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SERIES Y.2000:
NEXT GENERATION NETWORKS

Migration scenarios from legacy networks to NGN in developing countries

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Foreword

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Migration scenarios from legacy networks to NGN in developing countries

Summary

Many of developing countries faced to improve their telecommunication infrastructures which are based on telephone service oriented, that is, PSTN/ISDN. Providing enhanced services such as Internet is one of the reasons but already passed life cycle of systems used in legacy networks, especially circuit switching systems is being critical issue for all countries who used.

NGN is being developed to provide various advanced services including convergence which available over fixed and/or mobile broadband environments. But NGN should cover, at least, essential services which are provided in the legacy networks, typical example should be "Voice" service. Because of this, NGN is being considered as a new telecommunication infrastructure to be considered as a replacement for (or migration of) legacy networks, especially for PSTN/ISDN.

The most fundamental change driven by the NGN should be the simplification of the telecommunications architecture with two strata "Transport strata and Service strata" which allow services available independently with underline transport technologies. This is the most important point what NGN is different with legacy but public telecommunications networks. In addition, this simple architecture of NGN extends its capability to support various multimedia services over both fixed and mobile accesses which are crucial for Fixed-Mobile Convergence (FMC).

Migration from legacy networks to NGN is not a simple task because it has a lot of impacts. Especially it deals with infrastructures so impacts are really huge and serious. Thus it is required enough understanding the features of NGN and careful considerations on differences with legacy networks. Such differences of architectures, key technologies and services which are used to implement for legacy networks and NGN raised various important issues for migration.

This Technical Paper provides comprehensive knowledge about the legacy networks and NGN including analysis of differences between them. This Technical Paper introduces key features of legacy networks and NGN based on ITU-T Recommendations. Based on this, this hand book analyzes "Gaps" between legacy networks and NGN in terms of services, architectures and technologies used in each networks. Those "Gaps" would be used for identify different migration scenarios from legacy networks to NGN. In addition, this Technical Paper addresses various issues to be considered for the developing countries when initiate migration project and also for choosing specific types of scenarios.

Introduction

Next generation networks (NGNs) is the 1st full IP-based public telecommunications networks developed by ITU-T coordinated with various SDOs (standards development organizations) such as ATIS, ETSI, TIA and 3GPP/3GPP2. NGN provides various changes to the telecommunications as consequences by technical features and characteristics of IP.

The most fundamental change driven by the NGN should be the simplification of the legacy telecommunications architecture which has been based on OSI (Open System Interconnection) seven layered model in general. NGN simplifies architecture with two strata "Transport strata and Service strata" which allow services available independently with underline transport technologies. This is the most important point what NGN is different with legacy but public telecommunications networks such as PSTN (Public Switched Telephone Network), PSDN (Packet Switched Data Network) and ISDN (Integrated Services Digital Network). In addition, this simple architecture of NGN extends its capability to support various multimedia services over both fixed and mobile accesses which are crucial for Fixed-Mobile Convergence (FMC). Therefore NGN has many capabilities to support of various services which are available over different legacy networks. NGN provides such services over single NGN platform while each different legacy network only supports specific services (e.g., voice over PSTN and data over PSDN).

NGN is being developed to provide various advanced services including convergence which available over fixed and/or mobile broadband environments. But NGN should cover, at least, essential services which are provided in the legacy networks, typical example should be "Voice" service. Because of this, NGN is being considered as a new telecommunication infrastructure to be considered as a replacement for (or migration of) legacy networks.

Migration from legacy networks to NGN is not a simple task because it has a lot of impacts. Especially it deals with infrastructures so impacts are really huge and serious. Thus it is required enough understanding the features of NGN and careful considerations on differences with legacy networks. For this purpose, this Technical Paper starts with analysis of features about legacy networks (e.g., PSTN, PSDN and ISDN) and NGN in terms of services, architectures and technologies identified by various ITU-T recommendations. Then this Technical Paper identifies gaps between legacy networks and NGN based on such study about those differences. Afterwards, NGN capabilities for supporting migration of legacy networks have been introduced following the relevant scenarios. Many of issues to be considered when design migration of networks such as user needs, policy and regulation including business environments are also explained. Finally this Technical Paper provides recommendation of using different scenarios.

1 Scope

This Technical Paper introduces key features of legacy networks and NGN based on ITU-T Recommendations. Based on this, this Technical Paper analyses "Gaps" between legacy networks and NGN in terms of services, architectures and technologies used in each networks. Those "Gaps" would be used for identifying different types of migration scenarios from legacy networks to NGN. This Technical Paper covers analysis of various NGN capabilities helping for migration of legacy networks into NGN. In addition, this Technical Paper addresses various issues to be considered for the developing countries when initiate migration project and also for choosing specific types of scenarios, for example, status of legacy networks and their business environments including relevant systems. Further considerations impacts for choosing migration scenarios such as user needs, policy and regulation environments of the country are also introduced.

2 Definitions

A number of terms are being used to describe legacy telecommunication networks as well as NGNs. Following terms are used in this Technical Paper with definitions, mostly based on relevant ITU-T Recommendations.

2.1 IP-based networks [ITU-T Y.1401]: A network in which IP is used as one of the Layer 3 protocols.

2.2 integrated services digital network (ISDN) [ITU-T I.112]: An integrated services network that provides digital connections between user-network interfaces.

2.3 legacy networks [Webopedia]: A network based on older, out-dated protocol that is not based on the IP (TCP/IP) protocol. IPX, SNA, AppleTalk and DECnet are examples of legacy networks.

2.4 next generation network [ITU-T Y.2001]: A packet-based network able to provide telecommunication services and able to make use of multiple broadband, QoS-enabled transport technologies and in which service-related functions are independent from underlying transport-related technologies. It enables unfettered access for users to networks and to competing service providers and/or services of their choice. It supports generalized mobility which will allow consistent and ubiquitous provision of services to users.

2.5 packet switched data network [Wikipedia]: A digital communications network that groups all transmitted data, irrespective of content, type, or structure into suitably sized blocks, called packets. The network over which packets are transmitted is a shared network which routes each packet independently from all others and allocates transmission resources as needed.

2.6 public switched telephone network (PSTN) [ITU-T Q.1290]: A telecommunications network established to perform telephone services for the public subscribers.

2.7 ubiquitous networking [ITU-T Y.2002]: The ability for persons and/or devices to access services and communicate while minimizing technical restrictions regarding where, when and how these services are accessed, in the context of the service(s) subscribed to.

3 Abbreviations

ADF	Adaptation Function
ATM	Asynchronous Transfer Mode
BICC	Bearer Independent Call Control
BRI	Basic Rate Interface
DCE	Data Circuit-terminating Equipment
DSL	Digital Subscriber Line
DTE	Data Terminal Equipment
FMC	Fixed-Mobile Convergence
IdM	Identity Management
IMS	IP Multimedia Subsystem
INNI	Internal Network-Network Interface
IP	Internet Protocol
IPX	Internetwork Packet Exchange
LAPB	Link Access Procedure-Balanced
LLU	Local Loop Unbundling
MDF	Main Distribution Frames
MMCF	Mobility Management Control Functions
MPLS	Multiprotocol Label Switching
MSAN	Multi-Service Access Nodes
NACF	Network Attachment Control Functions
NAT	Network Address Translation
NGA	Next Generation Access
NGN	Next Generation Networks
NNA	Naming, Numbering and Addressing
NNI	Network-Network Interface
NT	Network Termination
OAM	Operation, Administration and Maintenance
OSE	Open Service Environment

OTN	Optical Transport Network
PAD	Packet Assembler-Disassembler
PDH	Plesiochronous Digital Hierarchy
PON	Passive Optical Network
POTs	Plain Old Telephons
PPP	Point-to-Point Protocol
PRI	Primary Rate Interface
PSDN	Public Switched Data Network
PSTN	Public Switched Telephone Network
QoS	Quality of Service
RACF	Resource Admission and Control Function
SDH	Synchronous Digital Hierarchy
SNA	Systems Network Architecture
SIP	Session Initiation Protocol
SLAs	Service Level Agreements
TA	Terminal Adapter
TCP	Transmission Control Protocol
TE	Terminal Equipment
URIs	Uniform Resource Identifiers
VoD	Video on Demand
VPNs	Virtual Private Networks
WDM	Wavelength Division Multiplexing

4 Features of Legacy Telecommunication networks

"Legacy" is a relative term not an absolute term, thus it is importantly recognized that this Technical Paper should set up the concrete scope of "Legacy Networks" in terms of telecommunication networks relatively considering the NGN. This section identifies the scope of legacy telecommunication networks considering migration to NGN and the features of each specific legacy networks are described.

4.1 Scope of Legacy Telecommunication Networks

One of general approach to define the legacy networks is the usage of IP. Legacy network defined, normally, a network based on older and out-dated protocol that is not based on the IP (TCP/IP) protocol [1]. Whether set aside IP is old protocol or not (because practically IP has more than 30 years old history), this is one of trend to define legacy networks, for example circuit switched, X.25, IPX, SNA, AppleTalk and DECnet are examples of technologies used in legacy networks. Hence this Technical Paper deals with the migration to NGN of legacy telecommunication networks, so followings are proposed scope of the legacy telecommunication networks taking into account the necessity of migration from public telecommunication networks into NGN:

- Public Switched Telephone Networks (Circuit Switched networks);
- Packet Switched Data Networks, and;
- Integrated Services Digital Networks.

4.2 Public Switched Telephone Networks

Public Switched Telephone Network (PSTN) is the oldest and widest popular network in the world which identifies as the most dominant legacy telecommunications network established to perform telephone services for the public users (or subscribers). This network composed mainly based on "Circuit switching" technology establishing a dedicated communications channel (by circuit) between two nodes through the network before the nodes may communicate. The circuit provides the fixed bandwidth according to the channel size (bandwidth) and remains connected for the duration of the communication session. The circuit functions as if the nodes were physically connected as with an electrical circuit.

Critical example of the network using this circuit switching is a telephone network, providing telephone voice-based services. When a call is made from one telephone to another, circuit switches create a constant wire circuit between the two telephones, for as long as the call lasts. Key features of PSTN consequence of circuit technology (e.g., circuit based transmission and switching) are summarized followings:

- mainly voice-band services (voice and 3.1 kHz Audio-band data services);
- the channel remains reserved and not allow to use for competing users (even no actual communication is taking place);
- provides continuous transfer without the overhead;
- a dedicated path persisting between two communicating parties or nodes can be extended to signal content;
- the constant bit delay during a connection, and;
- guaranteed a QoS (Quality of Service) of the circuit (channel), so no circuit can be degraded of QoS by competing users.

Overall configuration model of PSTN is shown in Figure 1. Circuit switching and transmission technology are basement for configuring the PSTN networks. A subscriber cable (a pair of twisted cable) is dedicated to each end user so not allowed to use other users (or terminals) simultaneously. Since the circuit switch is based on 64 kbit channel based switching, all services should be restricted based on this channel capacity. In addition, PSTN uses 3.1 kHz based spectrum, for services as well as signalling information, service capacity in PSTN should be restricted to use this spectrum as well. Because of this, a modem is used for transcoding of digital signal to 3.1 kHz band signal.

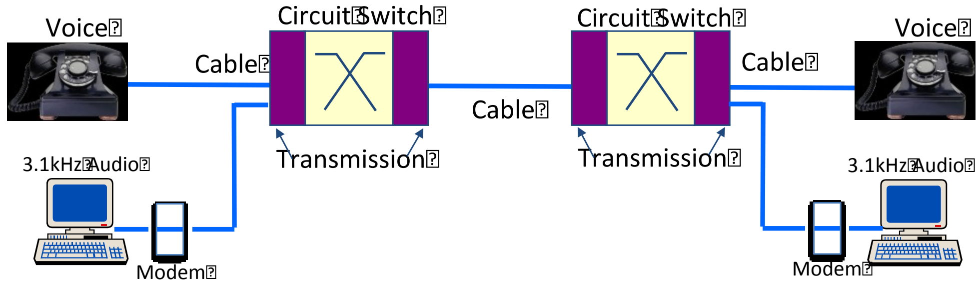


Figure 1 – Overall configuration model of PSTN

To provide telephone service to all users in nation-wide and/or international, PSTN normally uses hierarchical structure of the networks. There are several different models, but basic ideas similar such as providing connecting to end user (by Local Exchange, marked ① and ②), providing connectivity between nodes in the city level (by Tandem Switch, marked ③ and ④), providing connectivity between different regions (by Toll Switch) and, finally between countries (by International Gateways, marked ⑤). Each level of hierarchy has a different role for providing connectivity, relevant systems such as switch and transmission systems have been equipped with different technologies and capabilities. Detailed configuration model of PSTN based on these different roles is shown in Figure 2.

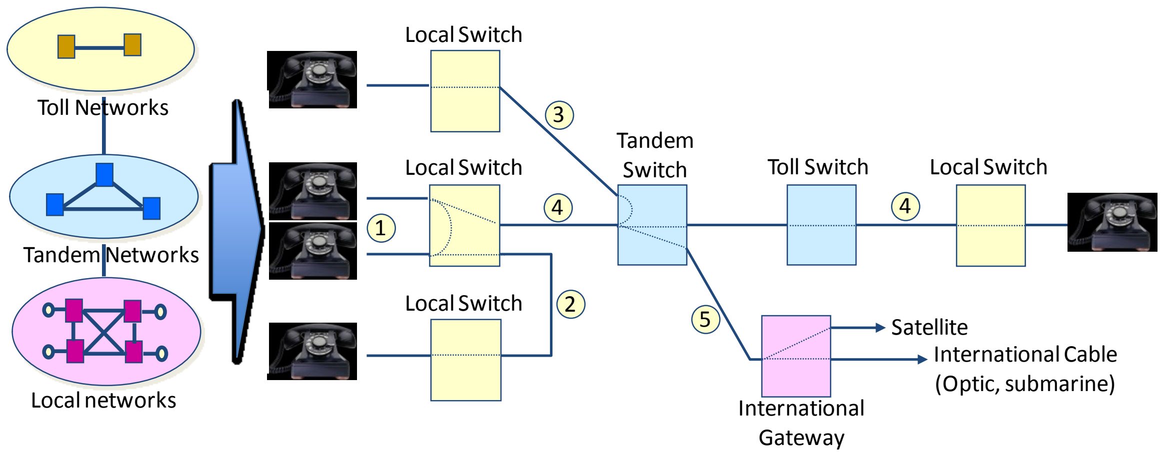


Figure 2 – Detailed configuration model of PSTN

4.3 Packet Switched Data networks

A packet switched data network identifies as a digital data communications network that groups all transmitted data, irrespective of content, type, or structure into suitably sized blocks, called packets. The network over which packets are transmitted is a shared network which routes each packet independently from all others and allocates transmission resources as needed.[2]

General meaning of the "packet" means a small container or a pouch, thus "Packet" in networks would be interpreted as a formatted block of data. If this understanding is reasonable enough, by the definition PSDN covers wide range of existing networks (X.25 based, Frame Relay and even IP) as well as future networks. However, following the scope of this Technical Paper and the concept of legacy networks, this Technical Paper focuses on the public telecommunications networks aspect which is a packet switched network using X.25 protocol.

X.25 is an ITU-T standard protocol suite for packet switched public data network. A Packet Switched Data Network (PSDN) based on X.25 consists of packet-switching exchange (PSE) nodes, leased lines and PSTN connections or ISDN connections as physical links. X.25 is a family of protocols that was popular during the 1980s with telecommunications companies and in financial transaction systems such as automated teller machines.

X.25 defined three basic protocol layers with followings and Figure 3 shows overall configuration model of X.25 based PSDN:

- Physical layer: specifies the physical, electrical, functional and procedural characteristics to control the physical link between a DTE (Data Terminal Equipment) and a DCE (Data Circuit-terminating Equipment). Common implementations use X.21, EIA-232, EIA-449 or other serial protocols;
- Data link layer: consists of the link access procedure for data interchange on the link between a DTE and a DCE. The Link Access Procedure-Balanced (LAPB) is a data link protocol that manages a communication session and controls the packet framing including error correction and orderly delivery; and
- Packet layer: defines a packet-layer protocol for exchanging control and user data packets to form a packet-switching network based on virtual calls, according to the Packet Layer Protocol.

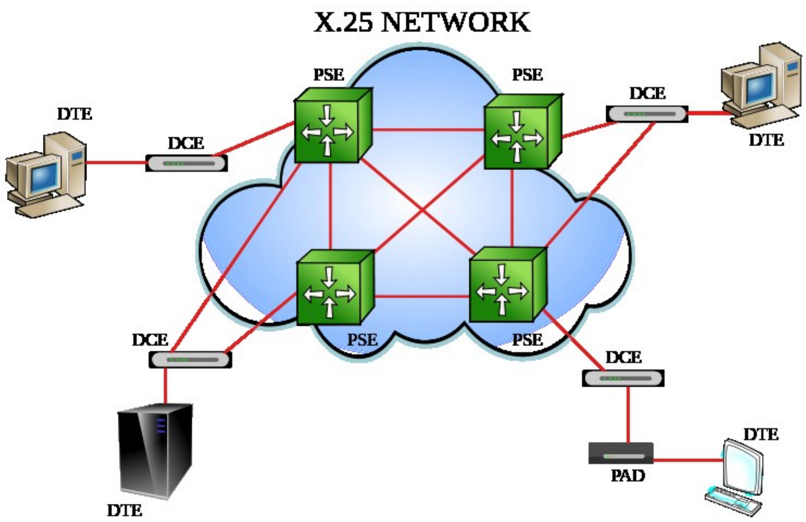


Figure 3 – Overall configuration model of PSDN

In addition, a Packet Assembler-Disassembler (PAD) is used for providing multiple of asynchronous terminal connectivity to PSDN or a host computer. PAD collects data from a group of terminals and places the data into X.25 packets (assembly). In the reverse, PAD takes data packets from PSDN or host computer and returns them into a character stream that can be sent to the terminals (disassembly).

Key features of PSDN are to optimize utilization of available link capacity, minimize response times and increase the robustness of communication. Packets are buffered and queued when traversing network adapters, switches and other network nodes. Therefore delay and throughput varies depending on the traffic load in the network, resulting variables and differences of QoS.

4.4 Integrated Services Digital Networks

Integrated Services Digital Networks (ISDN) is an integrated services network that provides digital connections between user-network interfaces identified with a set of communication standards for simultaneous digital transmission of voice, video, data, and other network services over the traditional circuits of the PSTN.

ISDN is designed to allow digital transmission of voice and data together over ordinary telephone copper wires (twisted copper wires). ISDN is a 64 kb/s channel (called B channel) based circuit-switched telephone network system (offering circuit-switched connections for either voice or data) with providing access to packet networks for data such as X.25 based PSDN. The key feature of ISDN is integrating voice and data on the same lines, adding additional features called supplementary services that were not available in the PSTN. There are several kinds of access interfaces to ISDN defined as Basic Rate Interface (BRI: 2B+1D, D is a signalling channel with 16 kb/s) with maximum of 128 kbit/s (in both upstream and downstream directions) and Primary Rate Interface (PRI) with maximum T1 (23B+1D, here D is a signalling channel but with 64kb/s capacity) and E1 (30B+1D, here D is a signalling channel but with 64kb/s capacity) capacity.

The network capabilities of the ISDN (mainly low layer capabilities) are specified in ITU-T Recommendation I.324 as shown in Figure 4.

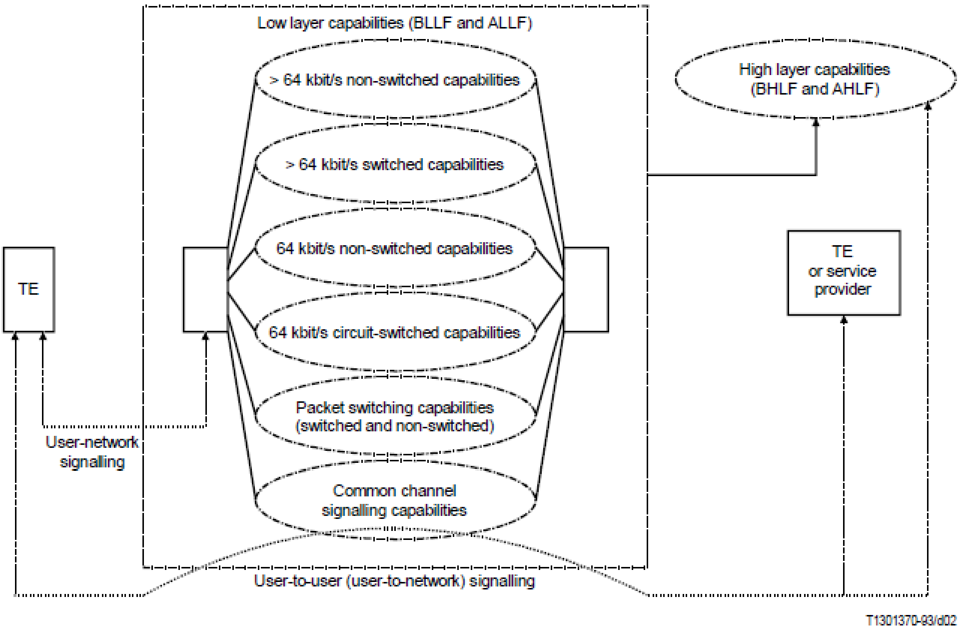


Figure 4 – Architecture model of ISDN

Low layer capabilities specifying transport capability of the ISDN are identified as following:

- Circuit switching capability: Provides circuit-switched connections with information transfer rates based on B-channel (64 kb/s) carried by at the ISDN user-network interfaces and switched at 64 kb/s by the circuit-switching functional entities. This also be applied to information transfer rates greater than 64 kb/s and in the case of user bit rates of less than 64 kb/s are rate adapted to 64 kb/s before any switching can take place in the ISDN;
- Packet switching capabilities: Provide number of packet mode bearer services based on two types of functional groupings;
  - packet handling functional groupings, which contain functions relating to the handling of packet calls within the ISDN;
  - interworking functional groupings, which ensure interworking between ISDN and packet switched data networks;
- Frame mode capabilities: Provide the order preserving bidirectional transfer of service data units (layer 2 frames) from one S or T reference point to another routed through the network on the basis of an attached label which contains a logical identifier with local significance, and;
- Signalling capability: Signalling associated with circuit switched connections is carried by the D-channel at the ISDN user-network interface and processed by the local CRF (Connection Related Function).

Overall configuration model of ISDN is shown in Figure 5 and features of relevant functions are summarized as following:

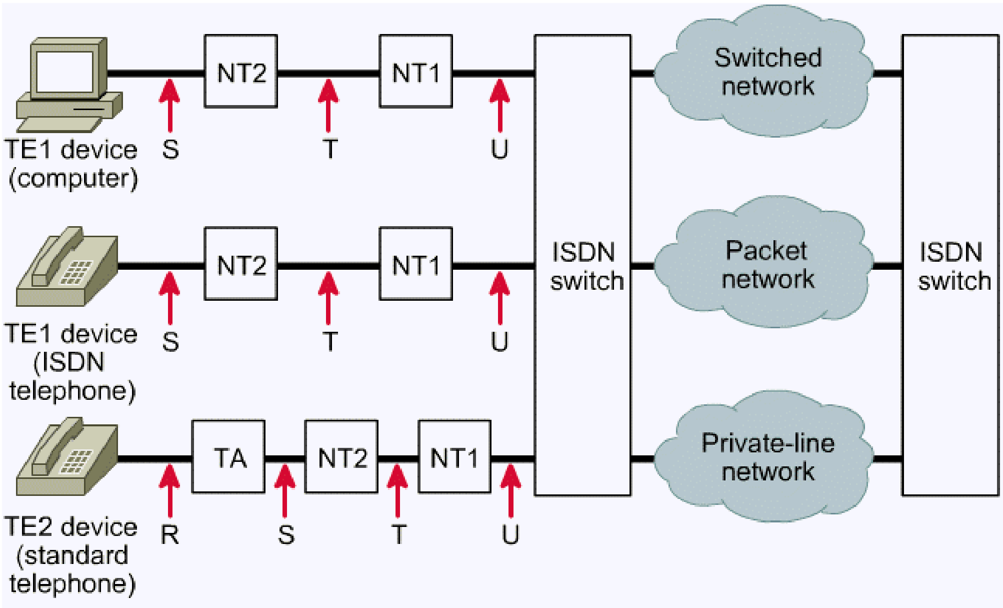


Figure 5 – Overall configuration model of ISDN

- Terminal Adapter (TA): A converter device that allows non-ISDN devices to operate on an ISDN network;
- Terminal Equipment 1 (TE1): A device that supports ISDN standards and connected directly to an ISDN. For example, routers with integrated ISDN interfaces, ISDN telephones, personal computers, or videophones could function as TE1;
- Terminal Equipment 2 (TE2): A non-ISDN device, such as a router, analog phone or modem, which requires a TA in order to connect to an ISDN network;
- Network Termination 1 (NT1): A connection box terminates the connection from the Central Office (CO) and converts BRI signals for use by ISDN line signal, and;
- Network Termination 2 (NT2): A device that provides switching services for the internal network (typically used with PRI), when they need to be divided for several functions. For example, some channels may be used for WAN (Wide Area Networks) data communications and others for the telephone system (such as PBX: Private Exchange) and/or video tele-conferencing.

The connection between two function groups (including cabling) is called a reference point and identified as followings:

- U (U-interface): is the actual two-wire cable, also called the local loop, that connects the Customer Premise Equipment to the telecommunications provider;
- R (R-interface): is the wire or circuit that connects the TE2 to the TA;
- S (S-interface): is a four-wire cable from TE1 or TA to the NT1 or NT2;
- T (T-interface): The point between the NT1 and NT2 used to divide the normal telephone company's two-wire cable into four-wires, which then allows the connection of up to eight ISDN devices and;
- S/T: When NT2 is not used on a connection that uses NT1, the connection from the TE1 or TA to the NT1 connection is typically called S/T.

Comparing the previous networks such as PSTN and PSDN, ISDN has been designed for integrating various services not only voice but also multimedia. Benefits of ISDN are summarized following:

- use the existing telephone wiring system (twisted pair-lines) without incurring additional costs and enhance wide area networks usage;

- provide integrated access to telephone services, circuit-switched data and digital video by using the telephone network;
- offer much faster call setup than modem connections by out-of-band (D channel) signalling;
- provide a faster data transfer rate than modems by using the B channel including multiple B channels are bonded;
- provide a clear data path over which to negotiate PPP (Point-to-Point Protocol) link;
- offer "Pay-as you-Go" which means you only pay for the time that you use the link, and;
- Telephone Company builds a totally digital network for increased bandwidth speeds.

5 Features of NGN

This section introduces key features of NGN based on ITU-T Recommendations including services, architectures and capabilities aspects of NGN.

5.1 NGN definition and characteristics

ITU-T identified a definition of the NGN through ITU-T Recommendation Y.2001 as following: "A packet-based network able to provide telecommunication services and able to make use of multiple broadband, QoS-enabled transport technologies and in which service-related functions are independent from underlying transport-related technologies. It enables unfettered access for users to networks and to competing service providers and/or services of their choice. It supports generalized mobility which will allow consistent and ubiquitous provision of services to users."

NGN definition clearly indicated that the NGN should be a packet-based network over the broadband infrastructures (both over fixed and mobile) with separation between service and transport. Because of these given nature of the NGN, fundamental characteristics of the NGN are summarized as following by the ITU-T Recommendation Y.2001:

- packet-based transfer;
- separation of control functions among bearer capabilities, call/session, and application/ service;
- decoupling of service provision from transport, and provision of open interfaces;
- support for a wide range of services, applications and mechanisms based on service building blocks (including real time/ streaming/ non-real time and multimedia services);
- broadband capabilities with end-to-end QoS;
- interworking with legacy networks via open interfaces;
- generalized mobility;
- unfettered access by users to different service providers;
- a variety of identification schemes;
- unified service characteristics for the same service as perceived by the user;
- converged services between fixed/mobile;
- independence of service-related functions from underlying transport technologies;
- support of multiple last mile technologies, and;
- compliant with all regulatory requirements, for example concerning emergency communications, security, privacy, lawful interception, etc.

Looking at the definition and characteristics of the NGN, high level features of the NGN are summarized following and these should be a framework to use of the NGN:

- Open architecture: open to support service creation, service updating, and incorporation of service logic provision by third parties and also support "Distributed control" as well as enhanced security and protection;
- Independent provisioning: service provision process should be separated from network operation by using distributed, open control mechanism to promote competition, and;

- Multiplicity: The NGN functional architecture shall offer the configuration flexibility needed to support multiple access technologies.

5.2 NGN Requirements

Various aspects of requirements for the NGN have been identified following the characteristics of the NGN. Most significant points of characteristics having great impacts to the NGN requirements are followings:

- "decoupling of service provision from transport" which means separation of service functions from the underline transport functions;
- "packet-based transfer but support for a wide range of services, applications and mechanisms based on service building blocks (including real time/streaming/non-real time and multimedia services)" which means providing integrated services using packet based transport means;
- "broadband capabilities with end-to-end QoS" which requires support of QoS from one end to other end;
- "generalized mobility and converged services between fixed and mobile" which available services crossover the of fixed and/or mobile access environments in any directions.

To realize such key characteristics of the NGN as well as covering other aspects, ITU-T identified "Requirements of the NGN" and announced as a Recommendation Y.2201 (1st developed at 2007 and revised at 2009). This Recommendation Y.2201 identified many of views of requirements but summarized mainly in three areas such as transport related, capability related and service related, as followings:

- Requirements for the NGN transport related:
  - ITU-T Recommendation Y.2201 specified to use of IP protocol as a mandatory transport technology for the NGN supporting for general, ubiquitous and global public connectivity. However Y.2201 recommends the IP protocol may be carried over various underlying transport technologies in the access and core portions of the transport stratum (e.g., xDSL, ATM, MPLS, frame relay, OTN) according to the operator's environment. Through this, NGN equipped with capabilities to support separation of service functions from the underline transport functions;
  - NGN transport provides various modes of connectivity and communication: use of IPv4 and IPv6, one-one/one-many/many-many/many-one, real-time/non-real time etc.
  - Especially Y.2201 identified "Network attachments" into the NGN transport as a mandatory to support registration at the access network level, initialization of end-user functions for accessing the NGN services and management of the access network IP address space, including a NAT (Network Address Translation) function. In this case, the user profile is required to keep user access authentication data and information related to the required network access configuration.
- Requirements for the NGN capabilities related: various capabilities are required to support of the NGN and summarized their requirements as followings:
  - QoS: ITU-T Recommendation Y.2201 mandated of the NGN to support end-to-end QoS across different networks of varying infrastructure technologies provided by multiple operators to ensure the required service level for users or applications. ITU-T Recommendation Y.2201 identified the NGN also support multiple levels of QoS, which may be negotiable between the user and provider and/or between providers;
  - Security: NGN has been mandated to support the security features incorporated in existing networks and allow for secure interconnection with other NGNs or non-NGN networks based on the application of ITU-T Recommendation X.805 to the NGN and thus address the following dimensions of the NGN security: access control,

authentication, non-repudiation, data confidentiality, communication security, data integrity, availability and privacy;

  - Mobility management: ITU-T Recommendation Y.2201 identified two distinct types of mobility are supported by the NGN:
    1) personal mobility exists where users can use registration mechanisms to associate themselves with a terminal that the NGN can associate with the user. NGN will be used interfaces where between users and terminals, and users and networks for user registration exist
    2) terminal mobility exists within and among networks where registration mechanisms are used to associate the terminal to the NGN. Where support for terminal mobility with service continuity exists, such support is expected to also be used for the NGN;
  - Management capabilities: ITU-T Recommendation Y.2201 identified the high-level goal of the NGN provide survivable and cost-effective networks supporting the planning, installation, operations, administration, maintenance, provisioning of networks and provisioning of services. Thus the NGN management capabilities support the monitoring and control of the NGN services and transport components via the communication of management information across interfaces between the NGN components and management systems, between the NGN supportive management systems, and between the NGN components and personnel of service and network providers;
  - Other capabilities: ITU-T recommendation Y.2201 identified other relevant capabilities of the NGN to support features and characteristics, covering “Routing”, “Identification”, “NNA(Naming, Numbering and Addressing)”, “Accounting and Charging”, “OAM (Operation, Administration and Maintenance) and others (see ITU-T Recommendation Y.2201 for details).
- Requirements for the NGN services related:
  - Open Service Environment (OSE): NGN has been mandated to enable new capabilities and support a wide range of emerging services, including services with advanced and complex functionalities supporting third-party application and service providers to develop new applications and capabilities accessible via open and standard interfaces, furthermore, software reusability and portability, and use of commercial software, are recommended to be supported to facilitate cost effective development;
  - Media handling and content management: NGN has been mandated to support various media resources and media resource management capabilities to enable a wide range of applications, including media recording/down-loading/streaming/duplication/insertion, playing recorded media, speech recognition and others. NGN is recommended to provide content management capabilities to manage various and huge content resources, taking into account classifications of contents such as enterprise content (e.g., business documents), web services content (e.g., HTML files, images) and IPTV services content (e.g., relatively large-size stream data);
  - Service specific requirements: ITU-T Recommendation Y.2201 identified requirements by considering specific types of services such as PSTN/ISDN emulation, multimedia real-time conversational services, IPTV services, enterprise services, Tag-based identification services, managed delivery services, visual surveillance services, ubiquitous sensor network services, multimedia communication center services and VPNs (Virtual Private Networks);
  - Public interest aspects: Specific requirements for public interest aspects are also identified covering lawful interception, malicious communication identification, emergency telecommunication, network/service provider selection, user with disabilities, number portability, service unbundling and others.

5.3 NGN Functional Architecture

One of the biggest challenges of the NGN is the separation between services from underline transport technologies. The basic reference model of the NGN is shown in Figure 6 (ITU-T Recommendation Y.2011) [8].

In general, any and all types of network technologies may be deployed in the transport stratum indicated as "NGN transport", including connection-oriented circuit-switched (CO-CS), connection-oriented packet-switched (CO-PS) and connectionless packet-switched (CLPS) layer technologies according to ITU-T Recommendations G.805 and G.809. Until today it is considered that IP is the preferred transport protocol used to support NGN services as well as supporting legacy services. The "NGN services" provide the user services, such as a telephone service even and Web services and others. Therefore "NGN service" may involve a complex set of geographically distributed services platforms or in the simple case just the service functions in two end-user sites.

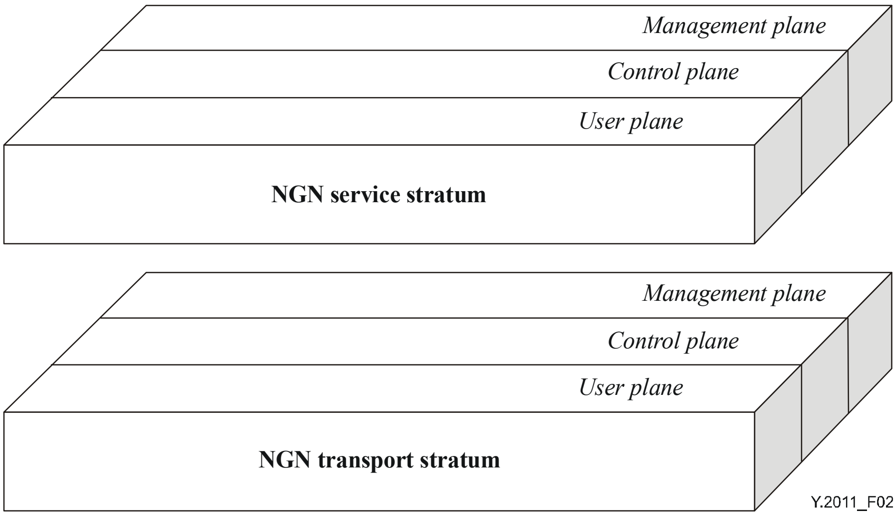


Figure 6 – Basic NGN Architecture

- **NGN service stratum**: provides the user functions that transfer service-related data and the functions that control and manage service resources and network services to enable user services and applications. The NGN service stratum is concerned with the application and its services to be operated between peer entities. User services may be implemented by a recursion of multiple service layers within the service stratum. From an architectural perspective, each layer in the service stratum is considered to have its own user, control and management planes;
- **NGN transport stratum**: provides the user functions that transfer data and the functions that control and manage transport resources to carry such data between terminating entities. Dynamic or static associations may be established to control and/or manage the information transfer between such entities. An NGN transport stratum is implemented by a recursion of multiple layer networks. From an architectural perspective, each layer in the transport stratum is considered to have its own user, control and management planes.

Based on the above basics of the NGN architecture, ITU-T developed the NGN functional architecture model with detailed functions and published by ITU-T Recommendation Y.2012 as shown in Figure 7.

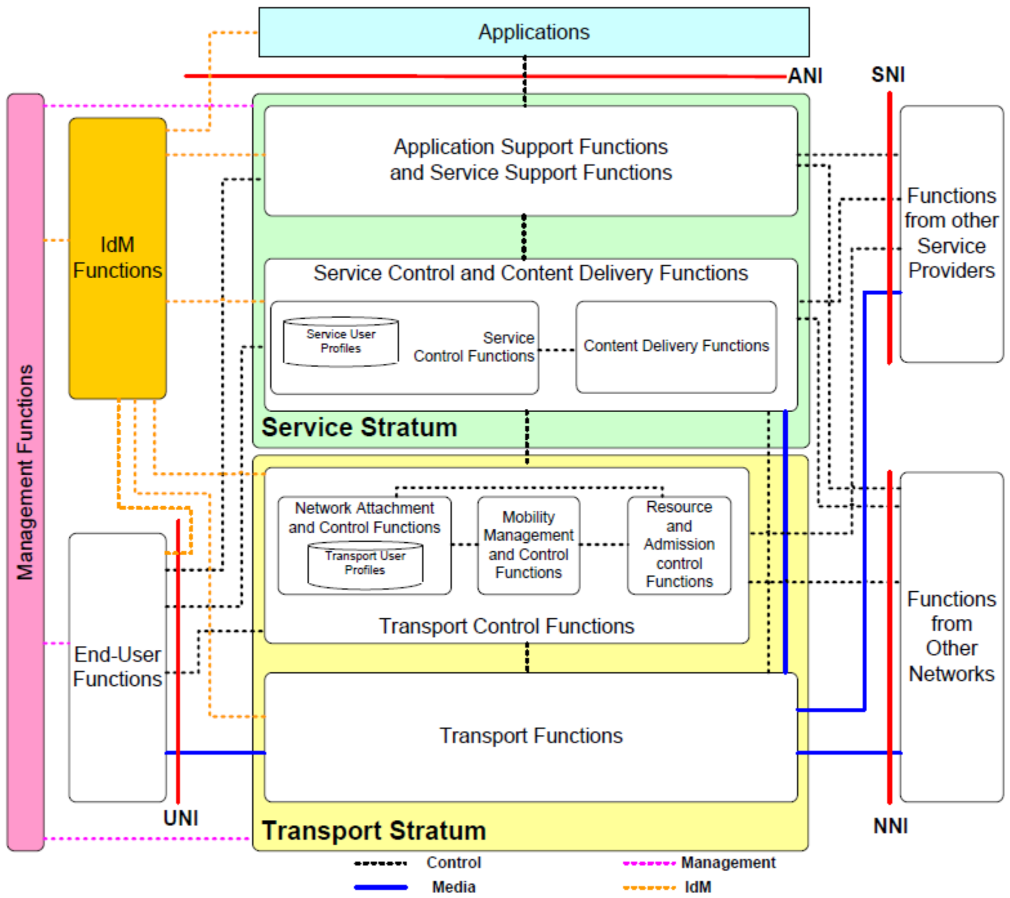


Figure 7 – NGN Reference Architecture

NGN Architecture in ITU-T Recommendation Y.2012 has been developed to incorporate the following principles:

- Support for multiple access technologies: The NGN functional architecture shall offer the configuration flexibility needed to support multiple access technologies;
- Distributed control: This will enable adaptation to the distributed processing nature of packet based networks and support location transparency for distributed computing;
- Open control: The network control interface should be open to support service creation, service updating, and incorporation of service logic provision by third parties;
- Independent service provisioning: The service provisioning process should be separated from transport network operation by using the above-mentioned distributed and open control mechanism. This is intended to promote a competitive environment for the NGN development in order to speed up the provision of diversified NGN services;
- Support for services in a converged network: This is needed to generate flexible, easy-to-use multimedia services, by tapping the technical potential of the converged, fixed-mobile functional architecture of the NGN;
- Enhanced security and protection: This is the basic principle of an open architecture. It is imperative to protect the network infrastructure by providing mechanisms for security and survivability in the relevant layers, and;
- Functional entity characteristics: Functional entities should incorporate the following principles:
  - Functional entities may not be distributed over multiple physical units but may have multiple instances;
  - Functional entities have no direct relationship with the layered architecture. However, similar entities may be located in different logical layers.

5.4 Service aspects of NGN

"Decoupling of service provision from transport operation" is one of key features of the NGN greatly impacts to service aspects of the NGN. Before the NGN, service provisions are tightly coupled with underline transport technologies, in general called silo-effect, as shown in left hand of Figure 8. These couples are caused by different transport technologies are developed and used for different specific services. Therefore different network infrastructures have been required to support various multiple services; consequently different systems and user devices have been also used as well as different providers are required. These difficulties have been resolved using such feature of the NGN as shown in right side of Figure 8. Thus the NGN looks like providing integrated services same as what ISDN objected but, major difference, using IP.

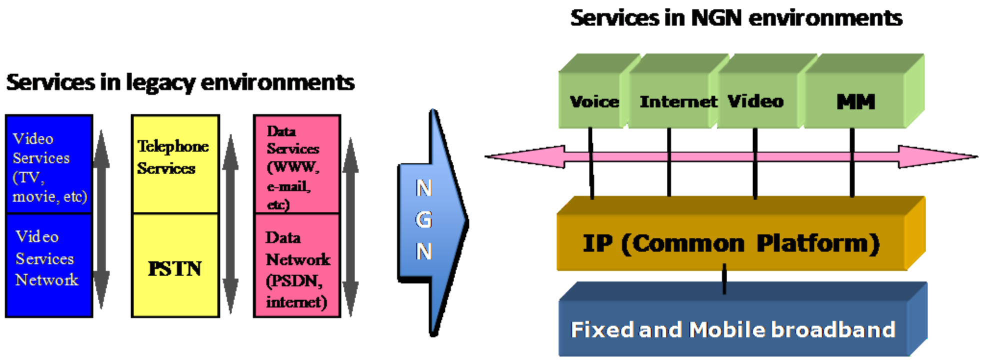


Figure 8 – Change of service environments of NGN

NGN enhances service aspects of telecommunications in two different angles: coverage and quality. Coverage of services using the NGN is largely widened than legacy telecommunication networks as well as traditional Internet. This caused by the NGN's powerful transport capabilities supporting real-time and non-real-time of not only narrowband but also broadband services including one-to-one and any-casting (multicasting, broadcasting etc). These powerful capabilities support the NGN transport as an infrastructure for integrated services covering from simple text to multimedia including voice and TV.

In addition, ubiquitous networking capability of the NGN contributed to widened service coverage as shown in Figure 9 [19] extending of users, not only for persons (using attached devices such as PC, PDA, mobile phones) but also objects (such as remote monitoring and information devices, contents). Ubiquitous networking supports three types of communications [19]:

- Person-to-Person Communication: persons communicate with each other using attached devices (e.g. mobile phone, PC);
- Person-to-Object Communication: persons communicate with a device in order to get specific information (e.g., IPTV content, file transfer);
- Object-to-Object Communication: an object delivers information (e.g. sensor related information) to another object with or without involvement of persons.

Ubiquitous networking of NGN aims to provide seamless communications between persons, between objects as well as between persons and objects while they move from one location to another.

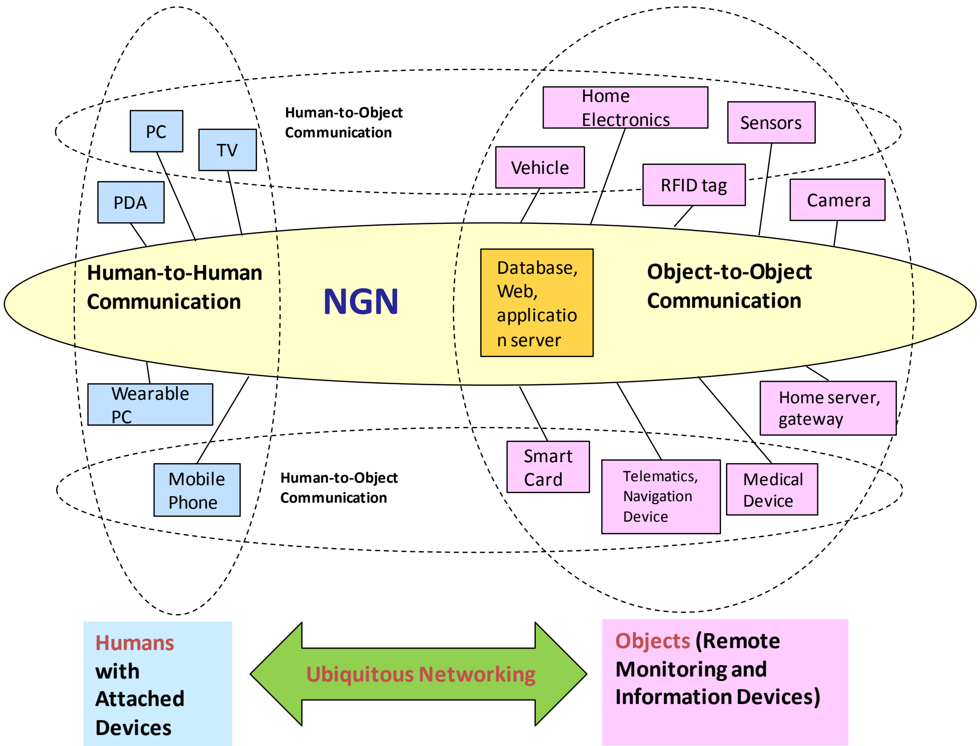


Figure 9 – Service coverage of NGN with ubiquitous features

Regarding the quality aspect, the NGN has been equipped with more powerful capabilities addressed on the QoS, Mobility and Security aspects, even though NGN use of IP same as Internet. Followings are brief summary how the NGN support enhanced capabilities of QoS, Mobility and Security:

- Quality of Service: NGN provides various classes of QoS which identified by ITU-T recommendation Y.1541 [10]. RACF (Resource Admission and Control Function) is the key functions for this QoS arranging transport resources to meet various QoS collaborating with service stratum as well as end user equipments. Through this RACF, the NGN provides guaranteed services when end user needed with their services such as guaranteed voice, multimedia and video conference services. NGN also provides general IP based services such as “Best Effort” and other existing services are also available through interworking with existing networks;
- Mobility: NGN does not have dependency with underground transmission technology, so the NGN services are available whether fixed or mobile or wireless (e.g., WiFi and WiMAX) environments. Thus the NGN has a capability to support mobility of services in various ways such as service mobility, terminal mobility and user mobility. These different types of mobility have been supported by MMCF (Mobility Management Control Functions) identified in ITU-T Recommendation Y.2018. MMCF in NGN functional architecture has a key role to support the mobility. This function collaborates with NACF and RACF providing different levels of mobility such as normadism, handover and seamless handover;
- Security: NGN provides much stronger security capabilities than other IP based networks such as Internet. For supporting of security, NACF (network Attachment Control Functions) and IdM functions take key roles. NACF identifies end user service requirements as well as their security preferences based on the subscription and service features. IdM function handles various identifications used for identifying end users, terminal devices, service providers as well as services and contents. Based on that information, security features have been identified and supported by the NGN.

5.5 Two types of NGN

There are two different types of the NGN: IMS based NGN and Call server based NGN. Both of two has been developed according to the ITU-T recommendations, especially based on those NGN principles [b-ITU-T Y.2018], requirements [b-ITU-T Y.2201] and functional architectures [b-ITU-T Y.2012], however approaches are different. Key differences between two types are identified the way of supporting PSTN/ISDN services such as voice services including supplementary services. Taken into account support of services which available over PSTN/ISDN, “IMS based NGN” more focused on mobile networks aspects while “Call server based NGN” focused on fixed networks aspects.

IMS (IP Multimedia Subsystem) [b-ITU-T Y.2021]

IMS, that is, IP Multimedia Subsystem, has been specified by the 3rd Generation Partnership Project (3GPP) and the 3rd Generation Partnership Project 2 (3GPP2). The IMS has been adopted into the NGN to support session-based services, and other services based on session initiation protocol (SIP). Thus IMS based NGN means how the IMS can be used in the NGN context following the fundamental principles described in [ITU-T Y.2001] and [ITU-T Y.2011]. Core functions of IMS based NGN has been realized in providing the IP multimedia service component into the NGN functional architecture.

IMS is a collection of core network functional entities utilizes SIP-based control for the support of SIP-based services. IMS supports the registration of the user and the terminal device at a particular location in the network including authentication and other security arrangements. The services supported by IMS may include multimedia session services and some non-session services such as presence services or message exchange services. IMS supports operator-provided services including operation and interworking with a variety of external networks via defined a number of network reference points. IMS also supports defined reference points for the collection of accounting data in support of charging and billing operations.

The NGN IMS component supports the provision of SIP-based multimedia services to the NGN terminals and the provision of PSTN/ISDN simulation services. NGN IMS supports the following:

- control of IP connectivity access networks (QoS, admission control, authentication, etc.);
- coordination of multiple control components to a single core transport for resource control;
- interworking and interoperability with legacy and other networks;
- mutual de-coupling of the applications from the session/call control and the transport;
- access technology independence of session/call control and applications.

Functional entities of an IMS may be used by an operator in support of transit network scenarios. The routing may be performed, depending on the entity performing the routing, and depending on the traffic case, signaling information, configuration data, and/or database lookup.

Call server-based NGN [b-ITU-T Y.2271]

Call server-based NGN mainly focused on how to support services available over the PSTN/ISDN through the NGN. Exact name of this is “Call server-based PSTN/ISDN emulation” identified as one of the service components of the NGN and provides PSTN/ ISDN basic and supplementary services. Call server-based PSTN/ISDN emulation service component co-exists and interworks with other components such as the IP Multimedia component (IMS) and the streaming component (e.g., IPTV) including interworks with the existing networks.

"Call server-based" indicates that service control logic and service execution environment is primarily located in a Call/Session Control Server (CSCS; briefly called “Call server”) which has responsibility of network entity for service delivery. This function relates to the service switching function (SSF) in PSTN/ISDN. The Call server-based service control concept is completely opposite with the IMS-based approach, because the application server houses the service control logic and service execution environment behind Call server entities.

Call server-based PSTN/ISDN emulation satisfies the following basic requirements:

- In terms of service provisioning, it inherits PSTN/ISDN basic and supplementary services, and provides IN (Intelligent Network) services;
- In terms of user-network connection, it supports existing PSTN/ISDN UNI interfaces.

The Call server-based PSTN/ISDN emulation component should support:

- PSTN/ISDN teleservices and supplementary services as per I.240 and I.250 series of ITU-T Recommendations;
- Capabilities provided by the application server (AS);
- Capabilities provided by traditional IN;
- Public interest services.

Consequently, using Call server-based NGN, PSTN/ISDN end users may use existing services and existing terminals without the knowledge of network being replaced by the NGN. This feature of Call server-based NGN is indicated one of the best ways for migration of PSTN/ISDN networks to the NGN.

6 Gaps between Legacy Networks and NGN

This clause analyzes gaps between legacy networks and NGN in terms of technologies used, capabilities, architectures including services and systems aspects. Gaps analyzed in this section would be helpful to identify migration scenarios as well as strategies.

6.1 Technology Gaps

Legacy networks use various different technologies according to the services as shown in Figure 10.

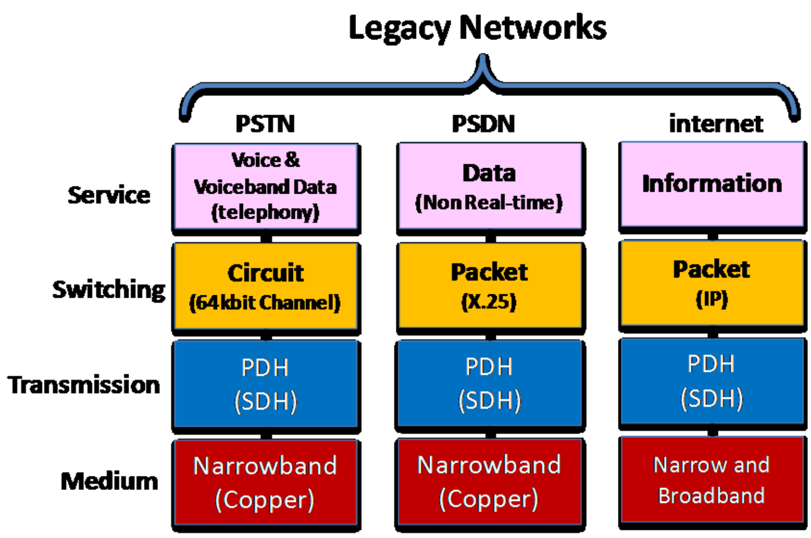


Figure 10 – Various technologies used in Legacy Networks

PSTN uses 64 kbit/s based channelized circuit for layer 3 as a key technology which caused to support 3.1 kHz audio service (that is voice). Because of a circuit consisted with a series of 64kbit streams, it requires fixed time based control such as switching and transmission. In addition, PSTN requires echo cancellation using A/µ law according to the standards to support voice service caused by far end-to-end delivery of voice signals in telecommunication environment. Finally switching technology used in PSTN has been developed “digit based switching” and formed of number based addressing. Because of PSTN used as a global telecommunication infrastructure to connect the people with voice and 3.1 kHz Audio data services (e.g., FAX and Modem based services), this number based addressing mechanism of PSTN has been developed in global way so managed by ITU, called ITU-T E.164 numbering.

PSDN is a traditional packet network using ITU-T X.25 packet. ITU-T X.25 packet technology has been developed mainly for data services, thus very significant amount of technology addressed on securing delivery of data which contained in each bit of the packet. Because of the status of physical mediums (e.g., copper and air waves) as well as transmission technology were not enough to provide secure delivery of all bits without problem (e.g., lost bits, delay delivery, error of bit value and others), many of supplementary technologies such as HEC (Header Error Control) error control and handshaking should be incorporated into the X.25 packet and relevant processing of the packet.

Internet is another packet network and is little difficult to called as a part of legacy networks because it uses IP. But taken into account service features provided, this Technical Paper classified Internet as a legacy network. Because of Internet basically provides communication services with "Best effort" which cannot guarantee quality of services at all, thus services are only available according to the given status of any parts of the networks, sometimes are not available even the connection is still maintained.

One of the key technical characteristics of the NGN is identified of using a single transport technology that is IP, which placed between services and underline various transmission technologies. This single transport technology takes a role to decouple services from underline technologies such as switching (or routing) and transmission. In other word, IP provides a single bridge for various services to use different transmission technologies according to meet service requirements. Because of this, the NGN covers non-real time as well as real time multimedia services including voice services, even though QoS in the NGN has been strongly correlated with the underline capabilities such as level of broadband connectivity.

By considering such differences of technologies used in legacy networks and the NGN, followings are identified as issues to resolve when interworking and/or migration be considered:

- Between PSTN (including ISDN circuit mode) and the NGN: support of echo cancellation, adaptation of numbering schemes, provision of accounting and charging capabilities and packet assembly and dis-assembly;
- Between PSDN (including ISDN packet mode) and the NGN: support of adaptation of different formats of packetization, addressing schemes and accounting capability;
- Between Internet and the NGN: support of QoS and security including other aspects of managed capabilities such as accounting and managements of services and users.

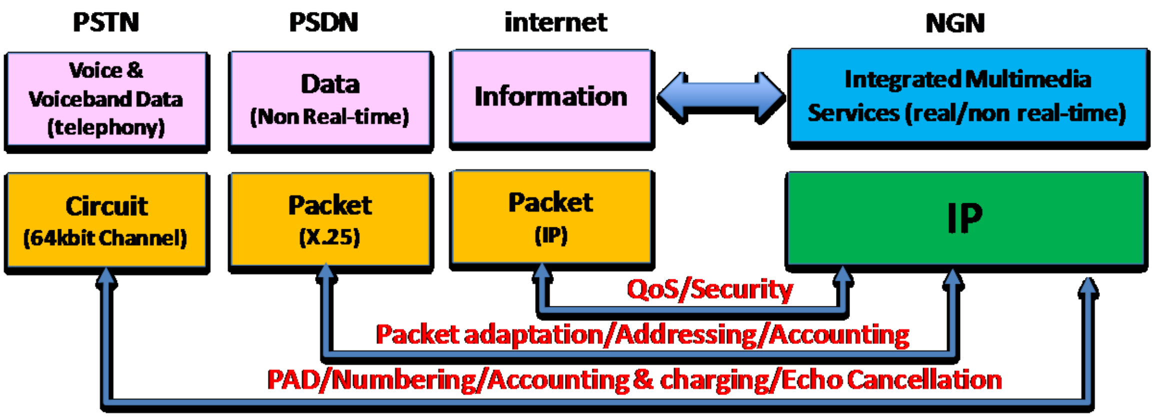


Figure 11 – Technical gaps of Legacy Networks and NGN

Figure 11 summarized these technical gaps between legacy networks and the NGN focusing on underline technologies, while services are integrated smoothly into the NGN. However it is required further considerations from service provisioning aspects such as SLAs (service level agreements), accounting and charging and others.

6.2 Architectural Gaps

There are two aspects needed to identify architectural gaps between two different networks: functional aspect (via vertical architecture) and distribution aspect (via horizontal architecture). Vertical architecture, in general, is useful to define relevant functions from application/service to physical medium and their relationships. Horizontal architecture is useful to know how this network deployed showing distribution of relevant functions and systems according to geographical coverage.

Gaps in Vertical Architecture

Vertical architecture, in general, identified based on OSI (Open System Interconnection) 7 layered model. Following Figure 12 shows vertical architectures of legacy networks and the NGN. As shown in the figure, NGN and legacy networks commonly use most of underline network infrastructures such as physical mediums and transmission systems. One difference has been indicated in transmission layer caused by supporting broadband services of the NGN while legacy networks only support narrowband which is enough to use PDH transmission. Broadband for the NGN has been supported by xDSL initially and other broadband technologies are supported later and being developed now such as WDM, PON and Giga Ethernet.

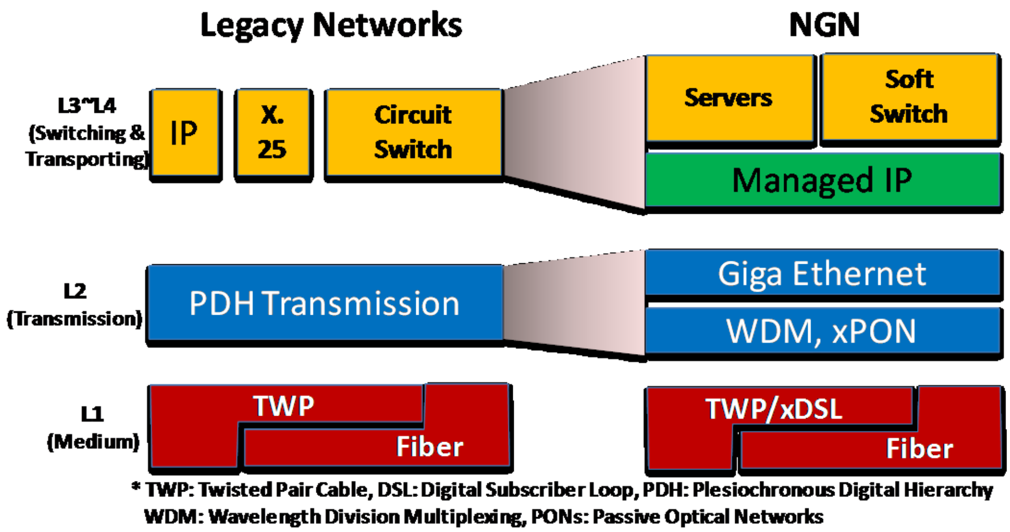


Figure 12 – Differences in Vertical Architectures

Key area of gaps between legacy networks and the NGN is switching (L3) and transporting (L4) layer technologies. Legacy networks use different switching technologies as well as transport according to the services which supported such as circuit switching for voice, X.25 packet switching for data and IP for information in case of Internet. NGN just uses IP with managed capabilities in the support of QoS and Security and services of real-time and non real-time natures are supported over this managed IP. Therefore these layers (L3 and L4) are the key areas need adaptation between different technologies when design migration of legacy networks to the NGN and interworking between them.

Gaps in Horizontal Architecture

Typical way of deploying legacy networks have been used hierarchy model covering geometric coverage. This model designs networks based on geometric distance with size of customers which are classified as, for example city, village and rural areas. According to these distance and size, legacy networks consisted with several different types of networks which form of hierarchies such as access network including remote access network, local exchange network, regional network and national network. These hierarchies are generally very helpful not only for installation and operation but also system developments. These hierarchies, especially, are quite well fitted with traditional telephone based service provision and network operation, in terms of identification, that is, E.164 number based. Following Figure 13 shows this hierarchical architecture of legacy networks.

Network systems composed of different hierarchy could have different features according the roles given that hierarchy. For example, role of systems in access network mainly collection of user traffics and delivery to/from local exchange. Role of systems in local exchange networks are identifying destination and routing traffics to that destination. Systems in regional networks collection of traffics from each local exchange networks and deliver to other regions which locates far distance. Followings are summary of key features of hierarchy based legacy networks:

- Hierarchical topology with 4 to 5 layers, connectivity to the upper next layer and within each layer as a function of economical optimization;
- Number of nodes as a function of output data traffic and nodes capacity;
- Service handling for media, signalling, control and management at all exchange nodes;
- Carrier grade quality with well-defined QoS criteria and standardized engineering rules.

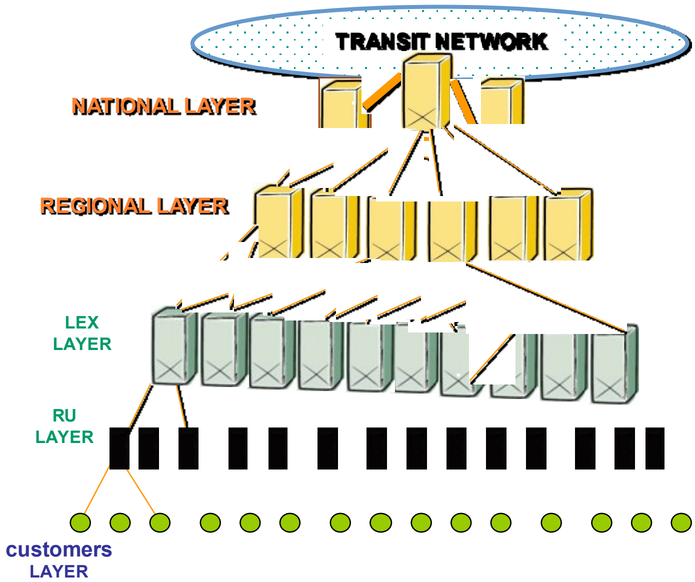


Figure 13 – Hierarchical Architecture of Legacy Networks

This hierarchy based network configuration of legacy networks is a point of gap with the NGN which use of IP as a key technology. This gap caused by the features of IP such as using flat address and dynamic routing taking consideration of providing end to end connectivity.

The NGN network can be logically decomposed into two different sub-networks, as shown in Figure 14. The major components of the NGN sub-networks are as follows [b-ITU-T Y.2012]:

- Customer network: a network within a home or an enterprise and connected to the NGN provider's network via a UNI (user-to-network interface);
- Access network: collects end-user traffic from the end-user network to the core network. The access network can be further partitioned into different domains, with the intra-domain interface being termed an INNI (Internal Network-Network Interface) and the inter-domain interface being termed a NNI (Network-Network Interface). The access network belongs to the transport stratum;
- Core network: The core network belongs to both the transport stratum and the service stratum. The interface between the core network and the access network or between core networks can be an INNI (in the case of partitioning as a single domain) or a NNI.

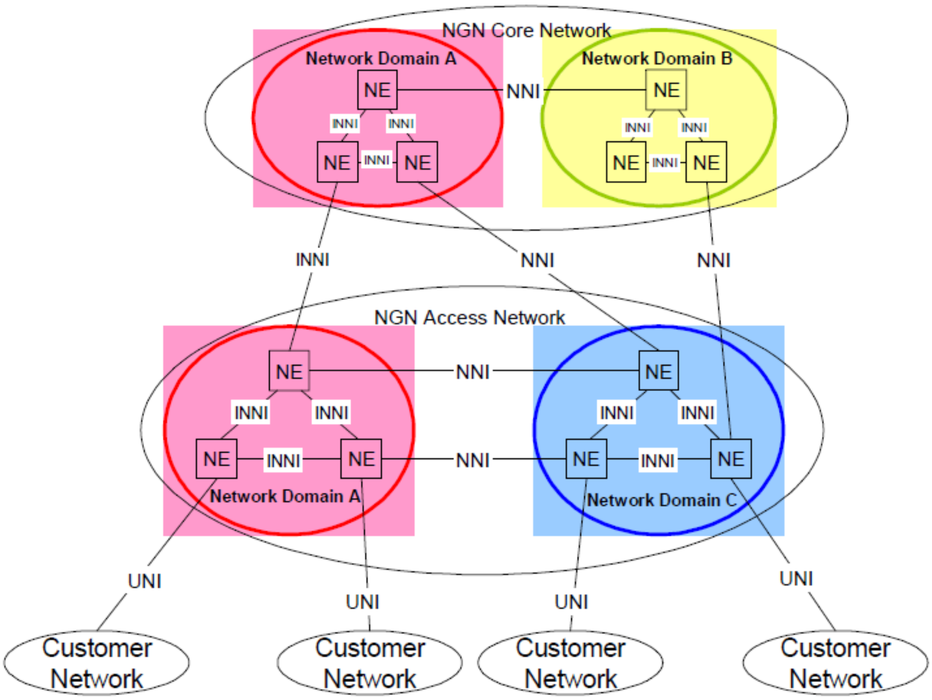


Figure 14 – Hierarchical Architecture model of NGN

6.3 Service Gaps

One of very clear differences of services between legacy networks and the NGN should be the level of integration of services. Legacy networks have been limited to integrate various services even though ISDN because of limited capabilities and capacities of underline access networks including transport. Each legacy network has certain set of list of services but limited for example, as followings:

- PSTN: support fixed-line based voice services including supplementary services and voice-band data;
- PSDN: support narrow-band data services;
- Mobile networks (2G): mobile based voice services, SMS and narrow-band data including mobile level (lower quality than fixed) of information services;
- ISDN: support fixed-line based voice services including supplementary services and narrow-band data;
- Broadband-ISDN: support fixed-line based multimedia services and data including limited connectionless services;
- Internet: Best effort based information services.

Because of each legacy network constructed based on different network related technologies (e.g., different transmission and switching), platforms for providing services also build upon differently. These differences between networks, between service platforms and between network and service derived difficulties and hurdles supporting “Openness” which provide fair and open accessibility to networks and service platforms from 3rd party providers as well various service providers and developers.

In contrast of these, NGN constructed based on common transport technology on top of different underline networks and supports various services which cover almost of services available over legacy networks. Thus the NGN widen services covering text to multimedia as well as not only fixed but also mobile features together. In addition, the NGN has more flexibility to support openness of networks and service platforms via OSE (Open Service Environments), thus 3rd party providers and other service providers including developers are easy to access the NGN resources and use capabilities.

6.4 Operational Gaps

As indicated before, legacy networks which have service oriented structure and network configuration cause duplication of infrastructural elements such as transmission nodes, switching and routing nodes which require operational costs such as office space, human resources, electric power and others. In addition these are also requested complicated operation of services and networks because different systems should be involved for different services.

Following Figure 15 shows network structures of both legacy networks and NGN in case of BT. Legacy networks comprised with various transmission networks and various different nodes which have different roles according to their responsible services and geographical position. In the case of core network of legacy networks, there are also different networks supporting different switching and routing according to the service specific features. These complicated structures required more offices where place relevant systems and human resources. In this case, BT need to operate around 8,800 access nodes (including hub facilities or small offices) and 115 offices (large offices) for core nodes operation.

In contrast, BT's NGN configuration, called 21C network, shows a rather simple structure but more powerful capabilities not only for voice services but also broadband services as well as also shown in Figure 15. Figure 15 is showing simplicity of structure and especially remarkable reduction of number of nodes (offices) while keeping full coverage of customers. This structure has been advantaged from "All IP features of the NGN" to make simple configuration in core networks, so all services should be routed by the IP core networks with different flows which have different treatment from the traffic management and service provisioning aspects but using same systems. And this structure is to shorten and to extend the contacting points of the customers allowing the network to cover customers more closely. This is the reason this structure keeps most number of the nodes located in the customer sides while removing other nodes from the previous structure.

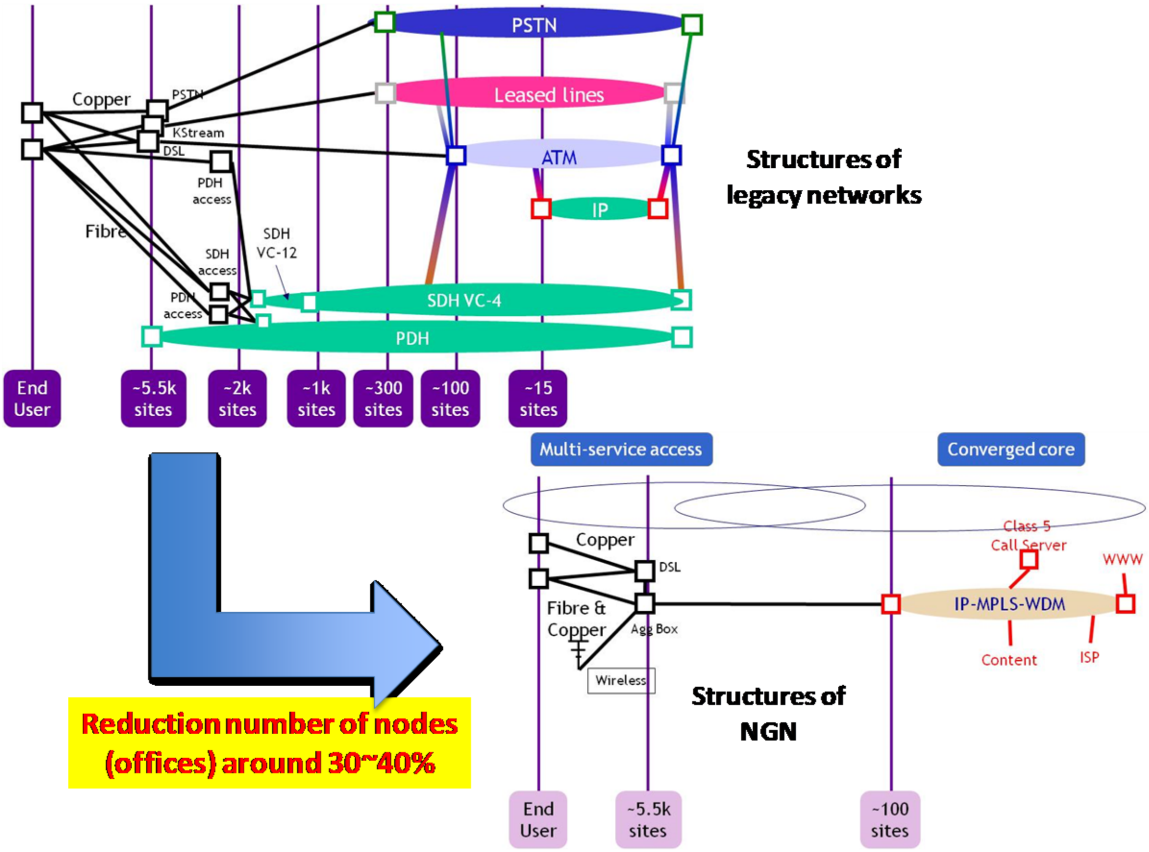


Figure 15 – Reduction of operational complexity

6.5 System Gaps

Systems used for legacy networks have strong dependency with supported services and networks according to the dependency characteristics between them. This yields to use different systems even same service but supported over different networks. For example, voice over PSTN, voice over ISDN, voice over mobile and voice over Internet, all service is the same of voice but all these cases use different systems. Thus complexity of using systems including duplication of them became quite serious problems in the legacy networks. In addition, this feature caused fundamental limitation of further extended use of systems when provide integrated services and upgrade of the services. Therefore life cycle of services has been heavy dependency of the relevant systems.

In the case of the NGN, systems have rather integrated capabilities in terms of supporting various services. For example, systems handling voice service in edge networks and core networks are same but only difference in access network areas because of different capabilities supported by different technologies such as over xDSL, optic and mobile. Thus complexity of systems should be reduced quite a lot. Life cycle of systems mainly depends on the capacity unless need to incorporate with specific technology which are not possible for the system.

7 NGN capabilities for migration

The most important services provided whenever change legacy networks including migration to any new networks is the voice service which recognized as a universal service. To help this for the migration, the NGN equips two different capabilities; emulation and simulation. NGN Emulation supports provision of PSTN/ISDN service capabilities and interfaces but using adaptation function for fitting to the NGN using IP. NGN Simulation supports provision of PSTN/ISDN-like service capabilities using session control over IP interfaces and infrastructure.

7.1 Emulation capability

NGN emulation is a capability mimicking a PSTN/ISDN network from the point of view of a legacy terminal by an NGN, through a gateway. All PSTN/ISDN services remain available and identical (i.e. with the same ergonomics) such that end users are unaware that they are not connected to a TDM-based PSTN/ISDN.

Adaptation Function (ADF) should take an essential role to use NGN Emulation capability. ADF provides connection to the NGN of legacy terminal devices such as legacy telephone and uses their services. ADF does an encapsulation process for non-IP information into IP and support all services available to PSTN/ISDN users through the NGN. Thus user does not recognize any change of experience using services by the network transformation.

Following Figure 16 shows a high level configuration view of the NGN emulation.

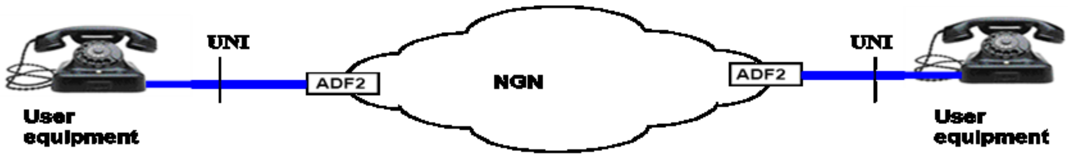


Figure 16 – Configuration of NGN Emulation

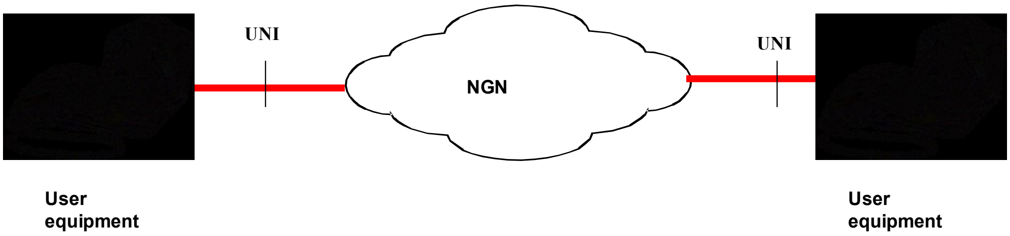
7.2 Simulation capability

NGN simulation is a capability for providing PSTN/ISDN-like service to the NGN users such as IP-phones. So NGN users will communicate with PSTN/ISDN users using this simulation capability. There is no strict requirement to make all PSTN/ ISDN services available or identical, although end users expect to have access to the most popular ones, possibly with different ergonomics. Key features of the NGN Simulation summarizes following:

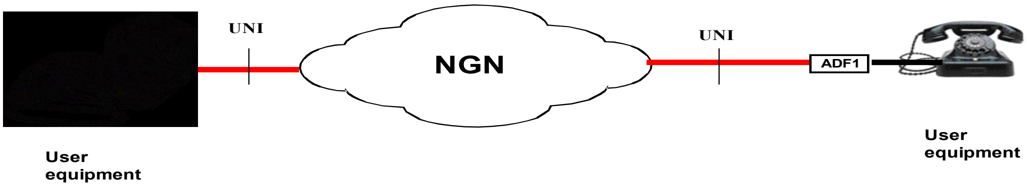
- PSTN/ISDN-like services available;

- Possibly available of new services from the NGN, but;
- Some of user experiences may be changed by the network transformation.

Figure 17 shows two different cases of configuration examples: a) shows a case that a NGN user uses PSTN/ISDN-like services using the NGN terminal; b) shows a case that a NGN user (with NGN terminal) communicate with another NGN user (with non-NGN terminal but using ADF).



a) NGN Simulation with NGN terminals



b) NGN Simulation with NGN terminal and non-NGN terminal

Figure 17 – Configurations of NGN Simulation

7.3 Interworking between Emulation and Simulation capability

Voice service whether over PSTN, ISDN or mobile should be reached to any others as soon as possible, because this is the fundamental and essential telecommunication service to connect the people. Thus the telecommunication world identified voice service is as the universal service. By considering such importance of voice service, voice service of the NGN should be communicated with voice service in PSTN/ISDN environment as well as mobile. Supporting this as maximum as possible, NGN emulation and simulation are used jointly wherever possible, for example interworking between the NGN and PSTN and/or ISDN.

Figure 18 shows an example of interworking between the NGN and legacy PSTN/ISDN. Simulation is used in the NGN side while interworking with legacy side is using emulation. Service features in this case are characterized as following:

- Service interworking between the NGN and PSTN/ISDN is required;
- Only PSTN/ISDN-like services available, and;
- User experience in legacy terminal cannot be fulfilled for end-to-end connection.

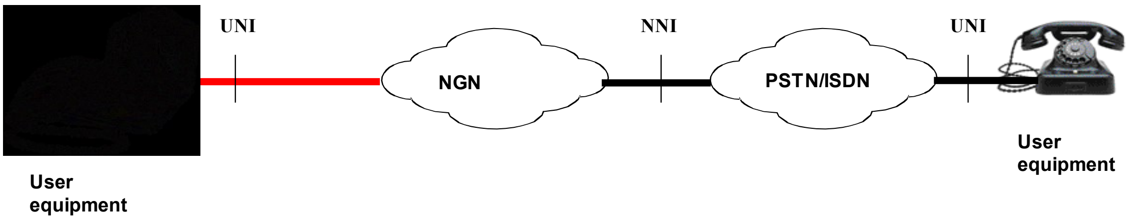


Figure 18 – Interworking between NGN Emulation and Simulation

Following Figure 19 shows another example of interworking between the NGN and legacy IP based network which support voice service (e.g. VoIP). Simulation is used in the NGN side while emulation is used in legacy side but connected by interworking. Service features in this case are characterized as following:

- Service interworking between the NGN and IP network is required, and;

- Both the NGN and IP network user experiences may not be fulfilled for end-to-end connection.

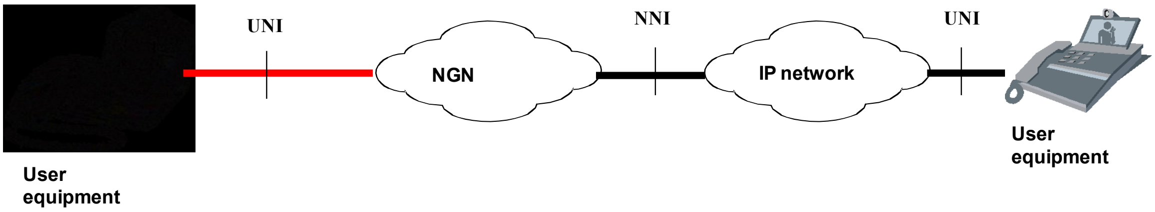


Figure 19 – Interworking NGN Simulation with Legacy IP

8 Migration scenarios

ITU-T Recommendation Y.2261 defines “Evolution to the NGN (same as Migration to the NGN)” as a process in which whole or parts of the existing legacy networks are replaced or upgraded to the corresponding NGN components providing similar or better functionality, while attempting to maintain the services provided by the original network and the possibility of additional capabilities. [5] Thus, there are many of ways about migration from legacy networks to the NGN which would be derived various ways according to the given environments, future vision and adoption of candidate technology. This section introduces various migration scenarios showing high level directions for helping detailed migration design.

8.1 Generic migration scenarios

One of the fundamental facts about migration to the NGN is that the result should be changed of all the network elements fitting to the NGN, that is, IP based. IP is one of transport technologies which use in layer 3 (network layer). But IP has been featured with “Everything over IP” as well as “IP over Everything” which request careful thinking where identify best place for replacing legacy systems to IP based systems. In this sense, changing TDM based to IP based should be the 1st step.

Next step should be taken into account the network configurations and possession portions in each country, for example between "Access network vs. Core network" and “Transport network vs. Service network”. In general, migration in “Core network” is easier than "Access network" because less impact on the service provision. Therefore it is generally recommended to introduce the NGN capability into Core network first, and then expand to the Access networks as shown in Figure 20. And it is also noted that service networks have significant dependency with transport capabilities, so migration plan for both transport and service networks should be considered together.

There are various ways of migration from legacy network to the NGN, so choosing NGN emulation and/or NGN simulation in the NGN side should be decided according to the specific scenario, for example according to each country or provider situation. NGN will be deployed and operate jointly with PSTN/ISDN. NGN will occupy more portions while PSTN/ISDN will continuously decrease and finally migration to the NGN. Thus at the beginning stage which legacy networks are majority, both NGN simulation and emulation capabilities should be provided together to the users who want to use advanced features supported by the NGN as shown in Figure 20. With growing of user demands, simulation will cover more users and areas with advanced services while emulation covers PSTN/ISDN users waiting until the time to replace their legacy networks to the NGN.

These two aspects of migration “Core network vs. Access network” and “Emulation vs. Simulation” should be considered together during the set-up of specific migration scenarios. There are, in general, two scenarios of migration: Overlay and Replacement. In any case, it is not expected to replace a network to other network at one shot. Thus it is recommended to set up long term plan rather than short term, and proper combinations among various available solutions. Followings jointly with Figure 20 should be considered as a process for identifying general aspects of migration scenario:

- Expand the core transmission capacity;
- Develop a core NGN overlay with call servers and media gateways, then interconnect or interworking with PSTN;
- Install NGN access nodes (e.g., MSANs: Multi-Service Access Nodes) at legacy access network sites, stop buying more legacy access system;
- Migrate those customers who want advanced features, or fast Internet, or new NGN services onto the NGN access nodes;
- May need to use a number portability technology for call routing if number is not going to change, since number block is normally related to the Remote Concentrator Unit, unless whole unit is replaced, and;
- When number of subscribers on legacy access nodes is small, then the remainder migrate to NGN nodes.

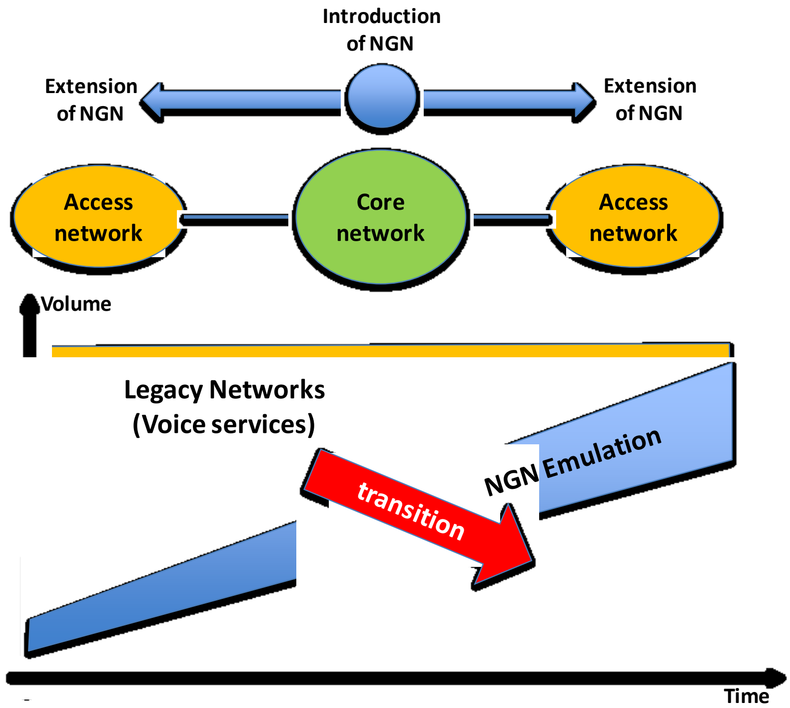


Figure 20 – General views of migration scenario

8.2 Overlay scenario

This is a scenario to deploy new NGN infrastructure overlay to the existing legacy networks which means two infrastructures both NGN and legacy networks exist together. NGN will take a role to provide advanced services while legacy networks keep existing services. Depending on the growing trend of the new services reflecting end users needs, the expansion speed of the NGN could be decided (also decided the level of shrink the legacy networks).

In any case, communication between users, at least universal services such as voice service, should be provided whether the user belongs to legacy or the NGN, thus it is essential to use interworking functions between two different networks. In addition, ADF function also needed providing the NGN connectivity to the legacy terminal devices.

Following Figure 21 shows high level configuration of this scenario.

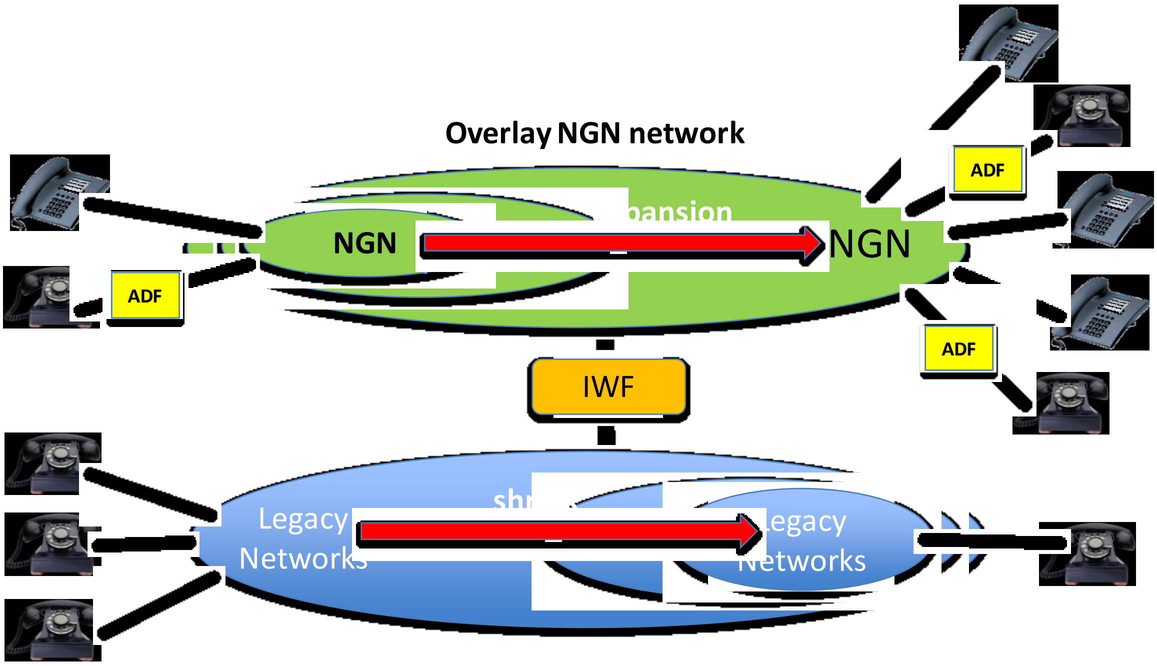


Figure 21 – Overlay scenario

8.3 Replacement scenario

This scenario uses mixed two NGN capabilities, simulation and emulation. NGN simulation has used for providing PSTN/ISDN-like services to the NGN users with advanced NGN features. NGN emulation widely uses to support voice oriented services but keeping the legacy terminal such as legacy telephone, thus end user could not recognize the change of technology behind their terminal. Therefore combining of these two capabilities will give flexible ways to migrate legacy networks according to the environments such as end user needs for advanced features, status of legacy network systems and business strategy of the operators as well as service providers (may include national vision for upgrading legacy infrastructure).

In this scenario, overlay NGN will be deployed first where there are needs for the advanced services. This overlay NGN takes a role to invite NGN users with advanced service features as well as deploying NGN terminal equipment. This will be a fundamental infrastructure for the future transformation of legacy networks. In addition, NGN access networks in this overlay NGN also install where there is not have enough PSTN/ISDN infrastructure which means lack of connectivity to support voice services. In this case, NGN access network should have emulation capability, so it easily incorporates existing legacy terminals. Consequently this is a replacement of legacy access network into the NGN. According to the growth of end user needs as well as status of legacy network capabilities, this replacement should be expanded.

Through this scenario, current users even using PSTN/ISDN have continuous support without any change of their terminal and operator will stop their deployment of PSTN/ISDN but will need other investment for replacement to the NGN. For this, operator will provide ADF (Adaptation Function) to the current PSTN/ISDN users to provide continuous usage of voice services.

Following Figure 22 shows high level configuration for the replacement scenario.

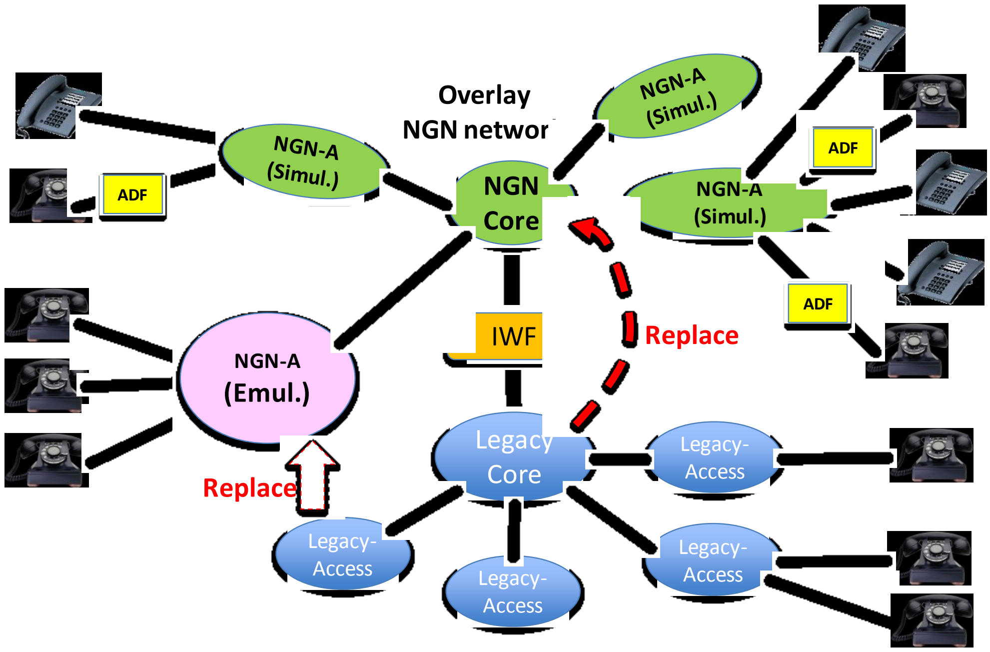


Figure 22 – Replacement scenario

9 Considerations identify the scenario

As explained in the previous section, each scenario has their own specifics, thus it is useful to take into account various issues to be considered. This section introduces various issues for choosing scenarios for migration of legacy networks into the NGN.

9.1 General considerations

There are many of issues to be considered when building migration plan from one to another. Legacy networks are not simple objective for replacement, because they consisted many of portions of telecommunication infrastructures as well as cover significant and fundamental communication services such as voice services. Therefore it is highly required to consider many of things from various perspectives during the set up of migration plan carefully. By considering this, there may neither a single way nor the best way in global and/or overall sense, because migration should be based on each country situation such as national vision, user needs, politic & regulatory environments, technology trends and business environments such as given condition by operators and industries.

High level aspects such as national vision, user needs, policy and regulations including business aspects should be investigated and analyzed as soon as possible before identify the scenario(s) for the migration, because they have a lot of impacts for the whole process of migration. And it is noted that understanding the exact status of such high level aspects generally requires in-depth study with wide knowledge of that country.

Identified scope of each subject areas are summarized as followings and show in Figure 23 which described the relationship among them:

- User demands: this is a fundamental point to know the status of end user needs for telecommunication services including any new requirements and analyze potentials for the future developments. This is also contributed to identify NGN as a social infrastructure from user point of view;
- Government Policy: this should cover translation of the national vision of ICT and telecommunications into government policy including relevant strategies and milestones for

the developments as well as identify the roles and responsibilities of players who will involve migration process;

- Regulation Environments: this provides regulatory guidance and preparation of necessary regulations to help and support various ways of migration (may be included for improvements or updates) of legacy telecommunication infrastructures into the NGN;
- Business Environments: this is for knowing the status of environments and practical capabilities as a business potential of the country.

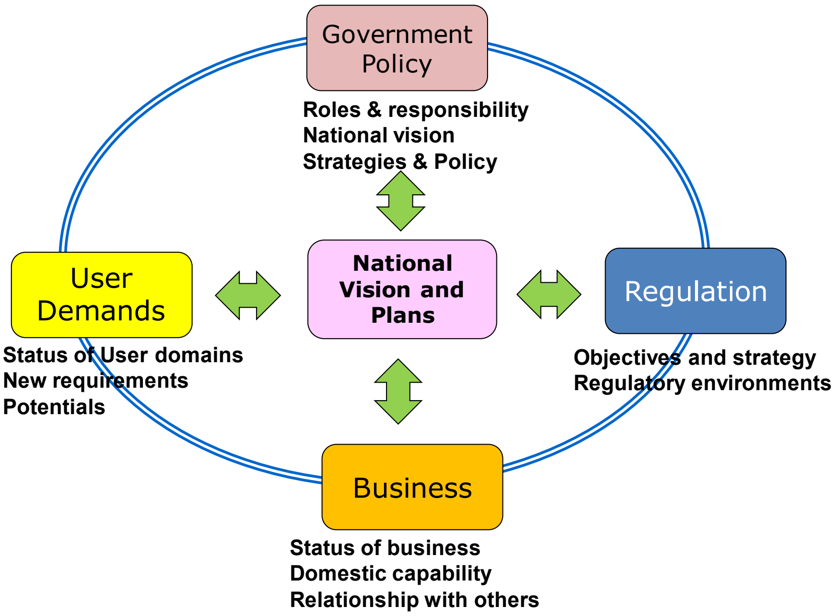


Figure 23 – Scope of considerations for migration

9.2 Technical considerations

Overall aspects

During the set-up of the migration plan, many of technical views and considerations would be carefully examined because it will impact to the whole of communication infrastructure including related regulations as well. ITU-T Recommendation Y.2261 identified that the PSTN/ISDN is the prime candidate for evolution to the NGN and the Recommendation Y.2261 recommend all aspects should be carefully examined and appropriate measures should be taken. In PSTN/ISDN, most of the functionalities are located in a single exchange and may use proprietary protocols. But, in the NGN, functionalities may be distributed amongst several elements. [5]

For better and smooth migration, followings are recommended as consideration points:

- Growth of voice service market and dilemma to grow with legacy PSTN/ISDN or with the NGN;
- Seamless continuity of services as well as backward compatibility of voice services;
- Inter-working with existing legacy equipment;
- Provision of new communication services to emerging users in addition to existing network services;
- Possibilities offered through NGN migration to grow new markets (broadband, triple/quadruple-play) and enrich infrastructure competition between distinct access platforms;
- OPEX with legacy networks vs. CAPEX for new NGN infrastructure;
- Timelines for the whole process of migration, and;
  - Decision to begin replacement of infrastructure;

– A significant portion of users switches to NGN services, the other direction, reduction of true PSTN/ISDN usage visible;

- Replacement parts of the infrastructure (e.g. local switch) by new infrastructure, without forcing all users to migrate.

Special consideration should be addressed for service expansion in rural remote areas. Migration to the NGN in the rural areas should not be abrupt, and both the older and the newer technologies should co-exist for a reasonable period of time.

In general, PSTN/ISDN is comprised of the following entities, each with one or multiple functionalities:

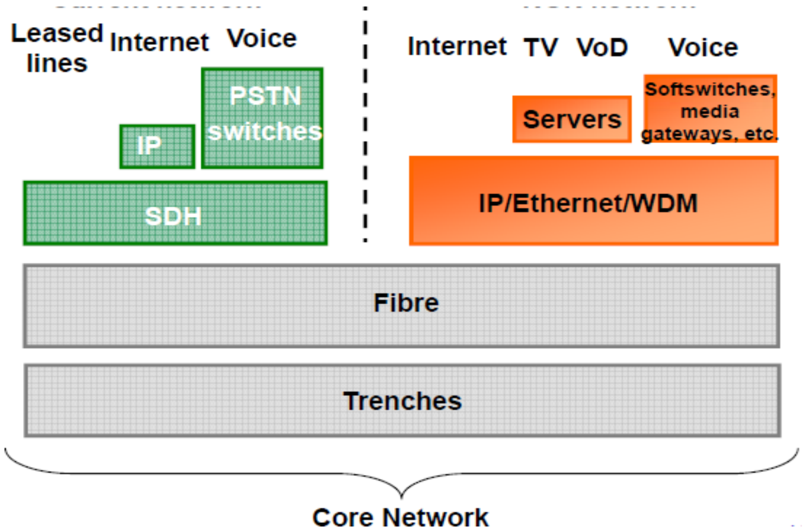
- Transport entities (including switching, transmission and physical mediums): physical PSTN/ISDN infrastructures with forming access and core networks;
- Control and signalling: identify communication end points and forming control center for the communications;
- Management: monitor, maintain and repair of communication services and networks to keep operations and provision properly;
- Service: mainly voice or speech class of services including voice-band data and in the case of ISDN narrow-band information services are also available.

Transport aspects

Transport is the most significant and fundamental parts to be considered whenever think about the migration or transition. There are two distinct domains: access network and core network (including switching entities).

Core network is recognized rather soft than other domains because it takes a role to transport bundle of traffics from one node to other relevant node(s) without much concerns about the service aspects. Thus there are fewer impacts for migration. However core network during the migration process should be prepared providing managed capabilities in terms support of QoS, security and mobility, but the level of capabilities should be identified according to the given conditions of each country or operator.

Figure 24 shows an example of structural configuration of core network during the migration process. It is expected that physical medium should be aimed using optic fibre based infrastructure whether SDH, IP, Ethernet, WDM will be used on top of the fibre together or not. In the case of switching capabilities, it is expected to use softswitch which are core part of call-server based NGN to support voice oriented services. In the case of supporting content oriented services such as IPTV and VoD (Video on Demand), it is required to use relevant servers.

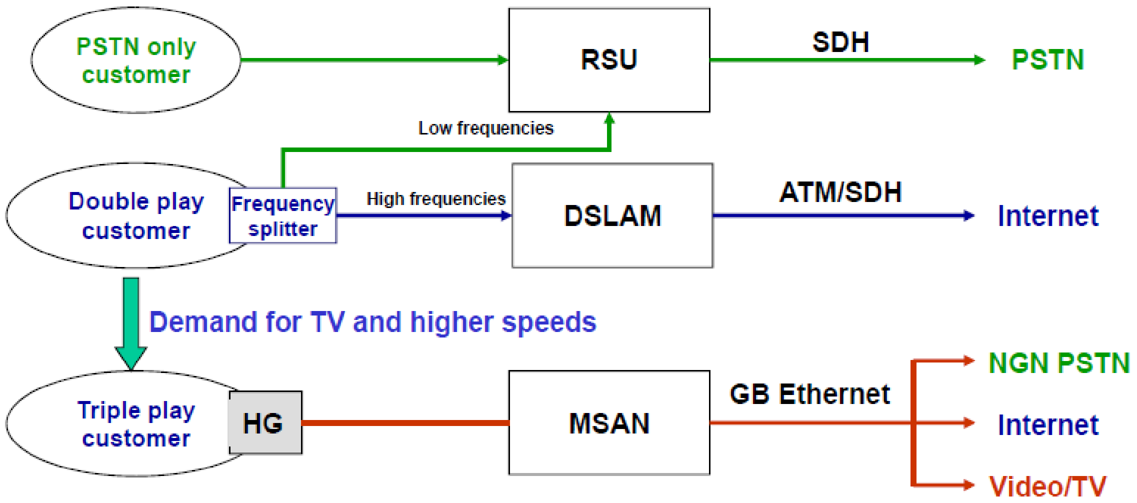


Ref: "Migration to NGN and NGN costs", ITU-TCI NGN Migration Strategy, John Horrocks

Figure 24 – Core network structure during migration

Access network, the most difficult part, has very complicated situations in terms of technologies as well as geographical coverage and distributions. Many of different technologies have been developed and used in access networks. Fortunately most of technology provides IP connectivity which is the critical technical feature to meet the NGN requirements. In fixed access networks, xDSL is mainly used for broadband access. xDSL gives the opportunity to use existing copper based access infrastructure as much as possible for deploying broadband infrastructure in economic way, but with limited capacity (maximum few 10s Mbps). Fibre optics is a kind of target technology in the area of fixed networks with its unlimited capacity. Only concerns are related to the cost and construction difficulties. Both concerns will be faced by the quick development of the technology. In any case, it is not recommended to choose only one specific technology to replace any legacy access network systems. It is rather recommended to consider harmonization among different technologies to cover customer requests in more flexible and economical way. Therefore it is recommended to use both xDSL and Fibre together in the access network as a preparation of migration to the NGN including preparation of enough broadband capability.

Following Figure 25 [4] shows an example how access networks in fixed networks be migrated taking consideration of service enhancements such as voice only, double play and triple play.



Note: HG (Home Gateway), RSU (Remote Service Unit), DSLAM (Digital Subscriber Line Access Multiplexer), MSAN (Multi-Services Access Node), GB (GigaBit), MDF (Main Distribution Frame)

Figure 25 – Migration in MDF site

It is useful and easy to explain access network migration based on the migration of MDF (Main Distribution Frame) as shown in Figure 25. A MDF is a signal distribution frame or cable rack used in telecommunication to interconnect and manage telecommunication wiring. The MDF connects equipment inside a telecommunications facility to cables and subscriber carrier equipment. Every cable that supplies services to user subscriber lines ends up at an MDF and is distributed through MDF to equipment within local exchanges.

Legacy networks, especially using traditional local loop (i.e. twisted pair cable), generally connected through RSU (including termination function of digital subscriber loops) to the local switch. This will be replaced with DSLAM if need to provide broadband access connectivity which forms also fundamental requirement of NGN and internet. If considering the triple-play which provides legacy services as well as content based services such as IPTV and VoD, it should be supported by MSAN jointly with HG.

Signaling and control aspects [b-ITU-T Y.2261]

PSTN/ISDN uses signalling systems such as analogue line signalling, channel associated signalling (CAS) like signalling systems R1 [Q.310-Q.332], R2 [Q.400-Q.490], and common channel signalling (CCS), like SS7 or Digital Signalling System No. 1 (DSS1) [Q.931]. All these signalling systems are for the circuit switched networks. Since NGN transport is packet-based (and call and bearer are decoupled), other suitable types of signalling (e.g., BICC, SIP-I [Q.1912.5], etc.) may be required. Also, the signalling function and call control function may reside in more than one NGN element.

Since the NGN has to communicate with the PSTN/ISDN and other networks, interworking between the NGN signalling systems and the legacy network signalling systems is required.

The NGN naming, numbering and addressing schemes, in accordance with ITU-T Recommendation Y.2001 shall be able to interwork with the existing E.164 numbering scheme. During PSTN/ISDN migration to the NGN process, it should be ensured that the country code numbering, naming, addressing and identification plans, is fully maintained. Also, as a minimum, support should exist for Internet IP addressing schemes including E.164 Telephone uniform resource identifiers (TEL URIs), e.g., tel: +98 765 4321 and/or SIP Uniform Resource Identifiers (SIP URIs), e.g., sip:my.name@company.org.

Management aspects [5]

PSTN/ISDN management is comprised of activities from a core exchange network, access network, intelligent network and the operations support system (OSS). ITU-T Recommendation M.3400 and M.3010 provide management principles for PSTN/ISDN. An NGN management system is comprised of three planes, namely the network management plane, the network control plane and the service management plane. Each of the three planes implements corresponding management functions to each layer in the NGN layered model.

Migration of PSTN/ISDN management (i.e., operations, administration and management) systems requires the ability to support the transition of PSTN/ISDN through intermediate stages towards the NGN.

Operation, administration and maintenance (OAM) functionality is used to verify network performance, and to reduce operational expenses by minimizing service interruptions, service degradation and operational downtimes. As a minimum, when performing PSTN/ISDN migration to the NGN, the ability to detect faults, defects and failures such as lost, errored or mis-inserted packets, should be provided. Additionally, there should be mechanisms to indicate connectivity status and provide support for performance monitoring.

9.3 Service considerations

PSTN/ISDN services which are traditionally provided by Circuit Switching systems whether digital or analogue may be provided by application servers (ASs) in the NGN. It is expected that some or all of the legacy services will be provided by the NGN.

However, there is no guarantee that all services will be provided when PSTN/ISDN is simulated. Use of legacy terminals via adaptation to the NGN is expected in order to support existing services.

- Bearer services: During the migration process from PSTN/ISDN to the NGN, bearer services should be provided continuously. All bearer services shall be transparent for use of the NGN to connect PSTN/ISDN. NGN should provide same or better QoS for PSTN/ISDN bearer services;
  - PSTN/ISDN simulation provides functionality that is similar but not identical to existing PSTN/ISDN bearer services.
  - PSTN/ISDN emulation shall be capable of providing all bearer services offered by PSTN/ISDN. However, there is no requirement for the NGN to support all N-ISDN bearer services identified in the ITU-T I.230-series Recommendations.
- Supplementary services: During the migration process from PSTN/ISDN to the NGN, supplementary services should be provided to the extent practical. PSTN/ISDN emulation shall provide support for all supplementary services offered by PSTN/ISDN while PSTN/ISDN simulation provides functionality that is similar but not identical to existing PSTN/ISDN services. The NGN need not support all ISDN supplementary services identified in I.250 series of ITU-T Recommendations. NGN shall appear transparent when used to connect supplementary services between PSTN/ISDN;
- Service requirements by national regulatory bodies: Following requirements are required by national/regional regulation or law, an NGN service provider shall provide which means in the case of interworking;
  - the basic telephone service with the same or better quality and availability as the existing PSTN/ISDN;
  - the capability for accurate accounting and charging;
  - capabilities to support number portability;
  - the availability of a directory inquiry service for PSTN/ISDN and the NGN users;
  - support of emergency telecommunications;
  - support for all users, including the disabled. Support should provide at least the same capabilities as the existing PSTN/ISDN. NGN offers the opportunity for more advanced support, e.g., network capabilities for text to speech;
  - mechanisms to support lawful interception and monitoring of various media types of telecommunications such as voice, data, video, e-mail, messaging, etc. Such a mechanism may be required of a network provider for providing access to content of telecommunication (CT) and intercept-related information (IRI) by law enforcement agencies (LEA), to satisfy the requirements of administrations and international treaties;
  - interoperability between an NGN and other networks e.g., PSTN/ISDN and PLMN (Public Land Mobile Networks).
- Accounting, charging and billing: During the transition period, maintaining the existing accounting, charging and billing procedures, to the extent practical, may be required. Migration from existing networks to the NGN will also imply replacement of the existing sources of the accounting data generation. The NGN shall support both offline and online charging;
- Interworking: Interworking is used to express interactions between networks, between end-systems, or between parts thereof, with the aim of providing a functional entity capable of supporting an end-to-end telecommunication. PSTN/ISDN migration to the NGN should take the following into consideration:

- – Ability to interwork with legacy networks such as PSTN/ISDN and internet
  - – Ability to interwork with IMS-based or call server based networks;
  - – Ability for inter-domain, inter-area or internetwork interworking;
  - – Support for authentication and authorization;
  - – Ability to perform call admission control;
  - – Capability to support network performance parameters as defined in ITU-T Recommendation Y.1541;
  - – Support for accounting, charging and billing.
- Call routing: When an NGN coexists with PSTN/ISDN, the routing scheme should allow the carriers to control where their traffic enters and leaves the NGN. This will make it possible for the carrier to optimize use of their network resources and to avoid multiple points of interworking between the NGN and PSTN/ISDN along the media path.

9.4 Status of legacy networks

One of the most important factors to be taken into account during the planning process of the migration knows and understands the exact status of legacy networks including related infrastructures supporting networks and services of each country. This has been accomplished through analysis of collected information about the status of legacy networks such as fixed and mobile legacy networks. Issues identified for collection of information are summarized followings:

- Fixed network infrastructures: status of telecom providers and services, especially for voice service oriented infrastructures such as POTs (Plain Old Telephons) and ISDN over PDH (as well as with SDH);
  - – Remaining life time of existing DSS (Digital Switching System): this status is essential factor because there are no more industries to provide DSS any more in the world. Therefore this factor should be used to identify the time to replace of new systems (for example, to support "All IP with NGN capability");
  - – Status of twisted copper cables: this status will used to identify the possibility of providing minimum broadband using xDSL and also the time to provide enhanced medium such as through FTTC and/or FTTH;
  - – Status of telecom operators: this factor will be used to identify the plan for enhancement (upgrade) of fixed infrastructures through promotion of completion and collaboration among those telecom providers;
- Internet and Broadband Infrastructures: currently internet is available almost everywhere, but to know the exact status of using internet including broadband is useful for planning of migration;
  - – Status of key access for Internet: many of developing countries used mobile, consequently caused limited quality of services including contents (because it mainly targeted to mobile environment). It is not desirable having serious dependency to mobile. It is recommended to balance between fixed and mobile;
  - – Status of fixed Broadband: many of developing countries are in initial stage of providing xDSL and need to expedite but, it needs to improve the deployments taking into account status of twisted pair cables to the subscriber loops;

As a result of the study on infrastructures, it is highly recommended to find out how to get balance between Fixed and Mobile infrastructures because status of most developing countries have too much dependency in mobile, but noting that fixed infrastructures are fundamental parts of both two fixed and mobile.

9.5 Regulatory considerations

In general, legacy networks have been monitored, guided and sometimes regulated by different regulations according to the business types which are based on different services. For example, PSTN/ISDN has been strong responsibility by the regulation for universal services, emergency services and interconnection. But PSDN has only strong guidance from accounting and charging aspect without other responsibilities. By the way, deployment of the NGN means that change the fundamental elements in the legacy networks such as services, network structure and the functioning model of the network structure in terms of business and regulation aspects. By taking into account these regulatory environments of legacy networks and features of the NGN, NGN raises regulatory challenges that can be linked, in one way or another, to the convergence process at the service provision and network access levels.

A number of challenges on the NGN from a regulatory perspective are being studied by ITU-D SG2 from several years ago in terms of general considerations, open access, market definition, QoS and interconnection. Followings are summary from the ITU-D SG2 report.

General considerations

The report from ITU-D SG2 indicated that it is important to remember NGN inherit some of the same regulatory obligations imposed on the PSTN/ISDN like lawful interception and access to emergency services. Lawful interception for packet mode services is already enabled by GPRS (General Packet Radio Service) in 2G mobile networks. GPRS has the capability to send a duplicate of all packets exchanged by a user over a PDP (Packet Data Protocol) context as well as the address of the entity accessed through this context. Lawful interception was introduced from the first 3GPP IMS R5 (Release 5) specification. Although NGNs and their services appear to offer numerous advantages, it is anticipated to get better understanding of all the options available and all the advantages and disadvantages related to NGNs. The followings are issues to be helpful for identifying these considerations:

- What networks for what services?
- What actions can the regulator envisage to facilitate migration to NGNs to the benefit of the consumer?
- How is the regulation of dominant operators modified by migration to NGN?
- What is the impact of the introduction of NGN networks on interconnection, tariff-setting for services, numbering, frequency spectrum management, etc.?

With a view to preparing transition of the existing telecommunication environment towards NGNs, possible problems raised by the NGNs, such as interconnection, consumer protection, redefinition of universal access, technological neutrality, quality of service, numbering and licensing should be carefully considered. Technical, economic and regulatory study on arrangements for migration to the NGN is very important with the purpose of determining the right time for migration. It is important to note that the regulator ensures the market emerging from the transition is fair, open and competitive and, on the other, to elucidate for the regulator all the technical, economic and regulatory issues raised by transition to the NGN, allowing it to identify as early on as possible the areas of interest related to its activity.

The following study issues have been considered for these objectives:

- review the legal and regulatory telecommunication regime and identify those elements that may require adaptation in order to accommodate convergence;
- gather the expectations of operators and service providers vis-à-vis NGN networks;
- examine the migration strategy of the major fixed and mobile telephone operators regarding the core network and access network segments;
- identify what elements hamper or boost migration to the NGN (at the technological, economic and regulatory levels);

- identify the new economic models that will be associated with the NGN and their suitability and durability;
- draw up the strategy for migration of fixed and mobile telephone networks to the NGN;
- propose for that migration an ambitious roadmap that is adaptable to new technological changes, along with a budget, realistic realization deadlines and indicators/mechanisms to monitor its implementation.

The study should be conducted according to the following proposed phases:

1) gathering and analysis of information on the legal and regulatory framework for telecommunications;
2) organization of a seminar/workshop on NGNs open to all players in the telecommunication and ICT sector;
3) collections of data from fixed and mobile telephone operators and Internet access and service providers;
4) analysis and exploitation of the data on the situation in each country and comparison with the experiences of other countries;
5) preparation of a roadmap, production of the final study report and the strategy document for transition to the NGN.

One of the ways to have regulatory perspective could be focused on the necessity of examining the NGN regulatory issues within the framework of a methodological approach. In this sense, a question about whether the NGNs are public goods or not is a good subject to examine many of aspects such as non-excludability in supply, non-rivalry in consumption and externalities. Study on these aspects may provide valuable inputs to direct very high level regulatory regime for the NGN, possibly adopting new regulatory approach which will have different regulatory frameworks than legacy networks.

Followings are summary of key features about aforementioned aspects:

- Non-excludability in supply: This determinant means that the supply of the related product should cover everybody without a manner of excludability. The product that has been supplied in the market in a country or a society is within the reach of all individuals there. A supply on the level of market operation cannot be made by market players. One of the fundamental elements here is that the supplied product has not been supplied upon request. A product which has been provided for a person, at the same time, has been provided for each person or player in the society. The supply of the related product is provided homogenously. The supply is itself should be a homogenous product;
- Non- rivalry in consumption: This determinant means that the consumption of the related product by a person does not pose a hindrance to another person's consumption of the product. Consumption preferences of individuals are not homogenous but heterogeneous. On the other hand, this heterogeneous nature of preferences about consumption does not generate a competition or rivalry in consumption;
- Externalities: This is the ratio relationship between benefit and cost for other units concerned with the product. A product which has been provided as a public good does not operate as efficiently within the framework of benefit-cost-balance unlike the functionality of free market. Public goods form a negative externality, so cannot be regarded as efficient situation in term of open market.

Open access with Next Generation Access (NGA) Networks

There was only a single access network infrastructure in legacy networks, thus it requires an obligation to reach access of local loop. However, in the scope of NGN which has no dependency on specific access networks, even fibre access is not an essential facility for NGN services. Thus it is worthwhile to focus on whether NGA (Next Generation Access) networks are essential facilities or not.

During migration to the NGN, PSTN/ISDN based access networks can be considered as an alternative to NGA networks. Consequently, NGN can be considered as a technologic device to give more IP based new services (video-phone service, broadband, IPTV and intelligent services, etc.) with respect to PSTN/ISDN based network structure.

Therefore, there needs to be a new regulatory approach for promoting competition, while encouraging investment in NGN access networks, such as the question of local loop unbundling (LLU) in a fibre environment. Today's local loop unbundling regulations focuses on the last mile. But the move to FTTH, FTTB and FTTC means the focus is on the last quarter mile or less. Given the costs and other resources involved, the LLU model appropriate for legacy copper may have to be adapted for fibre or different remedies identified. Where regulators mandate LLU one option could be a bit-stream offer at the Central Office level, where the nature of the access network is totally transparent. Other options could include requiring collocation at the street cabinet level and backhaul from the cabinet to the operator's node. In addition, there will be a new approach to LLU, throughout the NGN migration, different from the conventional perspective of LLU in legacy networks. Not having a regulation for LLU of NGA during the process of migration to NGN can be considered as a new approach. Because exposing LLU to the regulation in the migration process will aggravate the formation of distributive efficiency and fair competition. Companies deployed on the NGA networks should not be exposed to LLU, until sunk costs will have been recovered and the competitive environment will be emerged in the service market. The duration of the return of investment depends on the company business models, the market structure and the welfare of the society but it is generally understood that should be at least 4 or 5 years long. Obligation to LLU to NGA networks may cause the emergence of free-rider problem in the market. The free-rider issue must not be considered only for the return of the investments but also fairness and service differences of the various providers participated into the NGN.

After a competitive market structure is formed and the migration phase is completed, there exist other devices apart from LLU to benefit from fibre cable deployment such as bit-stream access, exchange and virtual unbundling. Beyond this, it should be also decided whether the competitive market is desired for retail service market or wholesale access market. However, backhaul could be difficult for competitive operators to provide for themselves unless duct-sharing is available.

Another issue, raised by FTTx, is possible removal of Main Distribution Frames (MDF) by the incumbent operator thereby making obsolete the "old" scheme of LLU for copper at least in its full unbundling and line sharing options, since LLU takes place at the MDF under traditional LLU scenarios. Where points of interconnection are withdrawn, it will be important for competitive operators both that they not face additional costs as part of the NGN migration process, and that they remain able to continue their current service offerings, and not face the problem of "stranded investments".

Market definition

The identification and definition of relevant markets are the basis of competition analysis used for the establishment of *ex ante* regulation in many countries, particularly in the EU. With NGN this task will become much more complex due to the blurring of the boundaries between technologies and services. This complexity could be at the source of disputes between regulatory authorities and market players.

Quality of Service

It is not the regulator's duty to enter into the detailed technicalities of QoS provision within the NGN. However, to support essential services, such as interactive voice, regulators could contribute to the definition of the basic requirements needed at interconnection points, in a similar way to what occurs today between legacy networks such as PSTN/ISDN.

NGN's unified transport of services raises issues related to the connection-less nature of IP transport, especially for real-time interactive voice or multimedia communication streams that are sensitive to packet loss, delay or jitter. However, many technologies that ensure QoS over an IP network already exist. These can be broadly split into technological approaches based on over-provisioning that is associated with relative priorities or on explicit end-to-end resource reservation.

It must be noted that the bulk of the Internet uses the "best-effort" model with no QoS guarantees. Many applications on the Internet use the Transmission Control Protocol (TCP) that reduces user traffic in the case of congestion. TCP, however, is not suitable for real-time applications like video streaming, voice or multimedia communications that cannot limit the rate of packet sending in case of congestion. Recently, more real-time applications such as voice telephony or video streaming are being represented, not only from fixed but also from mobile network environments, a significant amount of Internet core traffic. Today over-provisioned core network, as is the case of many Internet backbones, has serious challenges to handle this traffic including the problems about fair usage of network resources and data explosions.

However NGN relies on explicit guarantees provided by the network to its end-user for quality sensitive applications, such as IPTV and guaranteed VoIP. Such applications are expected to constitute a large portion of the NGN traffic. NGN is a managed and closed network, as such, many of the QoS techniques involving differentiated priorities and resource reservations that are not widely applied in the Internet because of scalability and cost issues. And, in the NGN architecture the transport domain is under the control of a service domain which guarantees that proper resources are allocated by the transport domain for the duration of a given service provision by the network.

The critical issue that remains is the need to ensure the coordination between different NGNs in order to provide end-to-end QoS. For this, end-to-end signalling should be applied over any packet transport bearer, the possibility of which was demonstrated by ITU's specification of the Bearer Independent Call Control (BICC) protocol which is an adaptation of SS7. By definition and design, IMS architecture uses the SIP protocol for call (session) signalling. SIP is essentially an Internet end-to-end protocol; however 3GPP and ETSI TISPAN have extended it to make it usable for network control functions in NGN voice and multimedia calls. This occurs in a manner similar to call and service control functions in legacy SS7-based intelligent network architecture. ITU-T SG11 has been developed NGN signalling protocols for resource reservation on a call-by-call basis applicable within networks, especially at network interconnection points. This work has been done in close cooperation with 3GPP and ETSI TISPAN.

Interconnection

The need for interconnection between telecommunication networks stems generally from the over-arching necessity of service completion. NGN is no exception in this regard. In fact, NGN introduces even more interconnection requirements than legacy networks as a consequence of the ubiquity of access to services it introduces.

In addition to the legacy interconnection requirements for service completion among different networks (including legacy networks, NGN and between NGNs) it must allow subscribers the ability to:

- Connect from any other network and get their service profile from their home network in order to be served according to it, which is similar to the concept of mobile roaming, but applied to all types of broadband packet access;
- Access the services of their own network in preference to those of the visited network, which is a feature currently present in mobile networks that allows roaming subscribers to receive, for instance, network information messages and access value-added service in their own language; and
- Access value-added services from a third-party service provider, which is a concept that is currently available for some 2.5 and 3G content services.

It is likely that the roaming issue will be even more complex with NGN. Today, the mobile industry has agreed on mutual roaming agreements without the necessity of regulatory intervention. Regulators have only intervened on the topic of roaming tariffs. With NGN, regulators will have to consider whether it will be necessary to mandate roaming. For example, should an NGN mobile access operator be required to allow clients of any NGN fibre access operator to roam on its access network and vice-versa?

9.6 Business considerations

To accomplish whole process of the migration in smooth and success, it is essential to get enough support from the business environments which provide practical means for the realization of migration. Business environments should be built with contributions from all players who involved in the telecommunication businesses whether as providers and/or consumers in services, networks and contents.

Following Figure 26 illustrates more detailed scope of business environments showing relationship with other considerations. It may possible to look at business environments with following four different areas:

- System Business environments: to know the domestic capability to develop and provide relevant systems into the market is the most important objective on this subject and this study also identify the relationships with/to foreign supports;
- Network Business environments: this is the most crucial point to know the exact situation of business based on legacy telecommunication infrastructure including future plans for each networks (or network providers);
- Service Business environments: this study provides the current status of legacy telecommunication services and helpful to know positions (or importance) of each service in the overall telecommunication services in the country which will guide for the future directions;
- Contents Business environments: this identifies the status of contents related productions including consumptions and this will impact also choose a specific scenario for the migration.

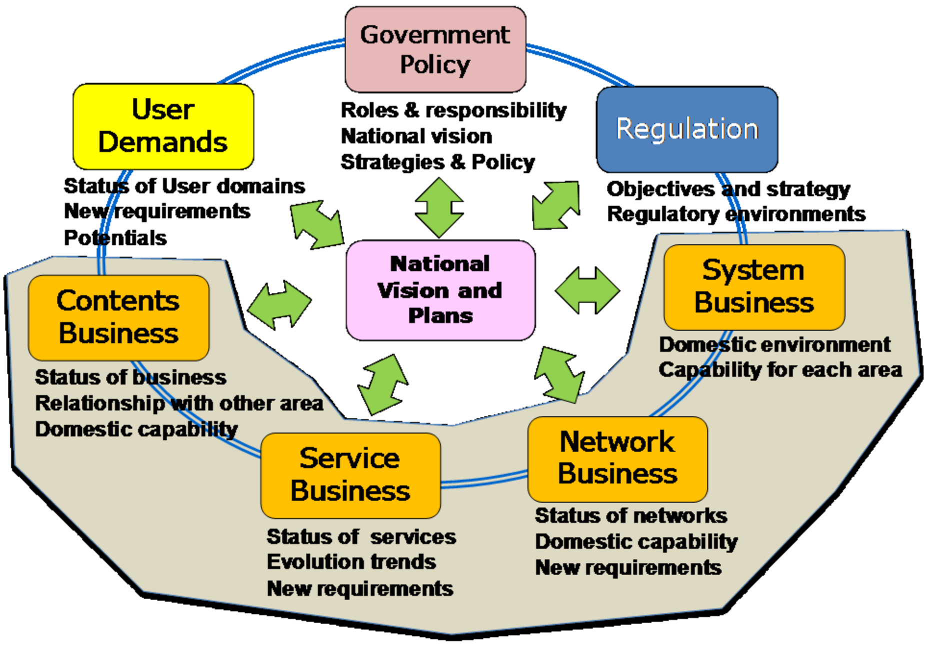


Figure 26 – Scope of Business considerations

10 Choose the scenario

After having all study and considerations, specific scenarios should be chosen. This section introduces what scenario should be used in what situation, especially applying for developing country.

10.1 Overlay Scenario

The Overlay Scenario will be useful in the case of country or operator who have well stable or new PSTN/ISDN infrastructure. In this case, it is hard to justify replace all PSTN/ISDN equipment to NGN because this legacy infrastructure could not yet return value to compensate all their investment. And the status of infrastructure is quite good stage and will use next several years without any serious amount of operation, administration and maintenance including fault management.

Through this scenario, operator will be gradually preparing enough resources for the next investment while keeping their customers in a good situation. In addition to this, operator will also meet users' requirements which use advanced capabilities through newly deployed NGN. According to the increasing of users who wish to use advanced capabilities, then operator will expand the coverage of NGN and consequently will decrease customers in legacy networks. Finally someday will fully deployed of NGN and cover all users. In this case, NGN users will communicate with PSTN/ISDN users using their simulation but through interworking between NGN and PSTN/ISDN networks.

10.2 Replacement Scenario

This scenario will be useful in the case of country or operator who does not have enough PSTN/ISDN infrastructures, where there is already lack of connectivity to support voice services. In this case, it is hard to continue the deployment of PSTN/ISDN equipments because this will also need new investment while investment for NGN will be also necessary. But in this case, current users even using PSTN/ISDN will be continuously supported without any change of their terminal if possible.

Through this scenario, operator will stop their deployment of PSTN/ISDN but replaced investment to NGN. Then operator will provide ADF (Adaptation Function) to the current PSTN/ISDN users to provide continuous usage of voice services which means expansion of NGN emulation capabilities. And according to the increasing of users who wish to use advanced capabilities, then operator will expand the coverage of NGN and consequently will decrease customers who using emulation services. Finally someday all users will be fully covered by NGN capabilities.

This scenario will be useful for some parts of PSTN/ISDN need to be replaced but other parts of PSTN/ISDN are still in good stage. In this case, operator should keep PSTN/ISDN networks with relevant customers until the time of returning their investment or the status of PSTN/ISDN will request serious amount of operation, administration and maintenance including fault management which means time to replacement. In other direction, operator will start to deploy NGN infrastructure replacing other parts of PSTN/ISDN which reach to time to replacement.

Through this scenario, operator will be gradually preparing enough resources for the next new investment while keeping their customers in PSTN/ISDN situation. In addition to this, operator will also meet users' requirements which use advanced capabilities through newly deployed NGN. According to the increasing number of users who wish to use advanced capabilities, operator will expand the coverage of NGN and consequently will decrease the number of customers in legacy networks. The final solution will be to fully deploy of NGN for covering all users.

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