Next Generation Networks
Techno-Economic Insights

Santiago Andrés Azcoitia
Network Techno-Economic & Regulatory Analysis
TELEFÓNICA I+D
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Index

01 **Introduction**

02 **Cost Basics**

03 **Issues on Next Generation Access Networks**

04 **Issues on Backhaul & Backbone Networks**

05 **NGN Cost Structure**

06 **Summary & Conclusion**

Index

01 Introduction

02 Cost Basics

03 Issues on Next Generation Access Networks

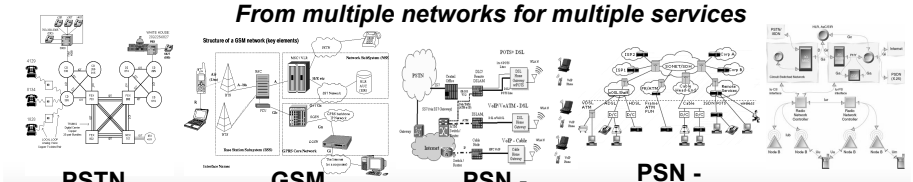
04 Issues on Backhaul & Backbone Networks

05 NGN Cost Structure

06 Summary & Conclusion

01 Introduction

From multiple networks for multiple services



PSTN **GSM** **PSN - Residential** **PSN - Business** **UMTS**

NGN Network

Towards one single network for all services

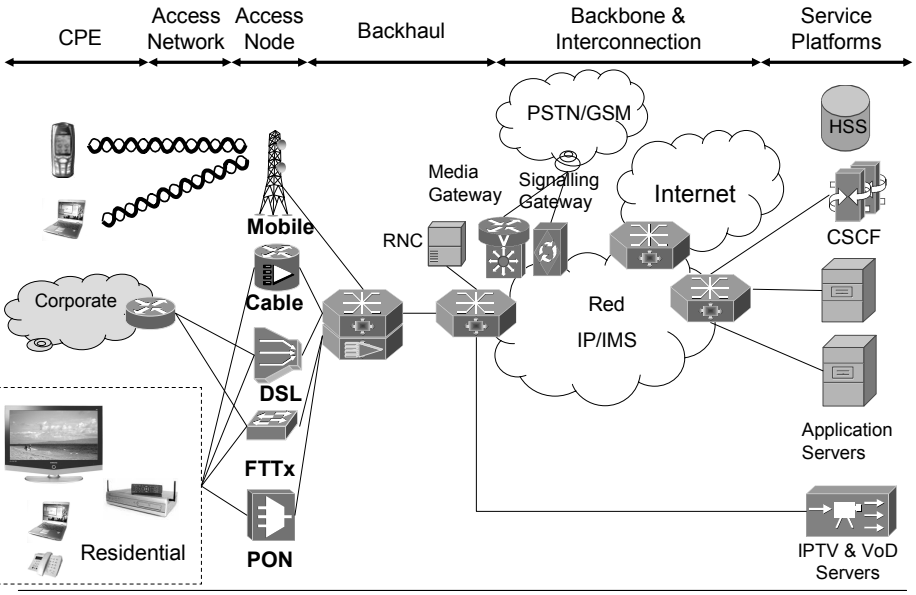
Effects

- Fixed – Mobile Convergence towards integrated operators
- PSTN → VoIP Migration

- Network convergence
  - Increments value offered to customers & users
  - Decrements unit cost per service

Hence network convergence increases the NG Operator competitiveness

01 Introduction



Index

01 **Introduction**

02 **Cost Basics**

03 **Issues on Next Generation Access Networks**

04 **Issues on Backhaul & Backbone Networks**

05 **NGN Cost Structure**

06 **Summary & Conclusion**

02 Cost Basics

- ***Cost*** *is the "Value of money that has been used up to produce something, and hence is not available for use anymore.*", Wikipedia
- *Historical cost* models consider original value of assets registered in a company's financial accounting when the asset was acquired.
- The *economic cost* of a telecom service is calculated as a ***forward looking*** cost of performing the activity in the most efficient way possible.
- *Current cost* accounting corrects historical cost of assets to reflect changes in their value over time, by calculating current replacement value of assets.
- **Long run cost** models assume that a carrier is capable of optimizing the network in order to provide telecom services most efficiently.
- On the other hand, **short run cost** models take into account current carrier commitments and current network capacity which usually leads to inefficient decisions and thus higher costs.

02 Cost Basics

Historical vs. Current asset valuation

HISTORICAL COST

Asset (e.g. Switching Exchange)

V_{acq} = 1.000.000 c.u.

L = 10 years

WACC = 20%

OPEX = 100.000 c.u.

$CC(n) = WACC \cdot V_{acq} \cdot (1-n/L)$

$Dep = V_{acq} / L$

CURRENT COST

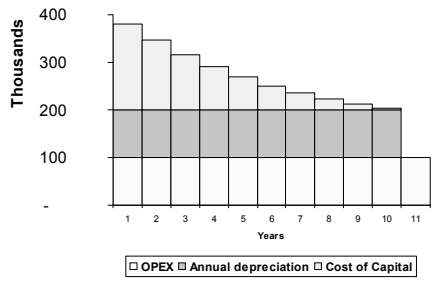
Annual asset acq. value depreciation:

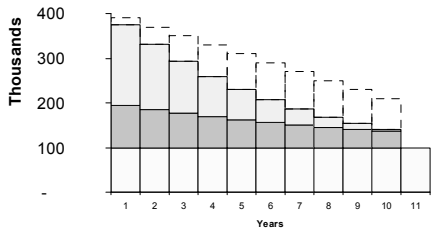
t = 10%

$Vacq_{CCA}(n) = V_{acq} \cdot (1-t)^n$

$CC(n) = WACC \cdot V_{acq} \cdot (1-t)^n \cdot (1-n/L)$

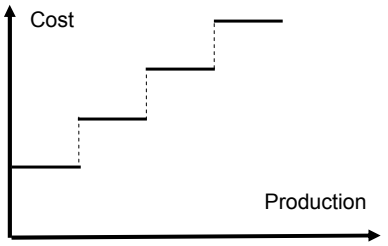
$Dep(n) = V_{acq} \cdot (1-t)^n / L$

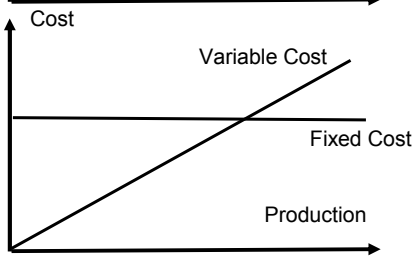




02 Cost Basics

- Depending on its behaviour as the production increases, costs are classified as:
  - *Fixed* (or *volume insensitive)* cost, which is constant for a given production range.
  - *Variable* (or *volume sensitive)* cost, when the cost depends on the production volume for a given range.
  - Fixed costs may vary in the long term. In case of substantial increment of the production volume, the capacity of an organization must adapt to the increasing demand.
  - It is always possible to build a curve describing cost-volume relationship (CVR) of a particular cost-concept.

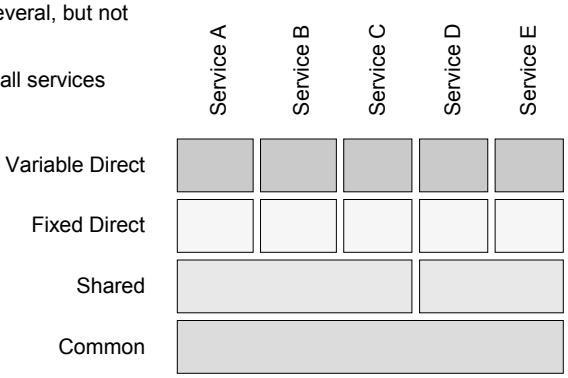




02 Cost Basics

Direct, indirect, shared & common costs

- Depending on the association between cost concepts and production activities (e.g. telecom services) costs are classified in:
  - *Direct costs*, .
  - *Indirect costs*, shared by several services
  - *Shared costs*, shared by several, but not by all services.
  - *Common costs*, shared by all services



02 Cost Basics

Unit, marginal & incremental cost

- Summing up cost contributions for a service, it is possible to derive total cost per service C(V) curves as a function of production volume (V).
- Unit cost C_{unit} (V): Cost of a service unit (e.g. VoIP minute) for a given production:

$$C_{unit}(V) = C(V)/V$$

- Total incremental cost ΔC(V, ΔV): Difference in total cost for a given increment in the production ΔV.

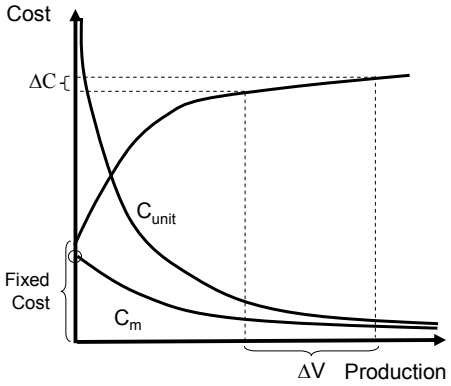
$$\Delta C(V, \Delta V) = C(V + \Delta V) - C(V)$$

- *Unit incremental cost*:

$$\Delta C_{unit}(V, \Delta V) = \frac{C(V + \Delta V) - C(V)}{\Delta V}$$

- *Marginal cost*: change in total cost that arises when the quantity produced changes by one unit.

$$C_m = \frac{dC(V)}{dV}$$



Index

01 **Introduction**

02 **Cost Basics**

03 **Issues on Next Generation Access Networks**

04 **Issues on Backhaul & Backbone Networks**

05 **NGN Cost Structure**

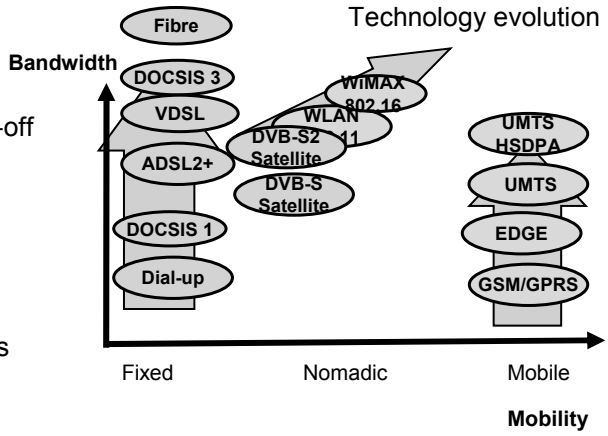
06 **Summary & Conclusion**

03 Issues on Next Generation Access Networks

Value in the Access:

- Bandwidth
- Mobility
- Others:
  - Coverage
  - Security
  - …

Trade-off

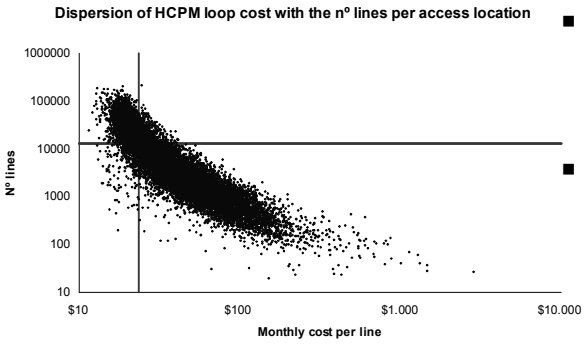


Technology Key Features

- Bandwidth
- Transmission media
  - Shared / dedicated → Determines access behaviour in stress situations
  - Wire line / wireless → Different limitations and dimensioning parameters
- Coverage radius in access node
  - Determines nº access nodes to cover a region

03 Issues on Next Generation Access Networks

- Transmission & infrastructure cost (AI) depends on the transmission media
  - Wireline → User density / scattering
  - Wireless → Fixed (in case of licensed spectrum) or dependent of goal rate per user (BW), which may require additional spectrum for cost-efficient radio network planning
- Wireline infrastructure cost is very dependent of the location and user density



- Federal Communications Commission built HCPM (Hybrid Cost Proxy Model) to quantify subsidies to universal service in USA
- Wireless infrastructure (spectrum) can be considered a fixed cost.
  - UMTS license monthly cost per user range extends from 5c€ to 2,5 € depending on the country for European auctions

03 Issues on Next Generation Access Networks

Access Node Cost (AN) depends on:

- Coverage goal $\propto$ surface to be covered / radius of coverage per access location
  - Determines deployment of AN to achieve this coverage
- Traffic / QoS $\propto$ Nº users within an AN location (i.e. user distribution U)
  - AN deployed to improve the availability or performance of the network in high user density zones

Wireline Access	Wireless Access
Access Cost = AI (r, U) + AN (r, r_{max}, U)	Access Cost = AI + AN (r, r_{max}, U)

xDSL vs. WiMax

Access location with n users, at mean r (km) distance from the AN

$Cost_{DSL} = (c_{ACC}(r) + c_{DSLAM}) \cdot n$

$c_{ACC}(r)$ → Mean access network cost per home passed (HP)

c_{DSLAM} → DSLAM cost per user

c_{SPCT} → Cost per user of spectrum licenses and usage fees

$Cost_{WIMAX} = n \cdot c_{SPCT} + C_{BS} \cdot N_{BS}$

C_{BS} → Cost per WiMax Base Station

N_{BS} → Nº WiMax Base Stations

03 Issues on Next Generation Access Networks

xDSL vs. WiMax to provide broadband services

Urban location with n users, at mean r < r_{max} (km) distance from the AN

Limiting factor is effective bit rate in the AN which depends on Nº concurrent users.

- In Wimax it is limited by spectrum allocation
- In DSLAM it is limited by line card capacity

Supposing that the sum of AN bitrate is equal in both cases:

$$BR_{DSL} = \frac{N_{DSLAM} \cdot BR_{DSLAM}}{n \cdot f_{conc}} = BR_{WIMAX} = \frac{N_{BS} \cdot BR_{BS}}{n \cdot f_{conc}} \Rightarrow \frac{N_{DSLAM}}{N_{BS}} = \frac{BR_{BS}}{BR_{DSLAM}}$$

$$\left.\begin{array}{l} BR_{DSLAM} = 1 \text{ Gbps} \\ BR_{WIMAX} = 35 \text{ Mbps} \end{array}\right\} \quad N_{BS} = 28{,}6\ N_{DSLAM}$$

In dense locations the number of Wimax base stations required to provide broadband services similar to DSL would be difficult to manage

Also, it is the most cost-effective scenario for wireline access infrastructure

- $c_{ACC} \approx c_{SPCT}$ →

Thus, this is a suitable scenario for xDSL

03 Issues on Next Generation Access Networks

xDSL vs. WiMax to provide broadband services

Rural location with n users, some of them at distances > r_{max} from the AN location

Limiting factor is now AN radius of coverage

— additional remote DSLAMs may be needed to cover all the potential accesses in the location.

- Supposing that users are regularly distributed in the surface (S) and given the range of DSL (r_{DSL}) and WiMax technologies (r_{WiMAX}):

$$S = N_{DSLAM} \cdot \pi \cdot r_{DSL}^{2} = N_{BS} \cdot \pi \cdot r_{WiMAX}^{2} \Rightarrow \frac{N_{DSLAM}}{N_{BS}} = \frac{r_{WiMAX}^{2}}{r_{DSL}^{2}}$$

r_{DSL} = 3 Km
r_{WIMAX} = 30 Km
} N_{DSLAM}=100 N_{BS}

Regarding access infrastructure cost, rural copper local loops are the most expensive due to the low population density in the location and high loop length.

Thus, it is a suitable scenario for WiMax technologies, increasing the number of frecuencies if needed.

Index

01 **Introduction**

02 **Cost Basics**

03 **Issues on Next Generation Access Networks**

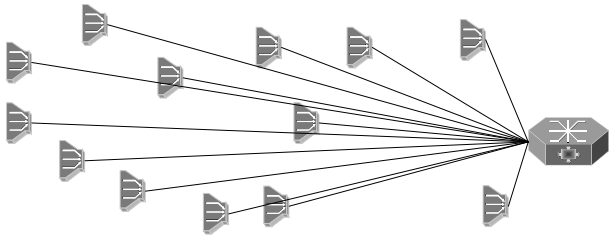
04 **Issues on Backhaul & Backbone Networks**

05 **NGN Cost Structure**

06 **Summary & Conclusion**

04 Issues on backhaul & backbone networks

- Backhaul networks connects access node to the backbone
- Supposing N access nodes depend from a backbone access router, this connection might be done either directly



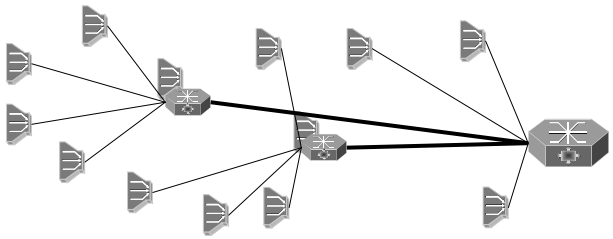
Backhaul Consolidated Architecture

Subscriber management is **concentrated** at the BRAS/PE, which has been traditionally the frontier between the backhaul and the IP backbone, for up to 100 K – 200 K users

04 Issues on backhaul & backbone networks

- Or using intermediate aggregators
  - Additional switching equipment
  - Less length in transmission links

Transmission vs Switching trade-off



Backhaul Non-Consolidated Architecture

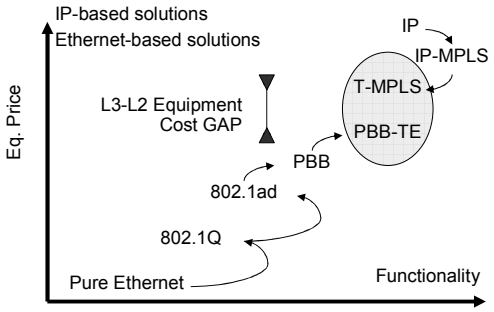
Whether transmission cost is affected by length in transmission links depends on the transmission network topology, on whether the operator is incumbent or entrant, on OF availability...

Subscriber management may be **distributed** to smaller BRAS (up to 10K – 25K)

- Some trends are willing to distribute subscriber management even to the Access Node

04 Issues on backhaul & backbone networks

- Backhaul networks may be either level-3 IP networks Or level 2 (e.g. Ethernet based)



Some equipment providers defend a (more scalable, more flexible, easier to manage) L3 backhaul network.

Allows distributed subscriber management

More efficient operation:

- No need for L2 VC or pseudowires
- Takes advantage of IP/MPLS self-healing and self-managing features as the backbone

Other vendors defend that L2 equipment functionality is enough for the backhaul, saves in IP addresses and has lower CAPEX

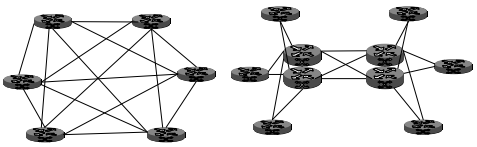
Scalability issues in MAC address that suffered pure Ethernet solutions are solved with H-VPLS and PBB

- There is no a one-size-fits-all solution:
  - Choosing between ethernet-based and IP based solutions for the backhaul depends on the history of the backhaul network in the operator
  - An operator with already deployed L2 backhaul network has higher incentives to maintain L2 networks

04 Issues on backbone networks

- Backbone networks provide connectivity for each pair of routers within an IP network as well as interconnection with other IP network.
- Main techno-economic issues to analyze are:

Switching vs. Transmission Trade-off

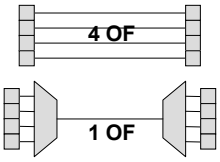


Higher level routers concentrate traffic of nearby access routers in order to minimize total transmission costs.

E.g. From 9 Long distance links (1) to 4 Long distance links (2)

Resilience and security against link and router failures to be taken into account in the network design.

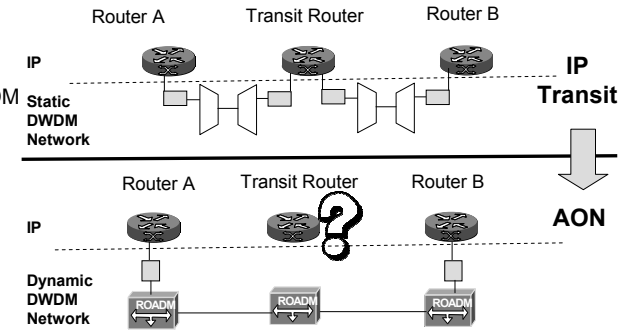
Transmission Equipment vs. infrastructure Trade-off

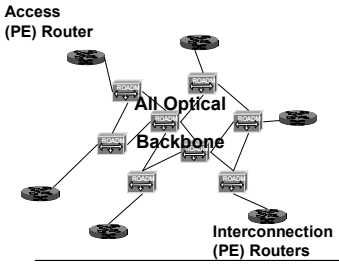


Investing in additional transmission equipment permits savings in transmission media and infrastructure (e.g. entrant operators with limited OF infrastructure).

04 Issues on backbone networks

- Trends in the backbone are moving towards intelligent optical networks:
- Replacing IP routers by ROADM to build a photonic mesh switching λ, minimizing transit routers in the backbone
- In the extreme view, all backbone PE (access or interconnection) would be the edge of a photonic mesh





- This has positive effects such as the reduction on the end to end delay of traffic.
- It seems to be a more efficient way to switch great amounts of traffic.
- New technologies permit transmission of 40 Gbps and 100 Gbps on a single link.

Index

01 Introduction

02 Cost Basics

03 Issues on Next Generation Access Networks

04 Issues on Backhaul & Backbone Networks

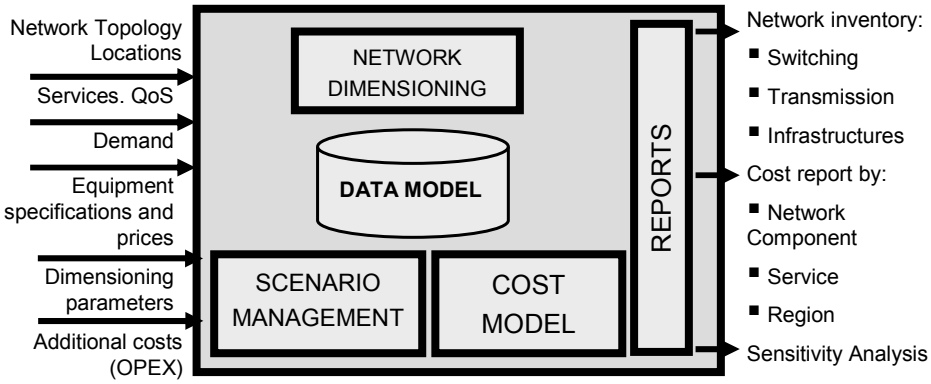
05 NGN Cost Structure

06 Summary & Conclusion

05 NGN Cost Structure

Description of the Cost Model

- In order to study the cost structure of a NGN, a bottom-up scorched-node FL-LRIC cost model has been used. The structure of the model is the following:



- Planning exercise has been done for a national incumbent considering a potential demand of 36 million fixed broadband lines similar to France or Germany.

05 NGN Cost Structure

Scenario specification

- 36 millions of potential lines
- Portfolio of services and demands for the base scenario.
  - Voice: VoIP for 40% of lines (minutes per line adjusted to PSTN demand as reported by the Spanish regulator) using G.711 codec.
  - Internet service (mean rate of 10 Mbps per access) for 40% of the lines
  - IPTV 200 channels MPEG-4, 50% HDTV, for 20% of the lines
  - Video on Demand MPEG-4, 50% HDTV, for 20% of the lines
  - Videoconference for 40% of the lines, minutes per line equal to 10% of voice.
- Technology Mix:
  - Access: 20% FTTx y 80% xDSL
  - Level 3 backhaul and backbone, hierarchical 3 levels
  - IMS platform for voice and videoconference
  - Video servers for VoD connected to network level 2
  - Carrier Ethernet & static DWDM as transmission technologies

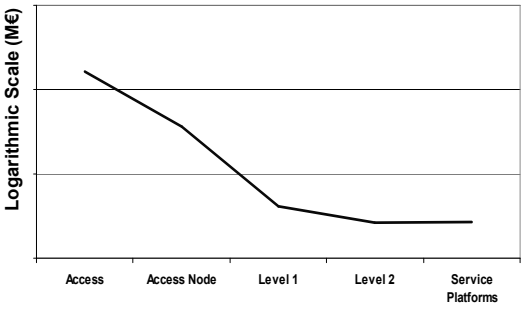
05 NGN Cost Structure

Scenario specification

- Cost Model includes:
  - FTTx access installation and deployment costs and CAPEX (including ONT / MDU for FTTx)
  - Copper local loop annual cost including maintenance and asset depreciation
  - Access node CAPEX and OPEX (as a mark-up)
  - Switching nodes CAPEX and OPEX (management, maintenance and planning using mark-ups)
  - Transmission equipment CAPEX and OPEX (management, maintenance and planning using mark-ups)
  - Transmission infrastructure costs using parameters from Telefónica in Spain (incumbent's point of view)
  - IP Internet transit & peering cost
  - IMS & Video on Demand Servers CAPEX and OPEX using mark-ups
  - Location and collocation facilities using mark-ups
  - Cost of capital considering WACC of 10%
- Cost Model does not include:
  - FTTx maintenance
  - CAPEX associated to copper local loop
  - Commercial / customer care/ common administrative costs of the company
  - IPTV head-end (distribution is done using IP network) and multicast
  - Backbone resiliency
  - Different QoS in the planning process

05 NGN Cost Structure

CAPEX per network segment



- Supposing all accesses are FTTx to include all CAPEX for the access
- Cost for Optical Distribution Network in FTTx access is optimistic.
  - Cost per access is adjusted for a group of urban OF loops.
  - No new access infrastructure (trench, ducts) needed.
  - No OPEX for access network

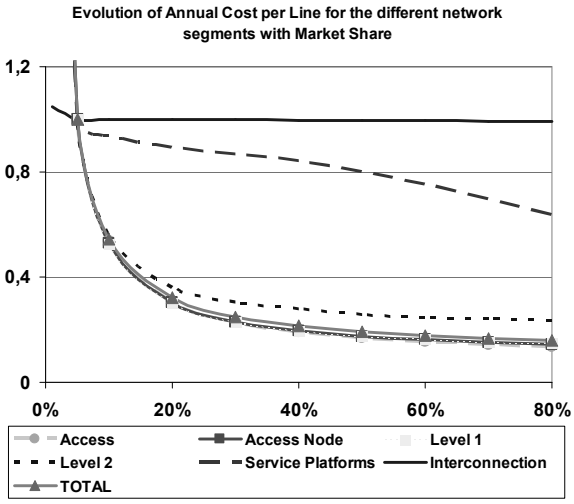
- Hierarchical Cost Structure
  - Cost decrements an order of magnitude when ascending one level in the network hierarchy.

	CAPEX	%CAPEX
Access	62,45	78,06%
Access Node	13,95	17,44%
Level 1	1,57	1,97%
Level 2	1,00	1,25%
Service Platforms	1,02	1,28%
	80,01	

* Capex normalized to Level 2 reported CAPEX

05 NGN Cost Structure

Economies of Scale in Network Elements

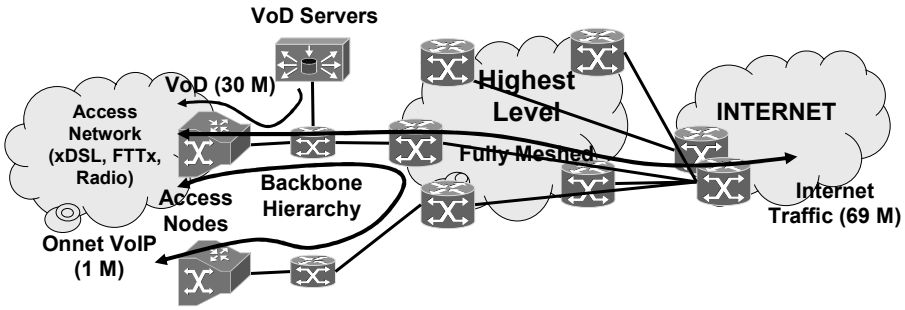


- Important economies of scale due to fixed cost of deployment of nation-wide network.
  - Maybe reduced by focusing in the most profitable part of demand (cherry-picking)
- If planning of upper backbone levels is optimized, a more variable behaviour of backbone cost is expected.
- Interconnection costs are considered variable in the model.
- Service platform costs have a less important fixed component

05 NGN Cost Structure

Cost per Services - Cost Sharing Criteria

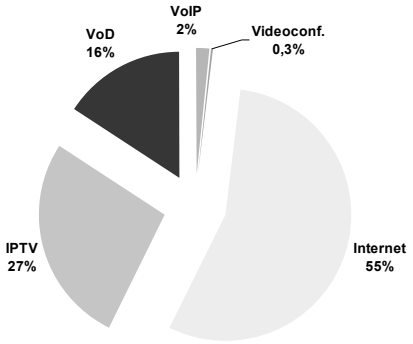
- Cost sharing among different services is done based on usage-based criteria.
  - Cost of different network elements is driven to services using the expected traffic flowing by the network element, as used in the planning process.



- DSLAM cost will be driven 30% to VoD, 1% to Onnet VoIP, 69% to Internet Traffic
- VoD Server will be driven to VoD service, IP transit cost will be driven to Internet service
- Highest level links in the mesh will be used only for onnet traffic

05 NGN Cost Structure

Cost Structure – Total cost per service



- Negligible traffic for voice and video-conference
  - For voice demands per user near PSTN registered maximum as reported by Spanish regulator.
- Important contribution of video services
  - High throughput required to transport HDTV contents
- Internet is the heaviest service in terms of traffic and accounts for more than half the network cost.
- Unit cost for the different services considered are the following:

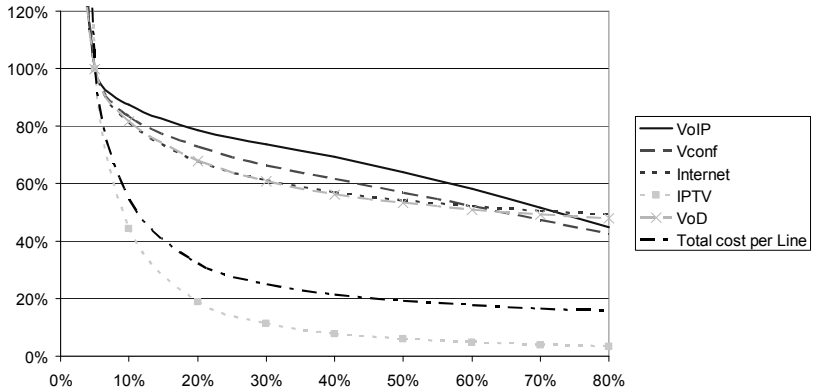
	Total Cost (%)	Units		Unit Cost (Internet Mbps x Month)
VoIP	1,99%	114.159.400.000	mins	0,0005
Vconf	0,30%	11.413.394.880	mins	0,0008
Internet	56,22%	1.712.009.232	Mbps x month	1,0000
IPTV	25,86%	1.426.674.360	Channel x Users	0,5520
VoD	15,63%	188.321.016	Sessions	2,5278

* Unit cost is normalized to monthly cost of 1 Mbps Internet cost

05 NGN Cost Structure

Cost Structure – Economies of Scale in Services

Evolution of Unit Cost per Service with nº accesses

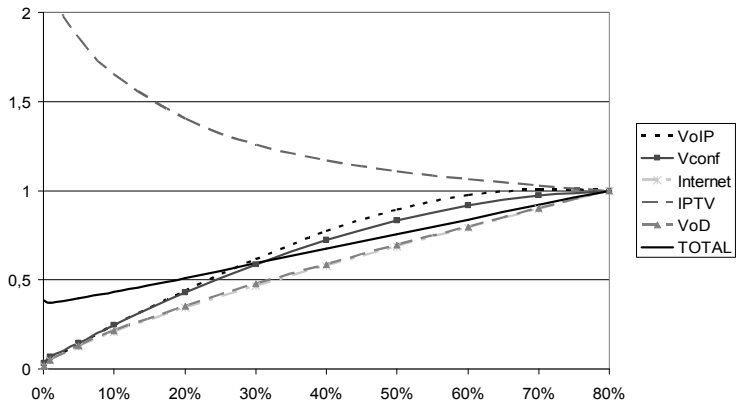


- Important economies of scale due to fixed cost of nation-wide access deployment
  - Especially on IPTV. Dimensioning of IPTV independent of demand (if broadcast supposed)
- Interconnection (variable cost) contribution reduces economies of scale in VoIP

05 NGN Cost Structure

Cost Structure – Economies of Scale in Services

Evolution of cost per service with nº acceses

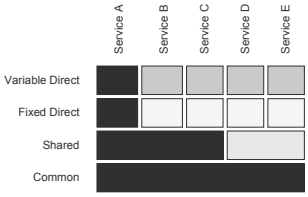


- Total cost attributable to IPTV is maximum in low demands as a consequence of cost driver used (traffic) → Network is planned to offer nationwide IPTV
- Broadcast IPTV is an offer dependent service whereas the rest are demand dependent and thus their cost increases with the nº users.

05 NGN Cost Structure

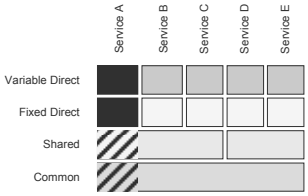
Cost Structure – Stand-alone & Total service Incremental Cost

- Stand-alone cost (SAC) of service s: Cost of the network used to provide only service s
- Total service incremental cost (TSLRIC) of service s: Decrement of cost in the network if s is no longer provided.
- Fully Allocated Cost (FAC) of service s: Cost of s resulting of sharing all direct, shared and common cost among services using causal cost drivers.
- By definition, it must be satisfied that SAC ≥ FAC & SAC ≥ TSLRIC
- If dimensioning is optimal and cost sharing criteria is causal FAC ≥ TSLRIC



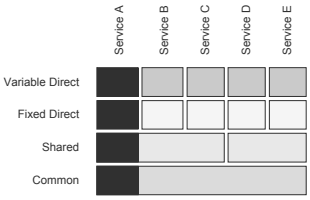
SAC of Service A

* Shared and Common Costs (Fixed & Variable) are totally driven to A



TSLRIC of Service A

* Shared and Common Variable Costs are partially driven to A.



FAC of Service A

* Shared and Common Costs (Fixed & Variable) are partially driven to A

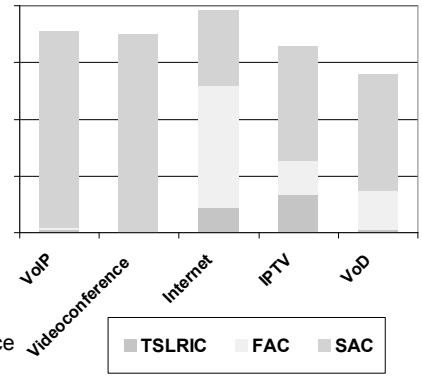
05 NGN Cost Structure

Cost Structure – Stand-alone & Total Service Incremental Cost

SAC, FAC & TSLRIC for different services in the model

	SAC	FAC	TSLRIC
VoIP	75,59%	1,70%	1,03%
Videoconference	74,46%	0,26%	0,005%
Internet	83,34%	55,18%	9,21%
IPTV	69,78%	26,92%	14,14%
VoD	59,44%	15,94%	0,97%
TOTAL	362,61%	100,00%	25,36%

* Costs are normalized to total cost for convergent network



- SAC > FAC > TSLRIC
- High SACs: fixed costs attributable to the access
- Negligible network cost of adding videoconference when VoIP is already being provided.
  - Only variable cost of interconnection and IMS platforms
- Negligible network cost of providing VoIP using NGN
  - VoIP traffic increment do not require network re-dimensioning
  - Incremental cost is mainly composed of IMS platforms and interconnection costs

05 NGN Cost Structure

Stand-alone costs for VoIP

- VoIP cost reported for the modeled incumbent operator is far from PSTN cost.
- The main reason for this is that VoIP services benefit from significant **economies of scope** as fixed components of network cost are shared among a higher number of services.
- To show this, network has been planned to provide only VoIP services, obtaining costs which are even over interconnection charges in fixed telephony (in the order of magnitude of c€)
  - at least an order of magnitude higher than those obtained when all services are considered.
- These figures are obtained supposing that access cost is shared by traffic services.
  - Interconnection charges in telephony exclude access-dependent cost
- If access cost contribution is removed from the cost of traffic services and considering only VoIP, unit cost of voice fall to the order of 0,1 c€.

05 NGN Cost Structure
Operational Expenditures (OPEX)

- OPEX is an important contribution to global expenditures in an operator
  - OPEX amount near depreciation cost in an incumbent, even above in entrants leasing capacity or mobile networks.
- Example of OPEX elements related to network & services:
  - Maintenance of equipment and components
  - Licenses
  - Charging & Billing
  - Service assurance
  - Network Management
  - Product & platform development
  - Rental of OF
  - Rental of transmission capacity
  - Rental of spectrum
  - Interconnection / Roaming
  - Contents
- Discussion on effects of NGN might be done over each of these categories and for different types of operators & networks (fixed / mobile, incumbent / entrant)

05 NGN Cost Structure
Operational Expenditures (OPEX)

- There is no detailed global study of OPEX in Telefónica I+D
- Regarding network maintenance & management, it seems feasible that contribution to total cost of OPEX associated to backbone and backhaul networks will be reduced in case of NGN networks in the long term and as long as true convergence takes place by switching off the “old” networks.
- Nonetheless, OPEX associated to backbone & backhaul is a reduced part of an operator total network & service provision OPEX, as backhaul & backbone CAPEX is a reduced percentage of total network investment.
- Access network expected OPEX is an important key feature of access technologies when deciding the most suitable solution for a location.
  - It is present in the business case studies and it may turn the odds towards a more CAPEX-intensive technology

Index

01 **Introduction**

02 **Cost Basics**

03 **Issues on Next Generation Access Networks**

04 **Issues on Backhaul & Backbone Networks**

05 **NGN Cost Structure**

06 **Summary & Conclusion**

06 Summary & Conclusion

- Cost structure by network segment of next generation networks is similar to structure of old PSTN → Hierarchical cost structure.
- Important economies of scale derived from fixed costs in the access and in platforms needed to provide services.
- Economies of scope due to the convergence of backhaul and backbone networks:
  - Network cost is shared among a larger number of services
  - It is a relevant factor in cost reduction, if stand-alone cost is calculated for voice services results resemble old PSTN costs
- Negligible traffic of VoIP and videoconference (for the supposed demand) if compared to Internet, VoD & IPTV expected traffic.
  - Incremental cost of VoIP and Videoconference is composed of network platforms to provide the services and software and applications in the customer premises

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G Glossary

AON – All – Optical Networks

CAPEX – Capital Expenditure

c.u – Currency Units

DSL – Digital Subscriber Loop

FAC – Fully Allocated Cost

FL – Forward Looking

FTTx – Fiber To The x (home, building, node…)

GSM – Global System Mobile

HCPM – Hybrid Cost Proxy Model

HDTV – High Definition TeleVision

IMS – Internet Multimedia System

IP – Internet Protocol

IPTV – IP based TeleVision

LRIC – Long Run Incremental Cost

NGN – Next Generation Network

OF – Optic Fiber

OPEX – Operational Expenditures

PON – Passive Optical Network

PSN – Packet Switched Network

PSTN – Public Switched Telephone Network

QoS – Quality of Service

SAC – Stand-alone Cost

TS-LRIC – Total Service LRIC

UMTS – Universal Mobile Telephone System

VoD – Video on Demand

VoIP – Voice over IP

WACC – Weighted Average Cost of Capital

Telefonica