility for the investment made.

Implementing a new NGN requires large capital investment, which in turn requires the system to have a return on investment. This need to determine the value received from the investment lead to the development of a system performance model that could be related back to business performance.

Performance management is examined from a user, service provider and enterprise perspective to determine the different views of performance and returns. The characteristics of a NGN are identified to determine the crucial performance parameters of a NGN and best practice for managing a NGN is established. The Business case of a NGN is examined from an enterprise and service provider point of view to enable the correlation between the performance of the NGN, investment cost and return on investment.

The result is a model that defines the performance of a NGN network from a network management, users and investment perspective.

Introduction

The CSIR has the responsibility of defining the System Specification for the new static and mobile Next Generation Communications Network (NGCN) infrastructure for a large South African organization referred to as the customer in the subsequent text.

The NGCN is a dynamic communication network that will provide voice, video and data services across South Africa and to remote sites outside the borders of South Africa. The challenge is to provide these services across a multitude of transport media (satellite, microwave, wireless, fixed wire or fibre-optics, etc.) and a wide range of user end devices.

The CSIR followed the process specified in Figure 1 to derive the logical and physical architecture that was needed to satisfy the current and future needs of the customer.

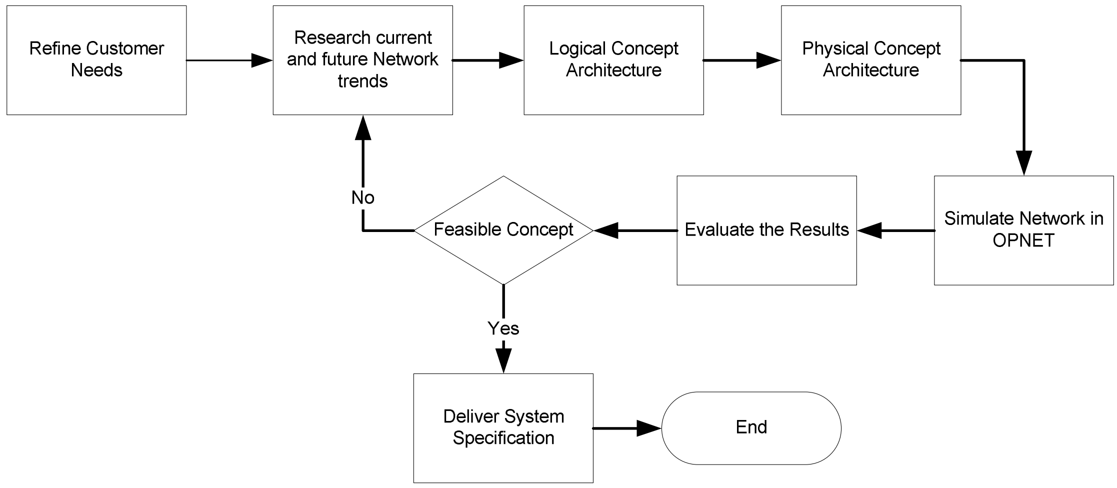

Figure 1. The NGCN System Specification Process

The process started with the Needs Analysis to ensure that the project team understood the needs of the customer defined in the functional study. Next a baseline of requirements was established and the project team started with research into the current and future Communications Network trends to establish a logical and physical architecture for the NGCN. The team decided that a Next Generation Network (NGN) would be the best architecture to satisfy the needs of the customer. The International Telecommunications Union (ITU) definition of a NGN is:

"*A Next Generation Network (NGN) is a packet-based network able to provide Telecommunication Services to users and able to make use of multiple broadband, QoS-enabled transport technologies and in which service-related functions are independent of the underlying transport-related technologies. It enables unfettered access for users to networks and to competing service providers and services of their choice. It supports generalised mobility that will allow consistent and ubiquitous provision of services to users.*" ITU-T Recommendation Y.2001 (12/2004).

The diagram below shows the architecture that has been defined for the NGN in ITU-T Rec. Y.2012.

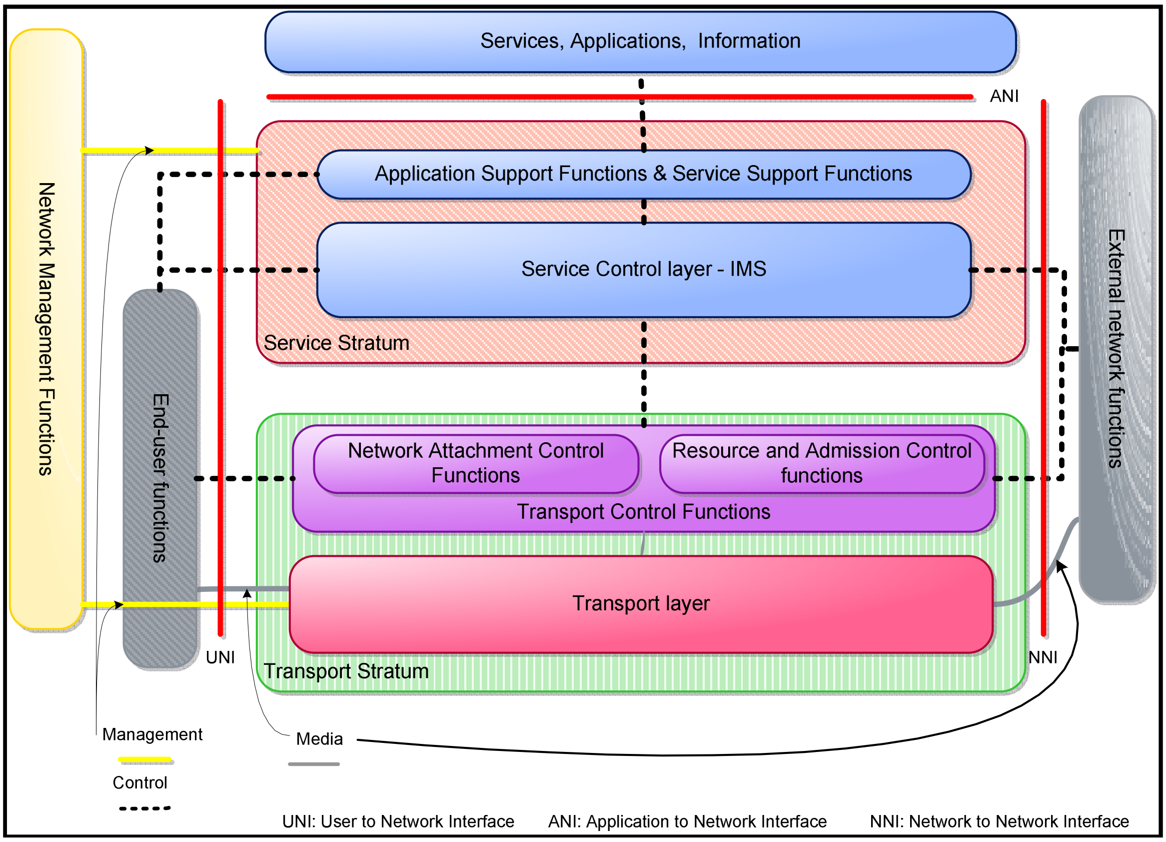

Figure 2. Functional Architecture

According to Y.2012, the NGN architecture supports the delivery of multimedia services and content delivery services, including video streaming and broadcasting.

The NGN architecture defines a Network-Network Interface (NNI), User-Network Interface (UNI), and an Application Network Interface (ANI) as indicated by the thick red lines. The Transport stratum provides Internet Protocol (IP) connectivity services to NGN users under the control of Transport control functions, including the Network Attachment Control Functions (NACF) and Resource and Admission Control Functions (RACF).

The architecture is composed of the service and transport stratum, the access device function, the service/application/content/information layer, network management functions and other customer and non-customer networks external to the NGCN. The thick yellow lines mark the management data paths. The thick grey lines mark the user data or media paths. The dashed black lines mark the signalling or control data paths.

Problem Statement

As part of the Systems Engineering (SE) process one should take the customers' business case into consideration to ensure that the SE activities on a project maximize the return on investment (ROI) of the project. Blanchard (2009) states the following:

"The purpose of engineering activities of design and analysis is to determine how physical factors may be altered to create the ***most utility for the least cost****, in terms of production cost, product service cost and social cost."*

The International Council of Systems Engineering (INCOSE) SE Handbook makes the following statement:

"Every system life cycle consists of the ***business aspect*** *(business case),* ***the budget aspect***

(funding), and the ***technical aspect*** *(product). The systems engineer creates technical solutions that are consistent with the business case and the funding constraints."*

Thus the SE activities for the NGCN project should provide maximum utility for the cost of the network.

But what is the business case and the utility to cost model for the NGCN?

The expected utility to cost function should theoretically be an exponential increase, the more money you invest in functionality the more functionality you will receive. The exponential growth is due to the combining functionalities to provide a higher level capability without a linear investment.

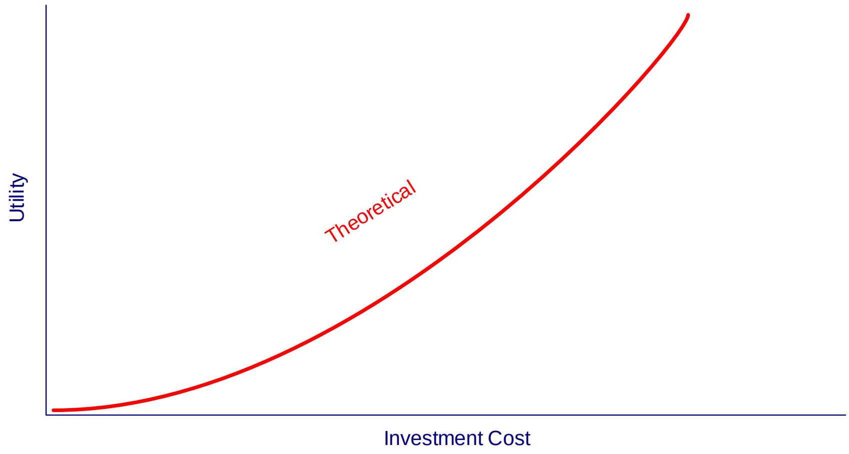

Figure 3. Theoretical Utility Function

The flaws with this theoretical model can be demonstrated by the law of diminishing returns. The law of diminishing returns state that the system will reach a point where increased investment cost will lead to excess utility that cannot be utilized. An analogy for the law of diminishing returns is the investment in an expensive high performance sports car that will be used on public roads with strict speed limits, the added investment cost does not provide extra utility since the utility is limited by the speed limit. This is illustrated in Figure 4, the customer can only utilize X utility provided through the NGN. Any investment providing utility more than X will be a wasted investment. The inverse is also true; investing in to little utility will cause an underperforming system which might become the bottleneck in the customer operations. Thus the utility to cost model for the NGCN should take into account what the customer can use now and in the future.

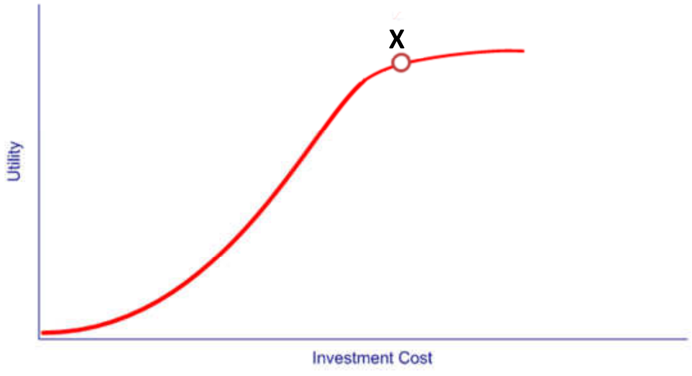

Figure 4. Customer Maximum Utility

Methodology

The NGCN as a network is a business enabler but cannot function on its own without applications, processes, users and user end devices such as cellular phones and computers. Thus in term of the utility to cost model we have to look at the User System Level (level 6) as defined by the systems hierarchy depicted in Figure 5.

Figure 5. System Hierarchy

The system hierarchy for the problem at an enterprise level is shown in Figure 6; the NGN is a subsystem of the organizational system, in this case the customer. On the same level as the NGN is the user system, the applications and processes (or doctrine) that forms part of the organizational system.

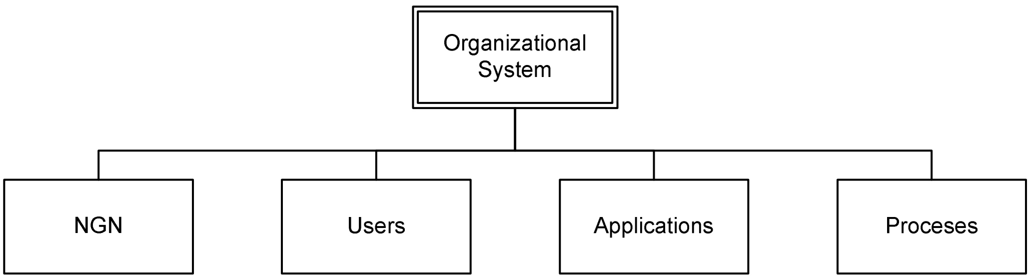

Figure 6. Problem System Breakdown

The utility to cost model for the NGN cannot be defined for the NGN alone, due to the fact the NGN on its own can't provide any utility without the other system elements. The utility to cost model should be determined through the influence the NGN has on the larger organizational system. The methodology that will be followed to solve the problem statement is depicted in Figure 7. The first step will be to determine the performance model for a NGN. The second step will be to determine the related organizational performance model for the NGN. Finally, the organizational model will be used to derive a NGN utility model.

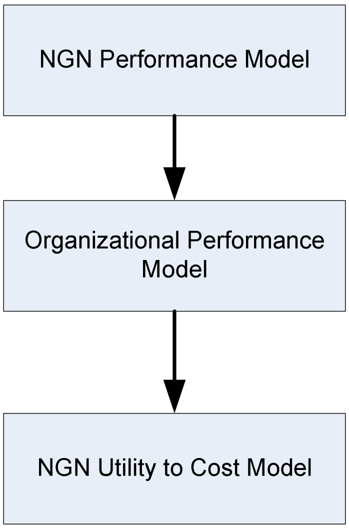

Figure 7. Methodology Followed

Characteristics of a NGN Performance Management Model

First we have to determine the utility for a NGN before we can define a model to measure performance into the business case. The utility definition will be done by deriving a NGN performance model. The primary focus of the NGN is the delivery of a service that satisfies the quality requirements of the customer/end users. The Quality of Service (QoS) comprises of requirements on all the aspects of a connection, such as service response time, loss, signal-to-noise ratio, cross-talk, echo, interrupts, frequency response, loudness levels, and so on. The quest for better QoS is also the reason why most network performance models have changed in the last few years from being data flow or connection orientated to service quality orientated.

The performance models should thus have a direct correlation to the QoS measurements within the network. Services are delivered by leveraging the Service and Transport layer of the NGN. To enable the performance model to deliver higher quality services we have to define a performance model that encapsulates both the Transport and Service layers of the NGN as defined by the ITU depicted in Figure 8, see ITU-T Y.2012.

Figure 8. The suggested NGN functional architecture as defined by the ITU

Transport layer Performance Model

The network performance is mostly dependent on the connection quality between terminal and terminal or terminal and machine. The NGN requires high-quality service delivery and thus naturally demands a high quality of network transport performance. The following capabilities adapted from Salina and Salina (2007) defines the performance model for the Transport Layer.

- Capable of adding, maintaining and removing the new/old access network, the transmission network and the transport network without affecting the delivery of service / application / content / information;
- Capable of managing multi-access networks and multi-transport networks which belong to different operators, including
  - registering and de-registering an access network,
  - monitoring the availability, load and performance of all the access networks,
  - registering and de-registering,
  - monitoring the availability, load and performance of all the access networks;
- Capable of setting up end(s)-to-end(s) connectivity with the optimum access and transport networks according to the service requirement provided by a Service Level Agreement (SLA), including
  - choosing the access network according to the user status (stationary or on-the-move, moving in the air or moving under the water), terminal capability, performance requirement and load,
  - choosing an adequate transport network according to the access network, interworked external network, performance requirement and load,
  - communicating the requirement to the interworked external network;
- Capable of maintaining the connectivity for an end-user moving at high speed across different wireless access technologies and networks (inter- and intra-system handover, roaming) without noticeable performance degradation of the connectivity;
- Capable of monitoring the performance of end-to-end connectivity, and activating the necessary measures when a potential or actual problem is dictated;
- Capable of providing consistent control mechanisms across access, transmission and transport, which are embedded in the network node to realize traffic prioritizing for end-to-end connectivity;
- Capable of interworking with interconnected networks across operators, across countries or across continents;

- Capable of monitoring the interconnected network performance (under the restrictions of the SLA);
- Capable of analyzing the collected past and current data to predict potential problems in the network, and activating preventive measures;
- Capable of detecting problems when they occur, analyzing the reason(s) for them and activating recovery measures; analyzing impacts on services and customers and providing essential information to management, operating personnel and customer care;
- Capable of acquiring information about the terminal connectivity capability (capable access technologies), access technology availability and network load;
- Capable of predicting network capacity according to traffic load monitoring and analysis.
- Capable of turning the network performance according to need.

Service Layer Performance Model

The service delivery is managed by the Service Layer and hence the Service Performance is dependent on the management of the Service delivery. The following capabilities define the performance model for the Service Layer:

- The Service layer will upon request of each service reference the SLA for the QoS requirements and will provide the QoS requirements to the transport control to set up adequate end-to-end connectivity
- The Service layer will monitor the availability and performance of each service and provide the capacity to ensure a constant service delivery.

The Service performance is perceived differently by the various stakeholders of a system owing to the differences in each stakeholder's frame of reference, cognitive processes and cognition. The stakeholders consist primarily of:

- Different types of system users which have different service use profiles.
- Business interest holders of the system which view the system performance from a business perspective.
- System operators which view the system performance from a technical viewpoint
- Smaller groupings with unique views

The above is placed in context in Figure 9.

Individual Frames of Reference: This is the baseline of all individual decisions and actions and is unique for each individual. It is also a constantly changing baseline which implies changing stakeholder behaviour.

Individual Cognitive Processes: The process of recognizing and understanding things by the individual. It is unique for each individual.

Stakeholder Cognition: The mental faculty of an individual for acquiring knowledge by means of reasoning, intuition, or perception and is intangible as it is in the minds of the stakeholders. In this space perception, value sets, assimilation, comprehension and decision making processes exist and decisions are made. It is the source of perceived reality and misalignment among stakeholders.

Reality: In this space the complete world data and information set exists. The individual will use only parts of the data and information as desired for whatever reason during the cognitive process. This data and information used is unique for each individual.

In short, all users of the NGCN will have a different perception of the QoS depending on their frame of reference. This perceived QoS should be the measure of the service delivered by the NGN.

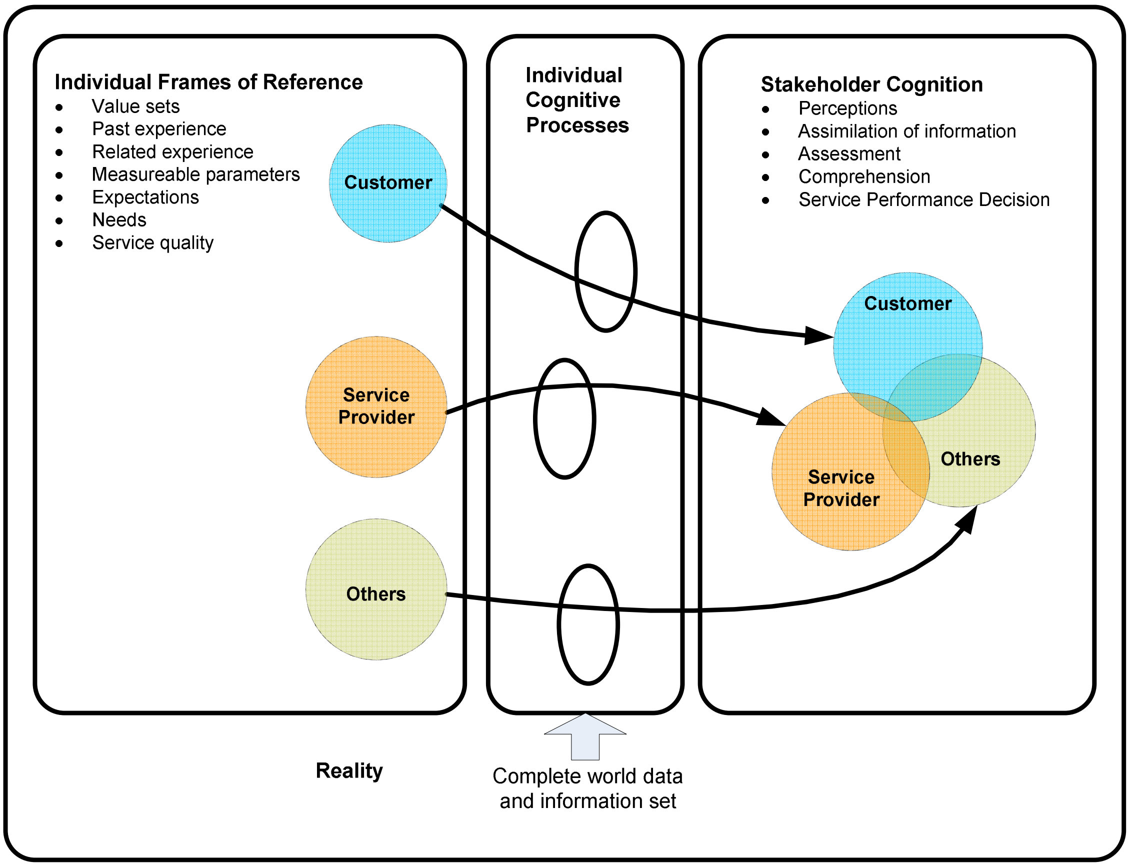

Figure 9. Stakeholder Performance Perspectives in Context

NGN Performance Overview

The factors identified in the previous section define parameters that enable the performance management of a NGN network. The performance parameters will be specified for two different levels. The first is the performance parameters on the network hardware level, determining the effectiveness with which the hardware is used. The second will be the performance parameters that measure the service delivery against the SLA, which in effect should measure the users' perceived service delivery. The customer perceived quality can be defined as the QoS that the customer expects. Quality that a customer expects is unfortunately a dynamic measure due to the fact that a new higher quality level today will be an accepted norm for service quality tomorrow.

The NGN performance model can be extended to include the effective use of resources. This refers to the utilization of the network resources. This can be defined as effective resource availability to ensure an end-to-end connection can be established with the minimum bandwidth and latency needed to deliver the service.

The NGN performance model can be summarized as:

$$NGN\ performance = Network\ Performance + Service\ Delivery\ Performance + Effective\ resouce\ Utilization \quad (1)$$

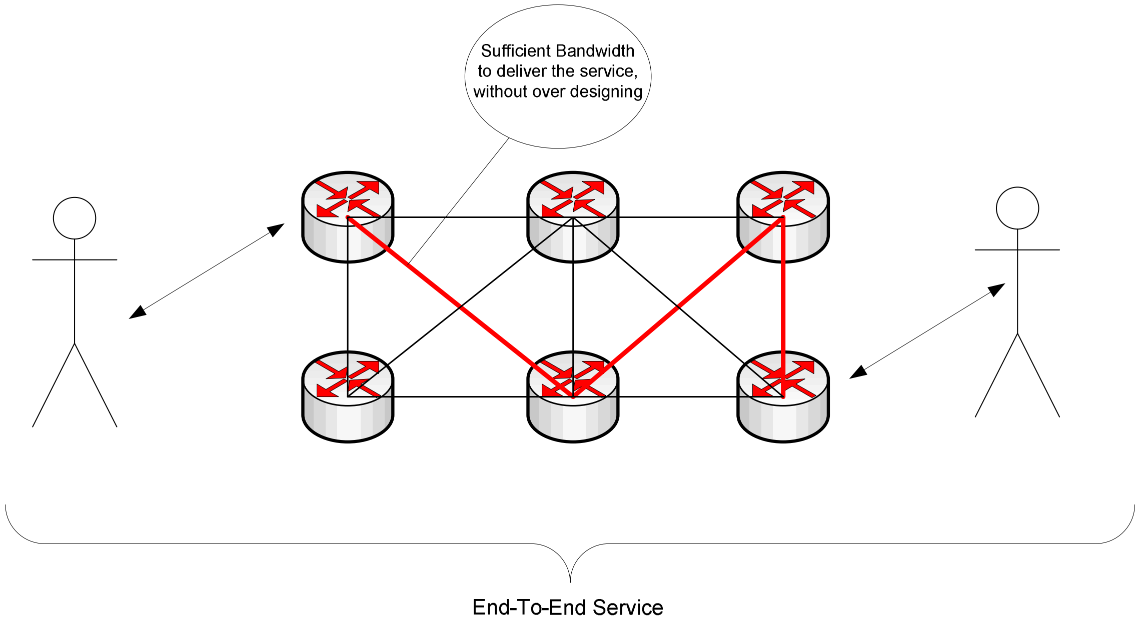

Figure 10. Effective End to End NGN utilization

Figure 10 depicts the NGN performance model. The network resources are effectively utilized to establish an end-to-end connection with the minimum bandwidth and latency needed to deliver the services required by the SLA. The network performance has to be managed as efficient as possible to ensure that the all the network resources is available for service delivery.

Organizational Performance Parameters

We have stated in the methodology section that the utility of the NGN cannot be measured on its own since a network cannot provide utility to an organization without devices like computers and cell phones connected to the network. The system will also need users and processes to perform tasks that provide utility to the organization. It is for this reason that we have to look at the influence that the NGN has on the organization, because the utility of the NGN needs to be measured at User System level.

The performance of the NGN does not necessarily mean that the organization that owns it gets optimal value from the network. The link between the performance of the NGN and the organization is very difficult to determine and dependant on whether the NGN is implemented as an Enterprise Network or Service Provider network.

For a Service Provider network the performance of the NGN can be directly translated to the ROI provided by the service income and can be considered a capital investment.

$$ROI = \frac{Net\ Profit}{Cost\ of\ investment} \quad (2)$$

For Enterprise networks the network infrastructure represents a capital investment and not a direct source of income. Bresnahan (Bresnahan and Trajtenberg, 1995) describes this type of technology implementation of the NGN for an enterprise as a “general purpose technology” and not as a traditional capital investment. The enterprise network can thus not be measured by using the ROI but instead should be measured on the enablement of the organizational business processes and Information and Communications Technology (ICT) services delivery through the network. The main focus of the NGN for the enterprise is to enable the enterprise to elevate any constrains in its operation which in turn should increase the profitability of the organization. Thus the NGN should increase productivity of the organization to better achieve the goal of profitability. This increase in productivity in turn has an impact on the quality of the product or service that the enterprise delivers. The increase in the organizational productivity indirectly increases the organizational profitability. This can be mathematically depicted by means of the following equations:

Productivity can be defined as a measure of output from a process per unit of input.

$$Productivity = \frac{Output}{Input} \quad (3)$$

Return on invested capital (ROIC) is a financial measure that quantifies how well a company generates cash flow relative to the capital it has invested in its business.

$$\text{ROIC} = \frac{Net\ Operating\ Profit - Taxes}{Capital\ Investment} \quad (4)$$

Thus ROIC can be rewritten as:

$$ROIC = \frac{Investment\ input}{Investment\ Output} \quad (5)$$

Thus ROIC is the productivity of the organization from the capital it has invested.

$$ROIC = Productivity \quad (6)$$

Thus by increasing the productivity of the organization the ROIC of the organization will increase if the productivity is in line with the organizational goal. Thus an increase in organizational productivity due to the implementation of a NGN network will contribute to the increase of the organizations ROIC.

The customer as a state institution does not have a ROI or ROIC as a normal commercial business organization, but has costs and returns in social, political, and economic terms. The customer also does not have a goal of making money like a commercial business. The goal of the customer is to defend the country while helping to promote the countries interests globally. In the same vein, the NGN should increase productivity of the customer to better achieve the goal of providing a national defence service.

Erik Brynjolfsson (2000) investigated the impact that information technology has on organizational transformation and business performance. He analysed different case studies and studies done on the subject to try and determine the influence of information technology (IT), and lists the following outcomes:

Impact of information technology on productivity: Estimates of the average annual contribution of computer capital to total output generally exceed \$.60 per dollar of capital stock often by a substantial margin, depending on the analysis and specification (Brynjolfsson and Hitt, 1995,1996; Lichtenberg, 1995; Dewan and Min, 1997). He also listed some other studies that had similar results. Another indirect implication from the productivity studies stems from evidence that effects of IT are substantially larger when measured over longer time periods. Brynjolfsson and Hitt (2000) examined the effects of IT on productivity growth rather than productivity levels, which had been the emphasis in most previous work, using data that included more than 600 firms over the period 1987 to 1994. When one-year differences in IT are compared to one-year differences in firm productivity, the measured benefits of computers are approximately equal to their measured costs. However, the measured benefits rise by a factor of two to eight as longer time periods are considered, depending on the econometric specification used. The explanation for this is the organizational change that takes place after the initial investment. IT without a change in the organization will result in a lower productivity growth. This not only results in a return owing to productivity increase but a return on human and organizational capital.

Intangible assets: The implementation of IT increases the intangible benefits of improved quality, new products, customer service and speed. The magnitude of investment in intangible assets associated with computerization may be large. Analyses of 800 large firms by Brynjolfsson and Yang (1997) suggest that the ratio of intangible assets to IT assets may be 10 to 1. This collection of results suggests that IT may be associated with increases in the intangible component of output, including variety, customer convenience, and service. Because it appears that the amount of unmeasured output value is increasing with computerization, this measurement problem not only creates an underestimate of output level, but also errors in measurement of output and productivity growth when compared with earlier time periods which had a smaller bias due to intangible outputs.

Direct measurement of the relationship between IT and the Organization: Drawing on a case study on the automobile repair industry, Levy, Beamish, Murnane and Autor (2000) argue that computers are a most likely substitute for jobs that rely on rule based decision-making while complementing nonprocedural cognitive tasks. This theory was strengthened by Brynjolfsson, Malone, Gurbaxani and Kambil (1994) who found that increases in the level of IT capital in an economic sector were associated with a decline in average firm size in that sector, consistent with IT leading to a reduction in vertical integration. But a variety of industry-level studies also show a strong connection between investment in high technology equipment and the demand for skilled, educated workers (Berndt, Morrison and Rosenblum, 1992; Berman, Bound and Griliches, Beyond Computation: Information Technology and Organizational Transformation 35 1994; Autor, Katz and Krueger, 1998). Again, these findings are consistent with the idea that increasing use of computers is associated with a greater demand for human capital.

The NGN Utility to Cost Model

The previous sections defined a NGN performance model and secondly an organizational performance model in terms of the NGN investment. The next step will be to combine the models obtained into a Utility to Cost model.

The organizational performance definition creates a mismatch between the NGN and the organization, because the organizational productivity is dependent on the applications and services connected to the NGN. Thus we should take the complete system with the user, application and process subsystems into consideration as indicated in Figure 6, to create the Utility to Cost model.

The performance model for the NGN can thus be divided into two different models for a Service Provider and for an Enterprise like the customer’s organization.

Service Provider Performance Model

The Service Provider wants to maximise his ROI for the new NGN. And to be able to do this the service provider has to maximize the utility to cost model to:

- Decrease investment cost
- Satisfy the customer needs
- Maximize the performance of the NGN

The utility to cost model for a NGN can be defined as: ***The maximum NGN performance to deliver a service that the customers perceive as a quality service at the best total investment cost.*** Total investment is defined as the total cost to establish the capability and includes all assets and costs incurred for the organizational transformation like human capital development and processes implementation.

$$NGN\ Utility\ to\ Cost\ Index\ = \frac{NGN\ Performance * Satisfied\ Costomers}{Total\ Invsetment}$$

Enterprise Performance Model

The enterprise wants to maximize its performance in the direction of the goal of the organization. The enterprise model can be defined as: ***The leveraging of the ICT infrastructure to obtain the highest organizational performance at the best total investment cost.***

$$NGN\ Utility\ to\ Cost\ Index\ \ = \frac{Orginizational\ Performance}{Total\ Invsetment}$$

In terms of the customer the optimal utility to cost for the NGN can only be achieved with an increase in organizational performance or organizational productivity in terms of the goal to protect South Africa. This increase should be at the lowest total investment possible to achieve the highest performance.

Conclusion

The ROI that the customer will receive from the new NGN can only be measured by looking at the complete system and not only the NGN itself. The ROI will increase only if the productivity of the customer in terms of its goal increases. Thus the customer should be capable of delivering better and more services with the same amount of personnel or deliver the same services with fewer personnel. If the literature is correct the customer should see a significant increase in productivity in the years after the implementation of the NGCN. The literature also suggests that the increase in productivity is dependent on the following:

- Organizational Transformation.
- Increase in skill levels to utilize the NGN.
- Management Leveraging of the technology.
- Strategy and leadership to direct productivity towards the goal.
- Implementation of user-end devices and applications that can utilize the power of the NGN.
- The technology is implemented towards the goal of the organization.

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Biography

Charl Harding (BSc Hons) is a senior Systems Engineer at the Council for Scientific and Industrial Research (CSIR) working in the Systems Integration Group (ISG) responsible for System of Systems Engineering. He is currently busy with a Masters in Engineering Management (MEM) at the University of Pretoria doing a Dissertation in the Systems Engineering business case. Charl has been a Systems Engineer in a range of national and international projects.

Brian Naude (Pr Eng) has 30 years of engineering experience. He started his career in the Telkom where he worked in the laboratory and later held a network planning management post. During national service he performed a radio equipment support function. He later went into the defence industry where he has worked in a system and logistic engineering role on a diverse set of military projects. He is currently the lead Systems Engineer for a communications system for the DOD at the CSIR. He holds a BSc (Eng) degree in electronics from the University of Pretoria