IP Interconnection Charging Methods

J. Scott Marcus

Director and Department Manager, “NGN and Internet Economics”

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IP Interconnection charging methods

- Migration from switched fixed/mobile networks to NGN “marries” the traditional telephone network with the Internet.
  - Different technologies, economics, traditions, rules
  - Which rules prevail?
- Voice interconnection in switched fixed and mobile networks.
  - Widespread regulation to address market power.
  - Wholesale termination fees in the absence of regulation will tend to be very high, for both large and small operators.
- Data interconnection in the Internet
  - Peering arrangements are typically negotiated freely (“Coasean”) between the network operators.
  - In general, no regulation of peering.
  - Peering: two providers exchange traffic only for their respective customers, often (but not always) with no explicit charges.

IP Interconnection charging methods

- NGN: Concepts and challenges
  - The basics
  - Core versus access
  - Policy/regulatory challenges
  - Evolution to fibre-based Next Generation Access (NGA)
- IP interconnection
- Voice interconnection: Economics, implications, challenges
- Implications of declining voice call Termination Rates (TRs)
- Quality of Service (QoS)
- Evolving the system?
- Concluding remarks

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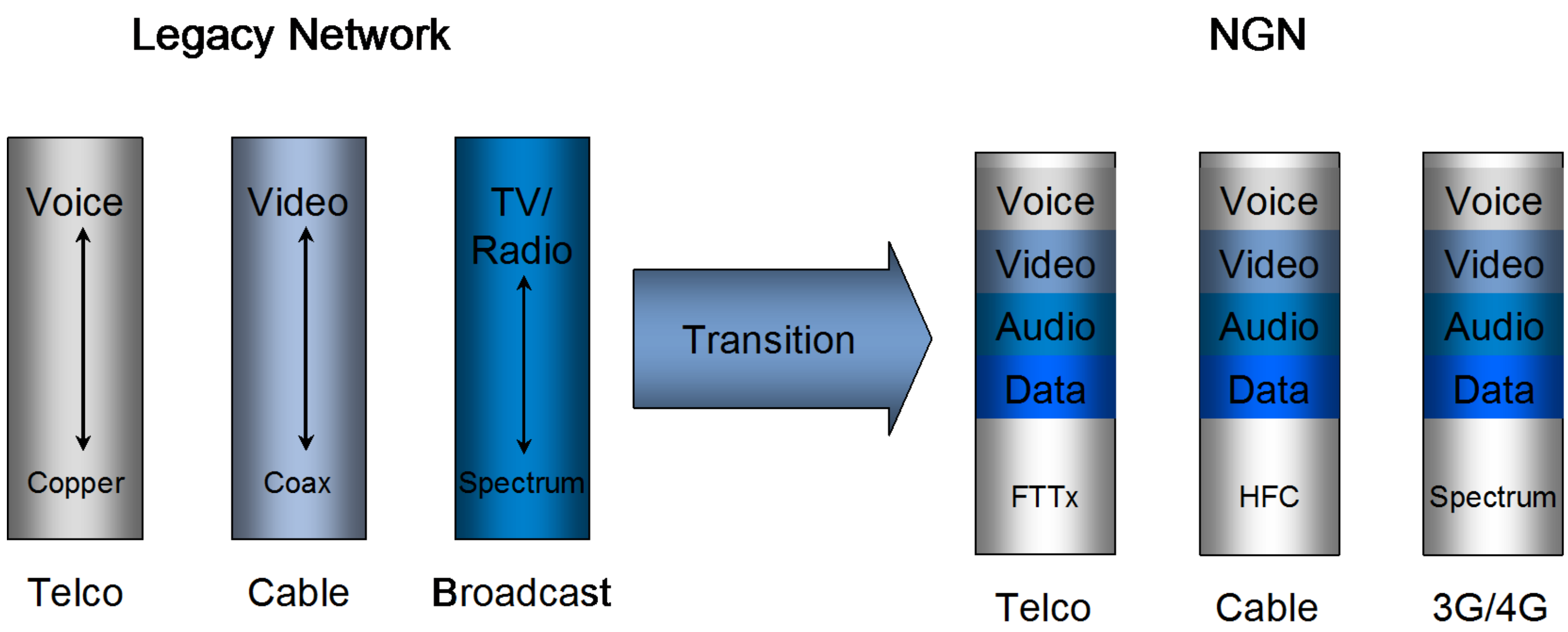
Next Generation Networks (NGNs)

- Throughout the world, public networks are evolving into *Next Generation Networks (NGN)* based on the *Internet Protocol (IP).*
- Different approaches to financing, business models, the role of government, and the regulatory approach are visible in different countries.

The shift to NGN



- Historically, many networks delivered a single service.
- With NGN, any network can deliver (nearly) any service.

Next Generation Networks

"A Next Generation Network (NGN) is a packet-based network able to provide services including 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 offers unrestricted access by users to different service providers. It supports generalized mobility which will allow consistent and ubiquitous provision of services to users."

[ITU-T Recommendation Y.2001 (12/2004) - General overview of NGN]

Next Generation Networks

- Network operators migrate to NGN core versus NGN access for different reasons.
- **NGN Core:** Replace traditional circuit switches with IP routers and VoIP gear.
  - Efficiency gains from fully merging voice and data networks.
  - Accelerate time to market for new services.
  - Traditional switches are hard to find and hard to maintain.
- **NGN Access (NGA):** Drive fibre deeper into the network.
  - Far greater speeds, improved reliability
  - Ability to support new applications
  - Lower OPEX

  BUT
  - High cost of implementation
  - Limited incremental willingness of consumers to pay for ultra-fast broadband (about € 5 / month)

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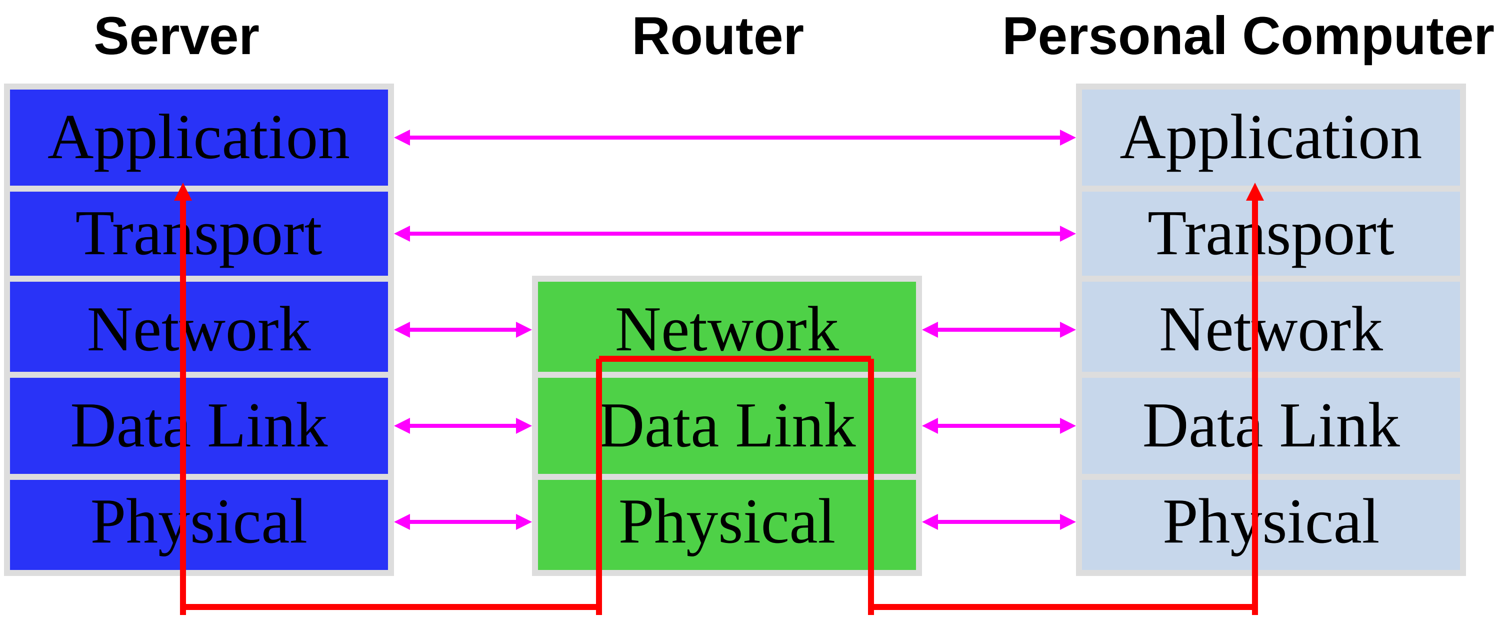
NGN: A range of public policy challenges

- Changes in the character of competition
- Changes in last mile remedies
- Challenges in deploying fibre-based NGA
- Migration of interconnection to an IP basis
- QoS and network neutrality
- Challenges during the migration period
- Standardisation and interoperability
- Spectrum management
- Functional separation

NGN: Policy challenges

- The migration of voice to IP-based NGN raises challenges due to:
  - The ability of any transmission medium to carry any form of traffic.
  - The evolution of the telecommunications network from a voice-only network to a multi-service network where voice likely represents only a small fraction of the traffic.
  - The emergence of service providers who do not even have a network.
  - The changing cost structure of the network.
  - The understandable desire of existing operators to maintain their revenue streams.
  - … and especially:
  - The BIG QUESTION: How is the roll-out of high speed fibre-based Next Generation Access to be funded?

Layers interact with peer layers



Layers derive services from successively lower layers

Basics: The TCP/IP Reference Model

- Physical Layer – the transmission facilities.
- Data Link Layer – the logical management of physical transmission facilities.
- Network Layer – forwarding and routing (Internet Protocol, or IP).
- Transport Layer – provides applications with datagram (UDP) or virtual circuit (TCP) services, as needed.
- Application Layer – provides services to the user.
  - Web
  - Email
  - VoIP
  - IPTV and other forms of video
  - Peer-to-peer file sharing

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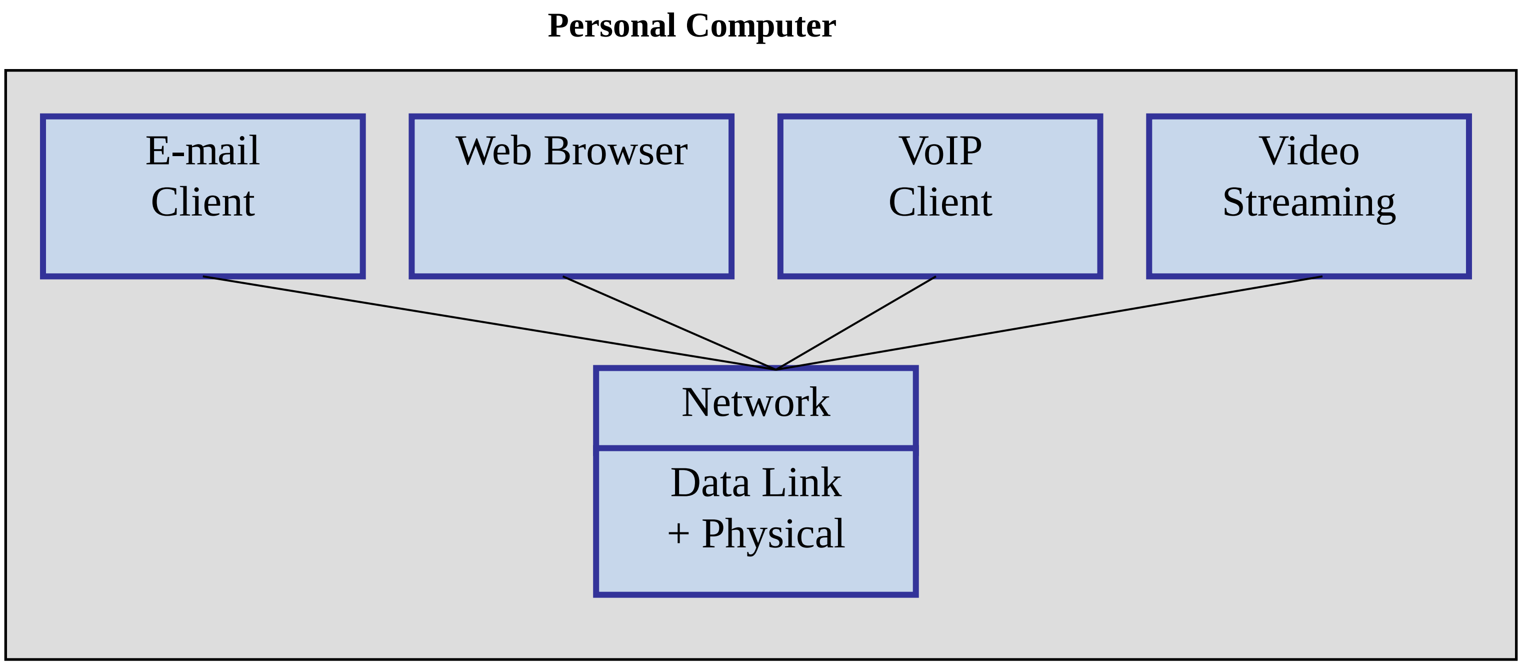
Basics: The TCP/IP Reference Model



Today, your broadband connection can support any combination of voice, video and data – provided that it is fast enough.

The migration to IP: Implications for regulation of interconnection

- There are three primary reasons for regulation of electronic communications, all related to market failure:
  - Addressing distortions of competition, especially those caused by some form of market power.
  - Addressing social needs that the free market might not, typically because the social value exceeds the private value to parties that might otherwise invest.
  - Allocating scarce resources that are unique to each country.
- The move to NGN raises issues in all three areas.

The migration to NGN: Key Changes

- In the value chain by which services are delivered to end-users.
- In the ability of different service providers (not all of whom are network operators) to compete with one another for the same services. Distinctions of cable versus telecommunications, fixed versus mobile, wired versus wireless all become less relevant.
- In the speed and the character of network access, and thus in the ability to offer bandwidth-hungry services (e.g. video).
- In the ease with which certain public needs can be satisfied.
  - Access to emergency services.
  - Lawful intercept.
- In the ability of end-users (or software developers on their behalf) to create new capabilities in the end-user’s device (PC), often without the active involvement of the network operator.

NGNs and evolving value chain

- *Bundling*: a single network operator / service provider can offer voice, video and data to their customers (*triple play*).
  - Economies of scope for the service provider.
  - These economies are typically reflected in discounts to the consumer.
  - Higher effective switching costs for the consumer.
- *Independent third party service providers*: service providers (e.g. SIPgate, Skype and Vonage for VoIP) offer a service over the customer's broadband service.
  - In the distant past, the telephone network operator provided the voice service.
  - Today, an independent service provider can offer voice or video services without operating a network of its own.

NGN: Changes in the nature of competition

- Much of regulation and public policy of electronic communications deals with market power (SMP).
- The shift to NGN implies changes in the value chain, and thus subtly alters market power.
- Implications for regulation?
  - New forms of competition emerge?
  - Old barriers remain?
  - New barriers emerge?

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Challenges of NGA deployment

- WIK report on Next Generation Access (NGA) for ECTA (2008) was based on sophisticated models of fibre roll-outs in France, Germany, Italy, Netherlands, Portugal, Spain.
- Key findings:
  - No country likely to achieve full coverage without public stimulus/subsidy.
  - Only limited prospect of replicating infrastructure.
  - Maintenance of adequate procompetitive remedies is vital.
- European institutions seek full coverage at 30 Mbps, and 50% served at 100 Mbps, by 2020.
- Typical cost estimates for achieving this are € 200-300 billion.
- Consumer incremental willingness to pay for high speed broadband is about €5 per month – this falls short.

Challenges of NGA deployment

Investment per home connected (in Euro), market share 50%, urban cluster, stand alone first mover **

Network Type	Country [in €]					
	DE	FR	SE	PT	ES	IT
VDSL	457	n.v.	352	218	254	433
PON	2,039	1,580	1,238	1,411	1,771	1,110
P2P	2,111 (54%)	2,025	1,333	1,548	1,882	1,160

** Based on the investment of the urban cluster and a market share of 50%. If other marekt shares are used, it is mentiond in brackets.

Challenges of NGA deployment

Viability of NGA roll-out for incumbents across countries and technologies

Network Type	Country					
	DE	FR	SE	PT	ES	IT
VDSL	71.5%	n.r.	18.3%	39.0%	67.4%	100.0%
PON	25.1%	25.2%	18.3%	19.2%	12.2%	17.6%
P2P	13.7%	18.6%	18.3%	19.2%	12.2%	12.6%

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Challenges of NGA deployment

Replicability of NGA roll-out for a second mover, 80 % access to existing ducts at current cost-based prices

Network Type	Country					
	DE	FR	SE	PT	ES	IT
VDSL	18.5%	n.r.	n.v.	39.0%	n.r.	17.6%
PON	0.3%	6.8%	n.v.	n.v.	n.v.	1.6%
P2P	0.0%	6.8%	n.v.	n.v.	n.v.	0.2%

IP Interconnection charging methods

- NGN: Concepts and challenges
- IP interconnection
  - Peering and transit
  - Routing
  - Shortest exit
  - Implications of the growth in video traffic
- Voice interconnection: Economics, implications, challenges
- Declining voice call Termination Rates (TRs)
  - Implications for retail prices
  - Implications for use of the voice service
- Quality of Service (QoS)
- Evolving the system?
- Concluding remarks

Peering, transit, and Internet access

- Transit
  - The customer pays the transit provider to provide connectivity to substantially all of the Internet.
  - Essentially the same service is provided to consumers, enterprises, ISPs, content provider or application service providers.
- Peering
  - Two ISPs exchange traffic of their customers (and customers of their customers).
  - Often, but not always, done without charge.
- Variants of both exist.

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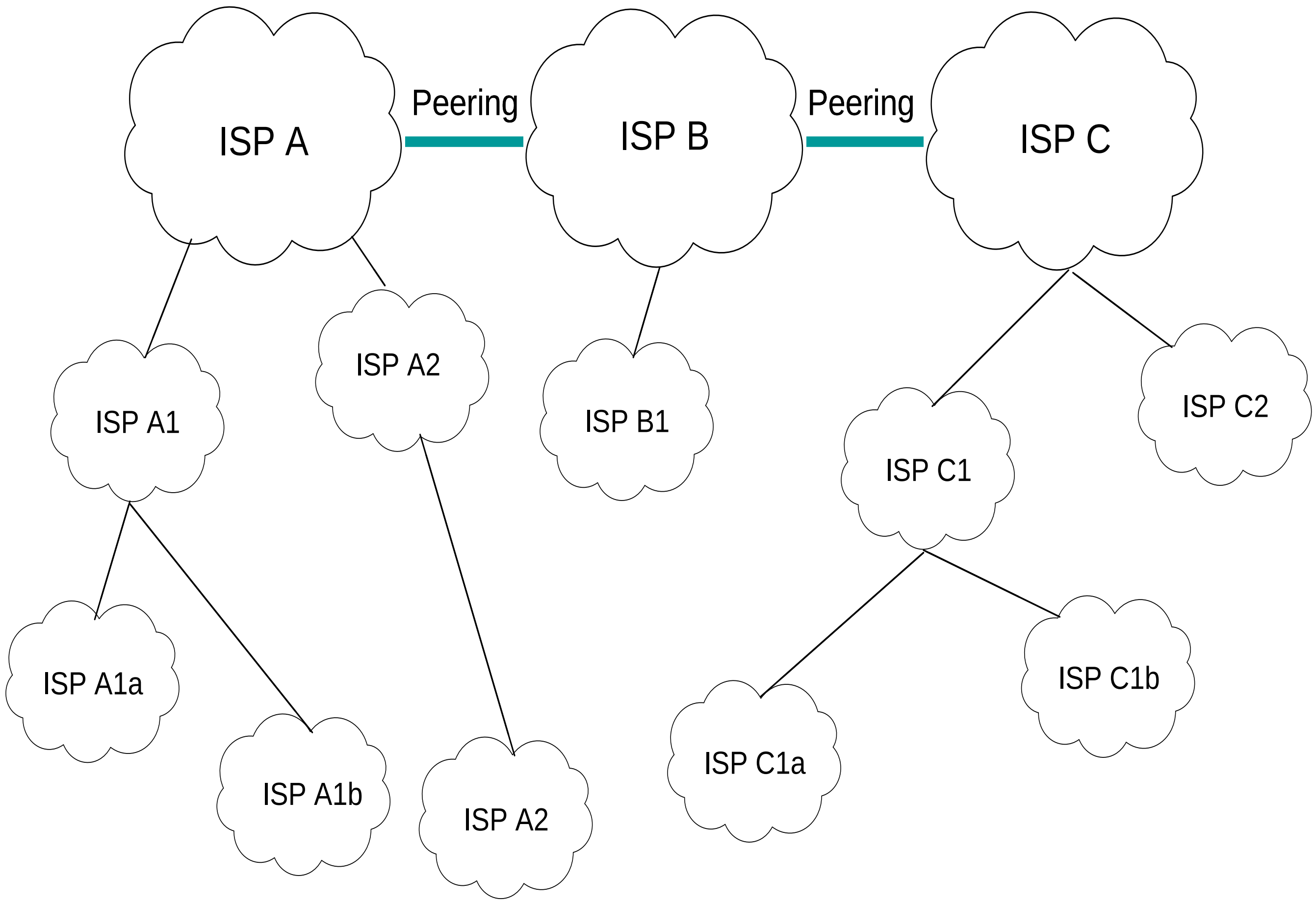
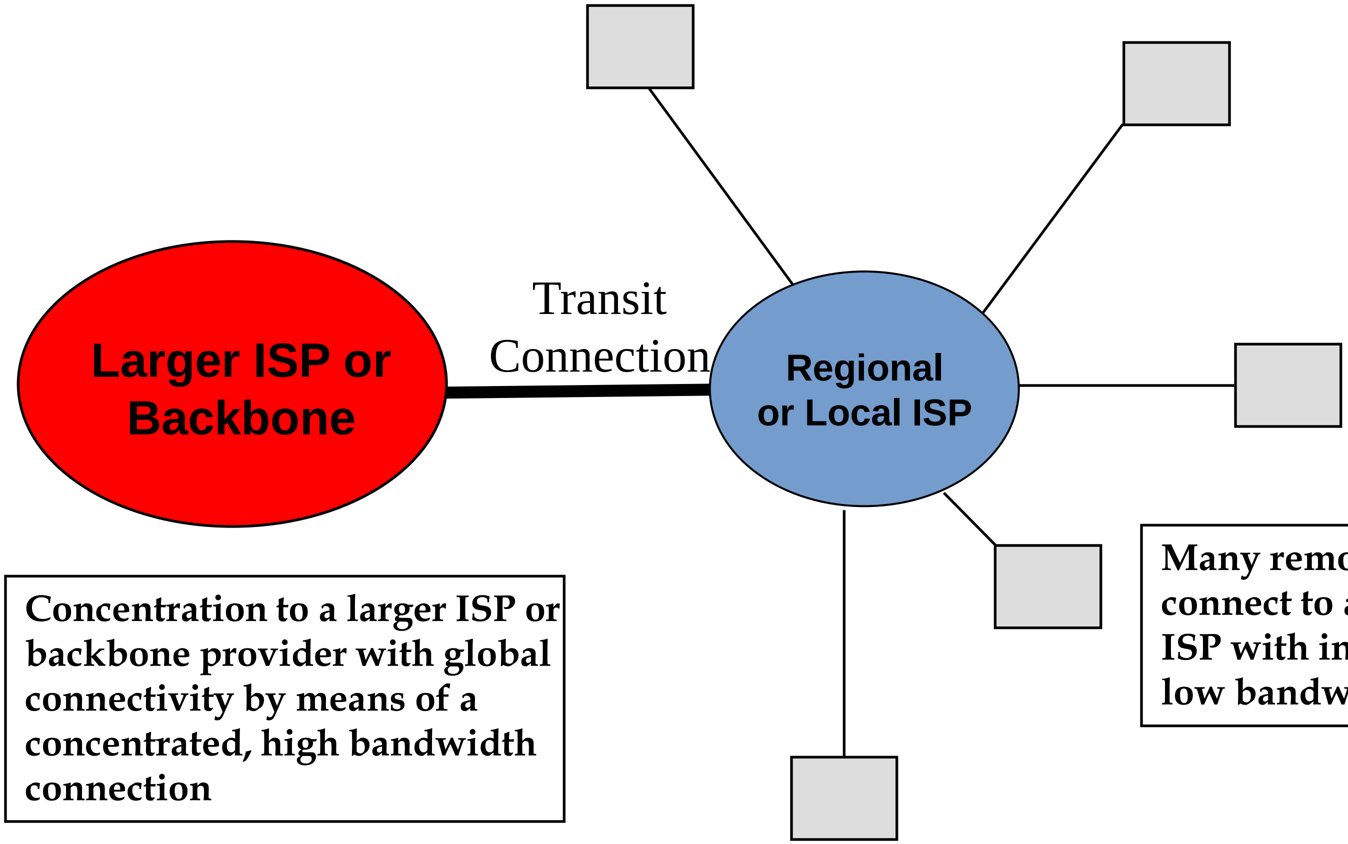
Peering, transit, and Internet access



Choices for network operators

- Numerous choices for reaching every other network:
  - Peering or transit?
  - “Public” peering versus private peering?
  - … and more

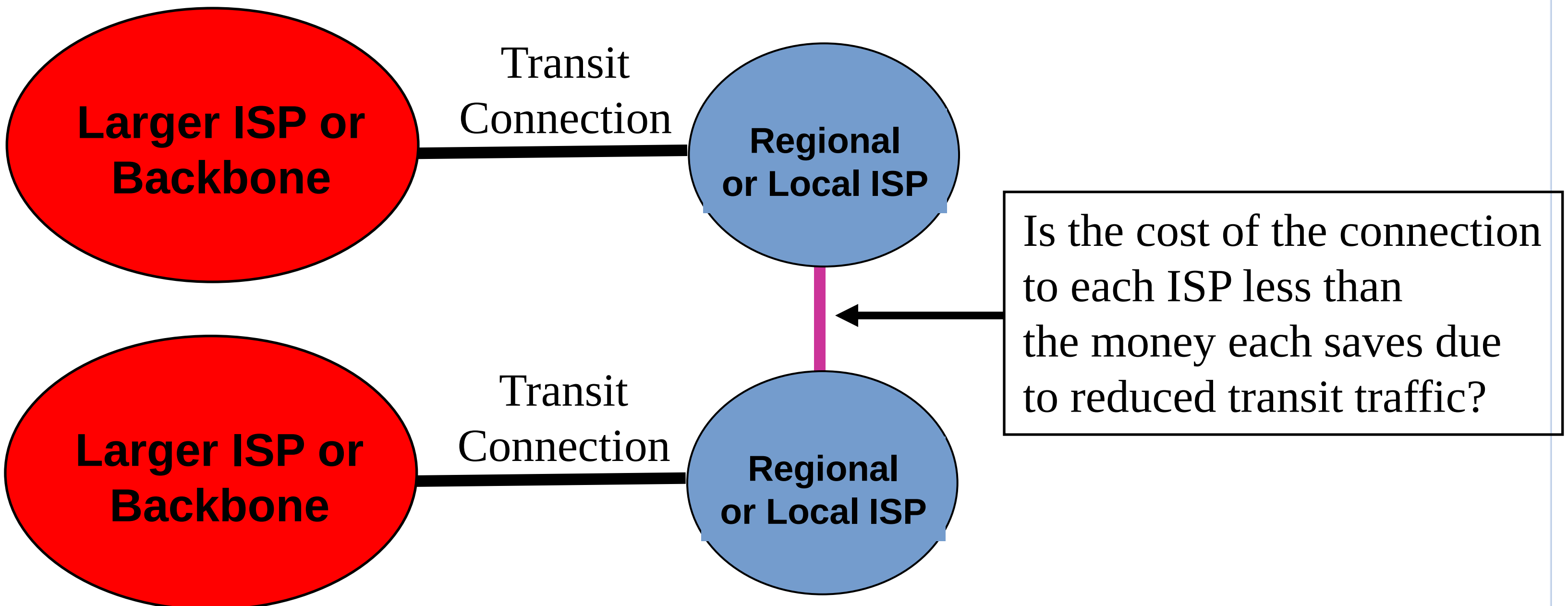
Transit service and the economics of an ISP



Concentration to a larger ISP or backbone provider with global connectivity by means of a concentrated, high bandwidth connection

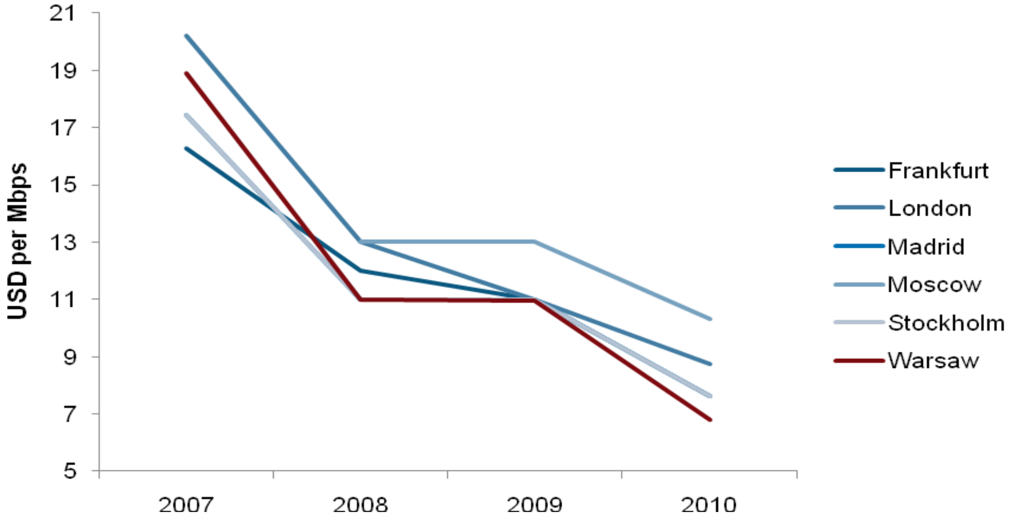
Many remote locations connect to a regional or local ISP with individual, low bandwidth connections

To peer or not to peer?



To peer or not to peer?

- Transit prices are progressively declining – some have suggested that peering may have less benefit over transit than in the past.



Source: Telegeography (2011), WIK calculations.

- On the other hand, as equipment prices drop, the cost of peering must also be declining.

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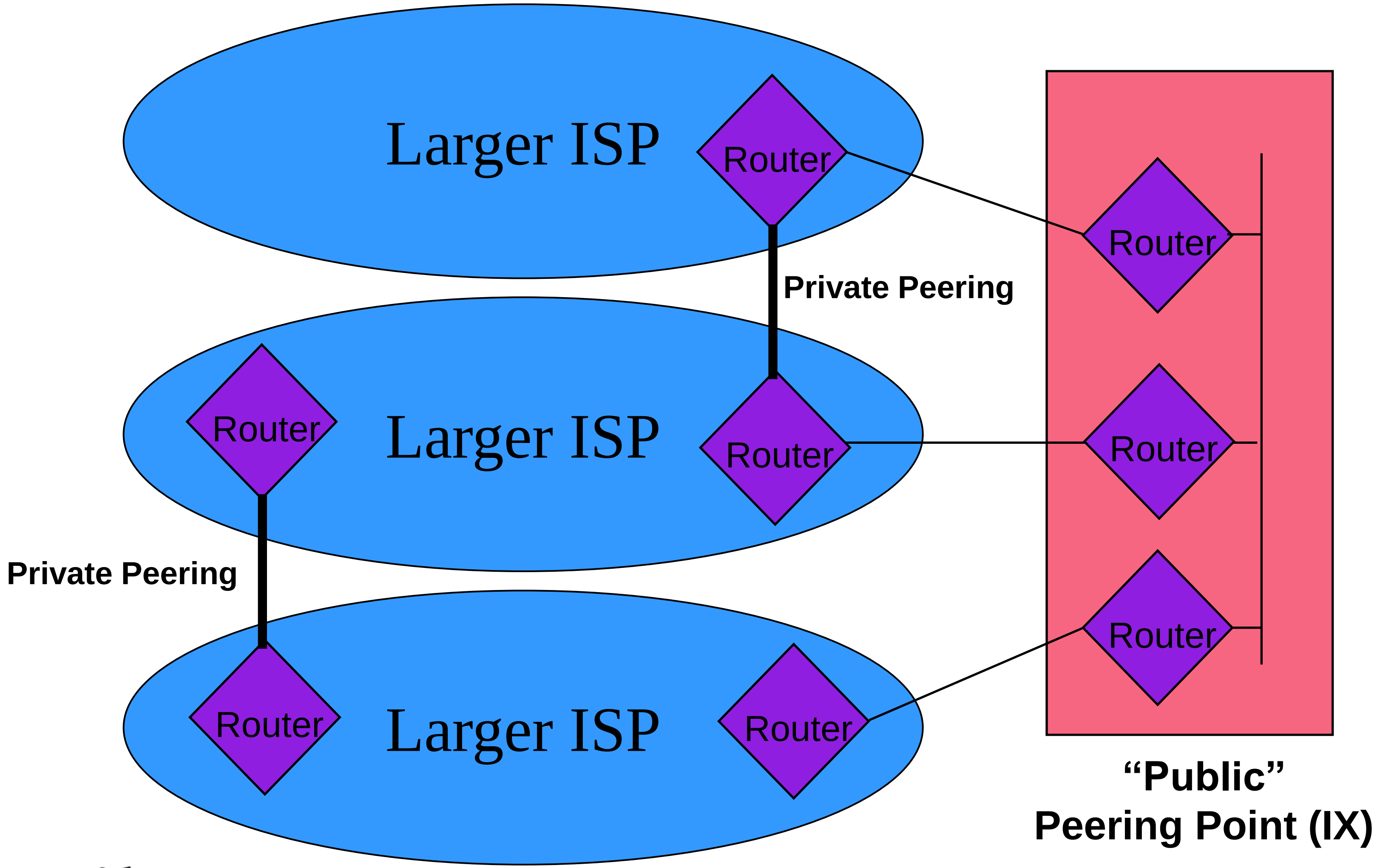
“Public” versus private peering



“Public” versus private peering

- With “public” peering, a single connection to an Internet Exchange point (IX) enables peering to a large number of partners.
- Private peering tends to be preferred when two ISPs have enough peering traffic to warrant a dedicated connection.
  - Critically depends on traffic levels.
  - Easier to justify if the cost of the dedicated connection is low.
- It is likely that by far the largest *number of peering interconnections* are “public”.
- Historically, the great majority of peering *traffic* was exchanged privately.
- Hard to know how this stands today – the fraction of total traffic carried by large backbone ISPs may have declined.

IP routing

- Interior routing – within a network, thus usually not relevant to network interconnection
- Exterior routing – between networks
  - Typically implemented (still!) using BGP-4
  - Routing rules are complex
  - Usually seeks to minimise the number of networks traversed by IP datagrams
  - Insensitive to traffic load / congestion!
- IPv6 implies distinct (and larger) tables, but the BGP routing mechanism is essentially the same as with IPv4.

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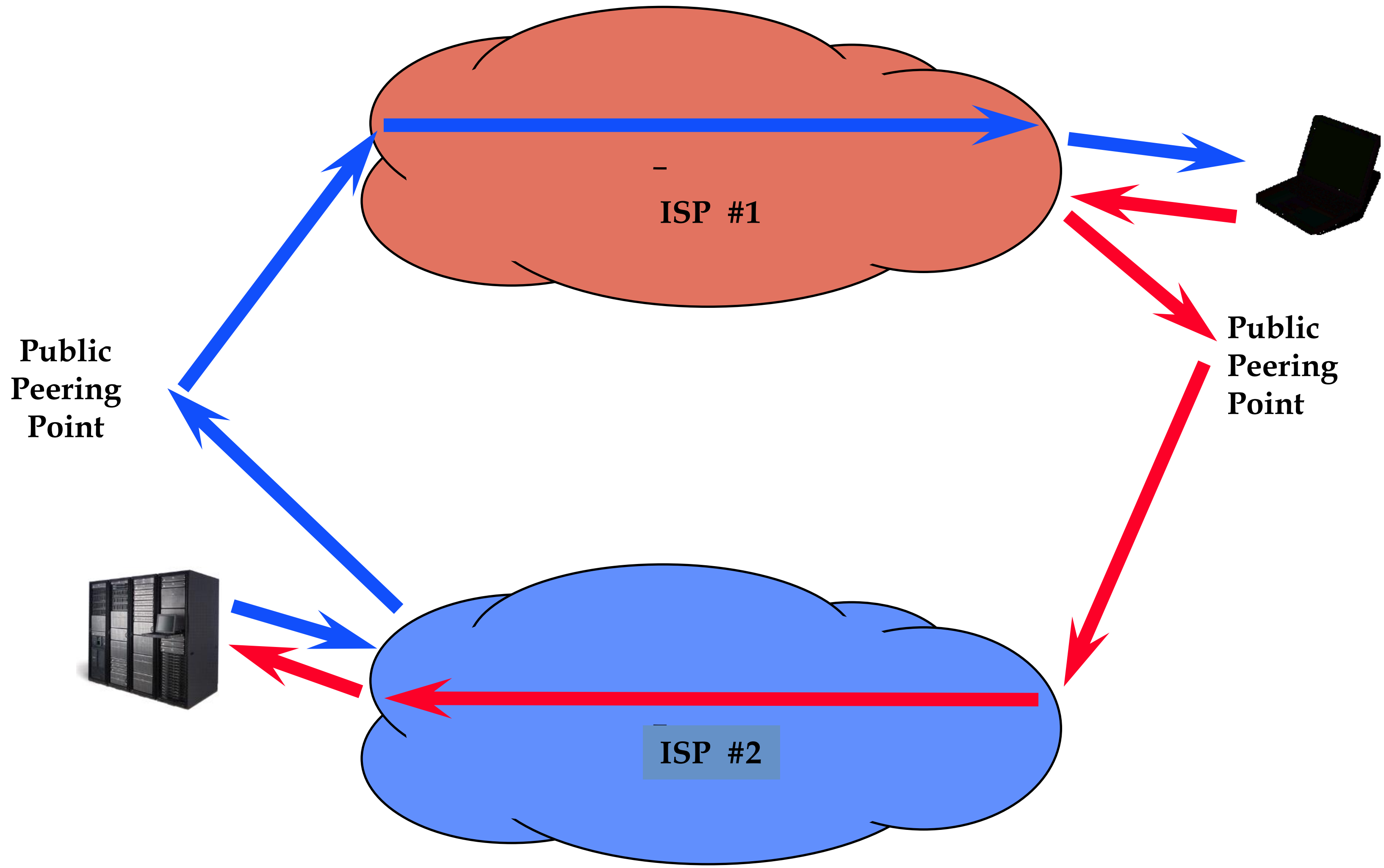
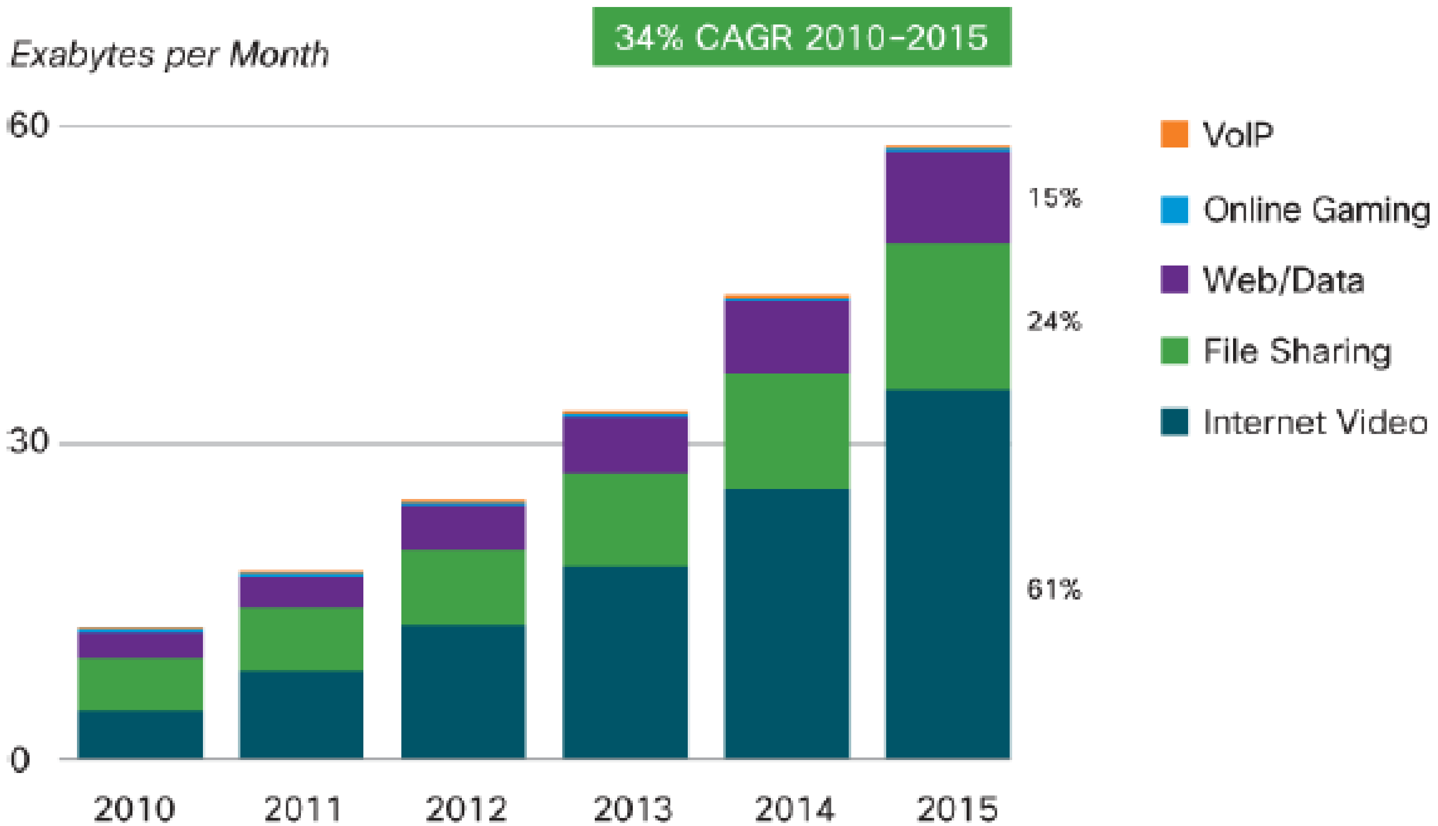
Peering and Shortest Exit



Traffic growth and Internet video



Source: Cisco (2011).

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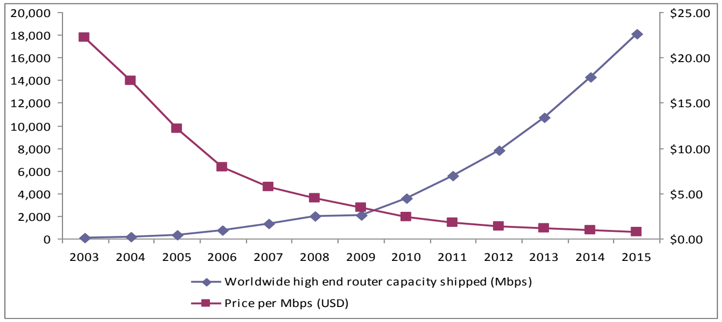

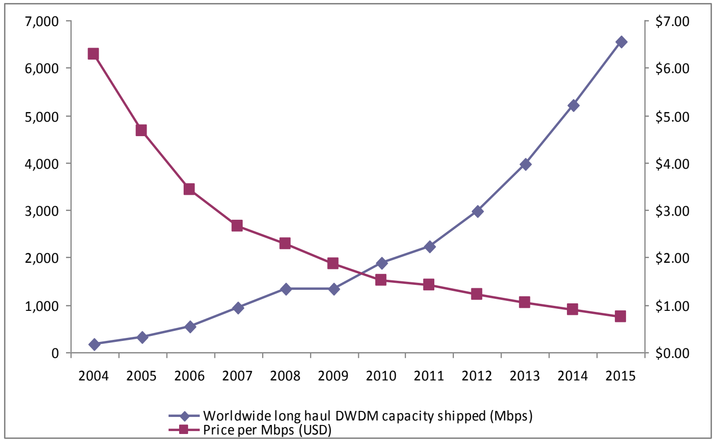

Here we have the shipment quantities in Mbps and the price per Mbps (USD) for high end routers and for long haul DWDM optoelectronic equipment.

These are among the key cost drivers for Internet core and aggregation networks.

The growth in shipments generally tracks the Cisco projections.

The growth in *shipment volume* does not equate to a growth in *costs*, because the decline in unit costs is nearly in balance with it.

Source: Dell'Oro (2011), WIK calculations.

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Internet video, costs and prices

- “In spite of the widespread claims of continuing and even accelerating growth rates, Internet traffic growth appears to be decelerating. In the United States, there was a brief period of ‘Internet traffic doubling every 100 days’ back in 1995-96, but already by 1997 growth subsided towards an approximate doubling every year …, and more recently even that growth rate has declined towards 50-60% per year. …Traffic growth rates of 50% per year appear to only about offset technology advances, as transmission capacity available for a given price steadily increases.”
- “[A]lthough service providers are pushing to throttle customer traffic, an argument can be made that they should instead be encouraging more traffic and new applications, to fill the growing capacity of transmission links.”

Source: “Minnesota Internet Traffic Studies (MINTS)” at http://www.dtc.umn.edu/mints/home.html.

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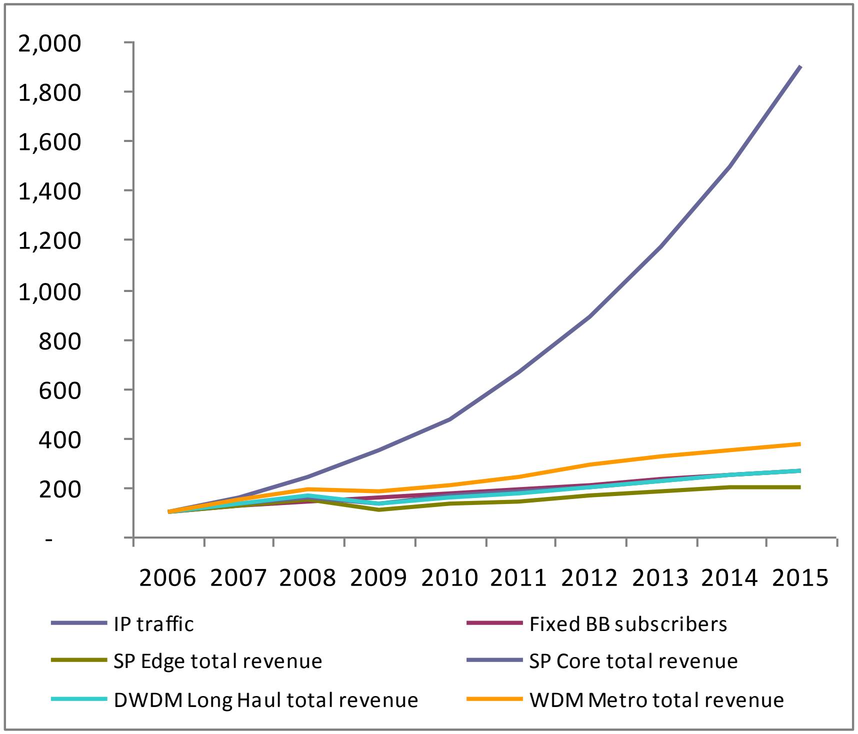
- Underlying equipment costs track with subscribership and revenue, not with the volume of traffic.



Source: Dell'Oro (2011), Cisco (2011), WIK calculations.

IP Interconnection charging methods

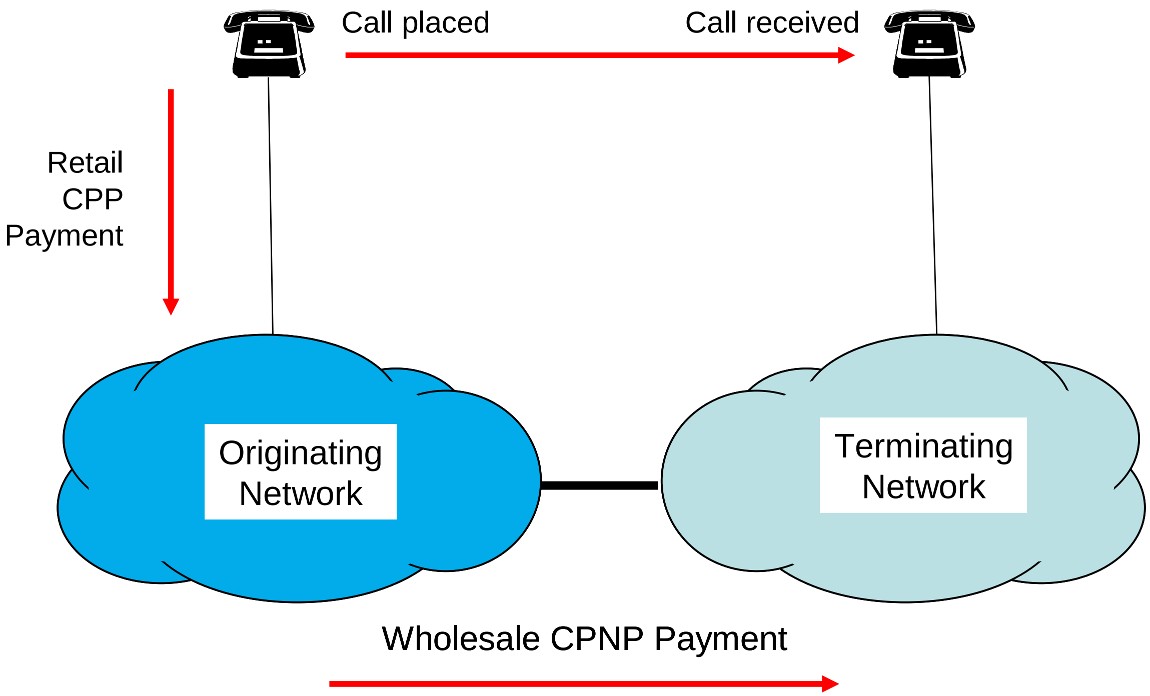
- NGN: Concepts and challenges
- IP interconnection
- Voice interconnection: Economics, implications, challenges
  - Retail versus wholesale arrangements
  - Declining voice call Termination Rates (TRs)
    - Implications for retail prices
    - Implications for use of the voice service
  - On-net off-net price discrimination
  - Challenges of NGN migration
  - Convergence of voice and data interconnection?
- IP Quality of Service (QoS)
- Evolving the system?
- Concluding remarks

Economic background : Traditional Fixed and Mobile Interconnection Models

- Retail arrangements
  - Calling Party Pays (CPP)
    - Traditional arrangement: the caller pays for the call, the called party usually pays nothing.
    - Reflects presumed cost causality.
  - Receiving (Mobile) Party Pays (RPP/MPP)
    - Shared utilities from calls, receiver sovereignty
    - True RPP systems are rare today.
  - Flat rates: Calls included in monthly fees (bandwidth)
  - Banded flat rates (buckets of minutes): “banded” flat rate
- Bulk of revenues comes from voice telephony; however, voice represents a sharply declining percentage of traffic

Economic background:
Traditional Fixed and Mobile Interconnection Models

- Calling Party's Network Pays (CPNP) wholesale arrangements



- An alternative (US and a few other countries) is to have negotiated arrangements under obligations of reciprocity, often resulting in no wholesale charges (Bill and Keep).

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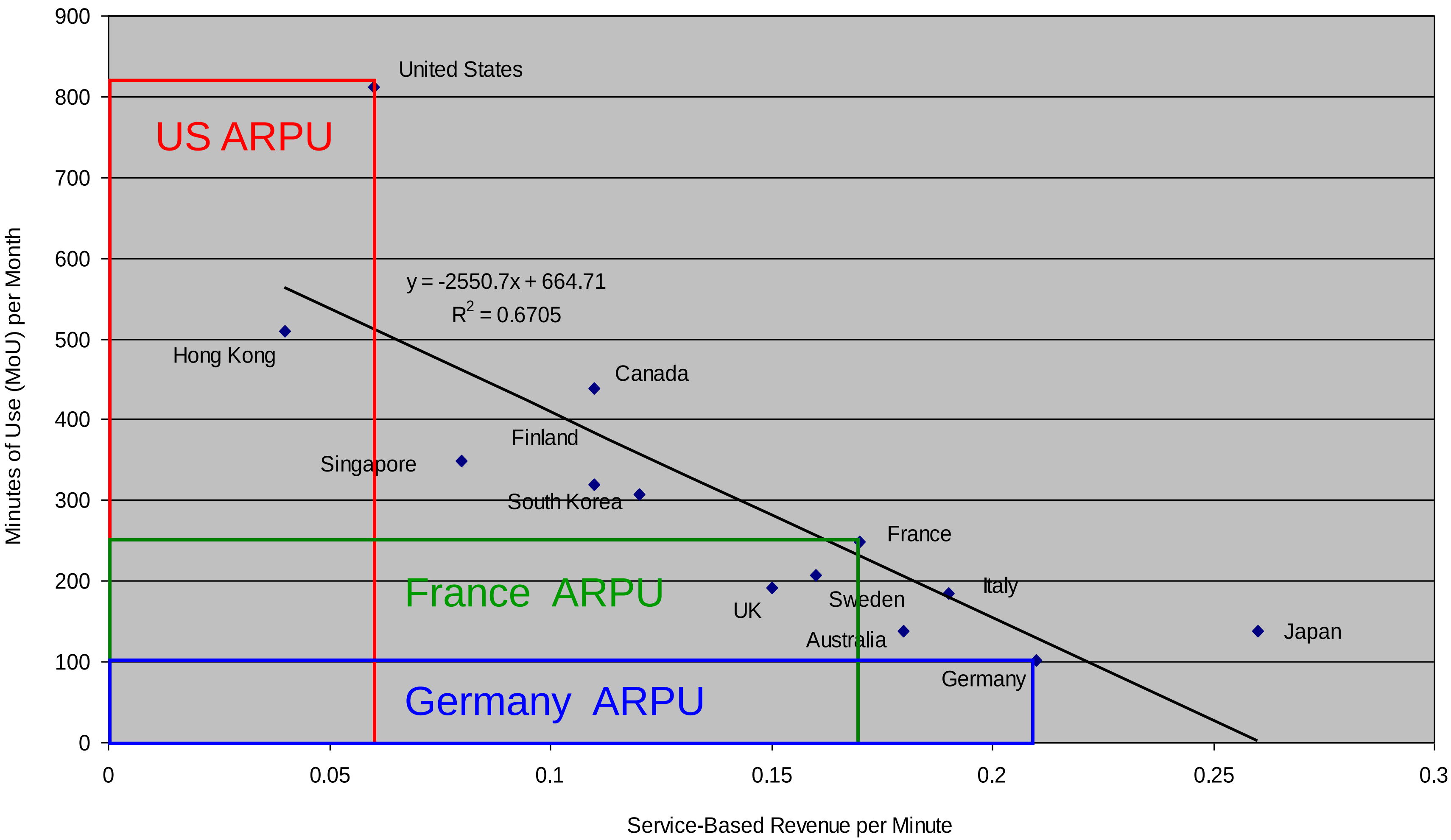
Economic background: Wholesale and retail

- In an unregulated CPNP system, carriers will tend to establish very high termination charge levels (the *termination monopoly)*.
  - Smaller operators would be motivated to set termination fees even higher than large operators.
  - The problem is addressed in the EU by regulating all rates.
- Several factors contribute to the termination monopoly.
  - Since the charges are ultimately borne by *another operator's customers*, normal market forces do not adequately constrain them.
  - Customers have no visibility into termination fees.
- Termination charges at the wholesale level have some interaction with retail pricing arrangements.
  - The termination fee generally sets a floor on the retail price.
  - Where termination fees are high, they generally limit the applicability of flat rate or "buckets of minutes" plans.

Economic background; Wholesale and retail



MoU and service based revenue per minute from Merrill Lynch Quarterly Wireless Matrix, as cited by the US FCC in 2008.
Merrill Lynch does not count on-net mobile terminated in CPNP countries, thus under-counting by not more than 20%.

Economic background: Challenges implied by NGN

- Network costs are driven by capacity requirements. In future integrated IP-based networks, where voice may represent only a small fraction of the traffic, total costs might have little to do with minutes of voice use.
- Traditional interconnection arrangements historically represented an attempt to use *wholesale* payments (between network operators) to correct for imbalanced *retail* payments (between service providers).
- To the extent that the network and service providers are different firms, and to the extent that voice is only a small fraction of the cost of the network, this system makes even less sense going forward than it did in the past.

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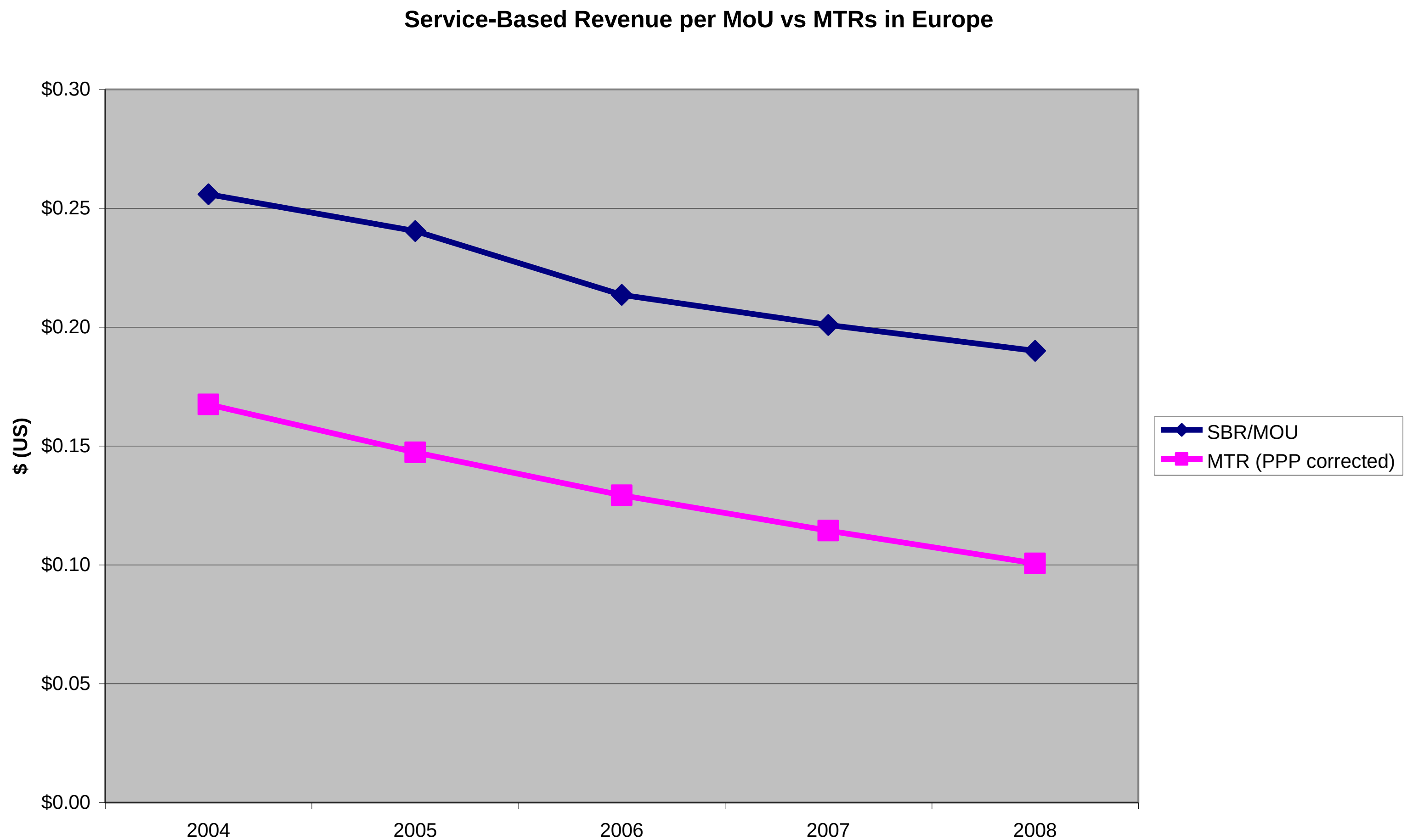
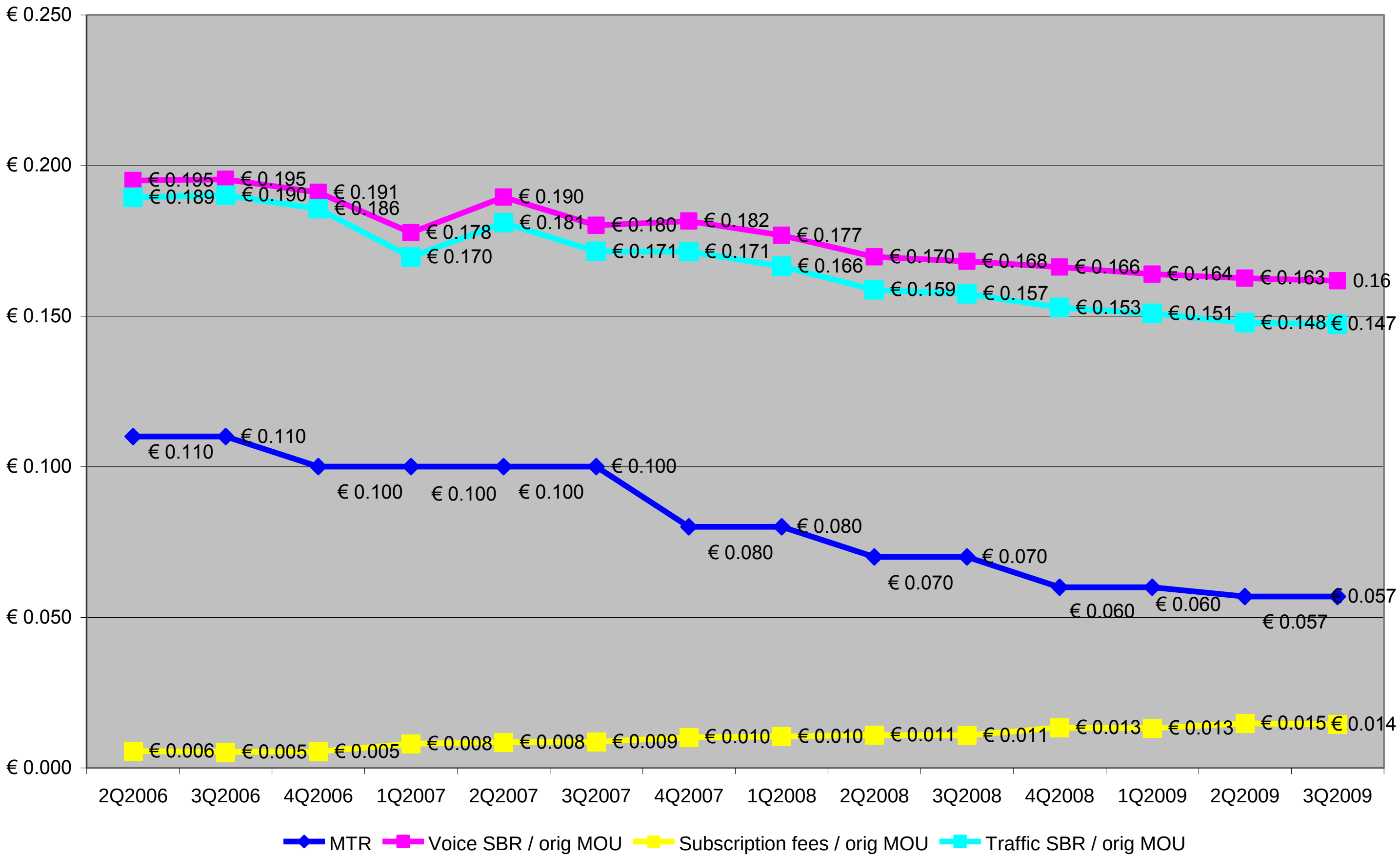
Economic background: Voice Interconnection

- Does IP interconnection equate to voice interconnection?
- Different answers are emerging for IP-based service providers, fixed incumbents, and mobile operators.
  - Independent VoIP service providers, cable operators who offer VoIP: Interconnection arrangements based on VoIP peering are emerging. This requires the ability to determine which service provider serves which telephone numbers (e.g. by means of carrier ENUM).
  - Fixed PSTN: As networks migrate to IP-based NGNs, IP peering does not automatically imply the ability to use VoIP to connect to the fixed incumbent's inherrent voice services.
  - Mobile PLMN: The GSM-A already provides an architecture for IP interconnection of mobile operators, the GRX/IPX. This *could* in principle be used for voice interconnection.
- Voice interconnection among large telecoms players is almost always implemented using circuit switched technology and Signalling System 7.

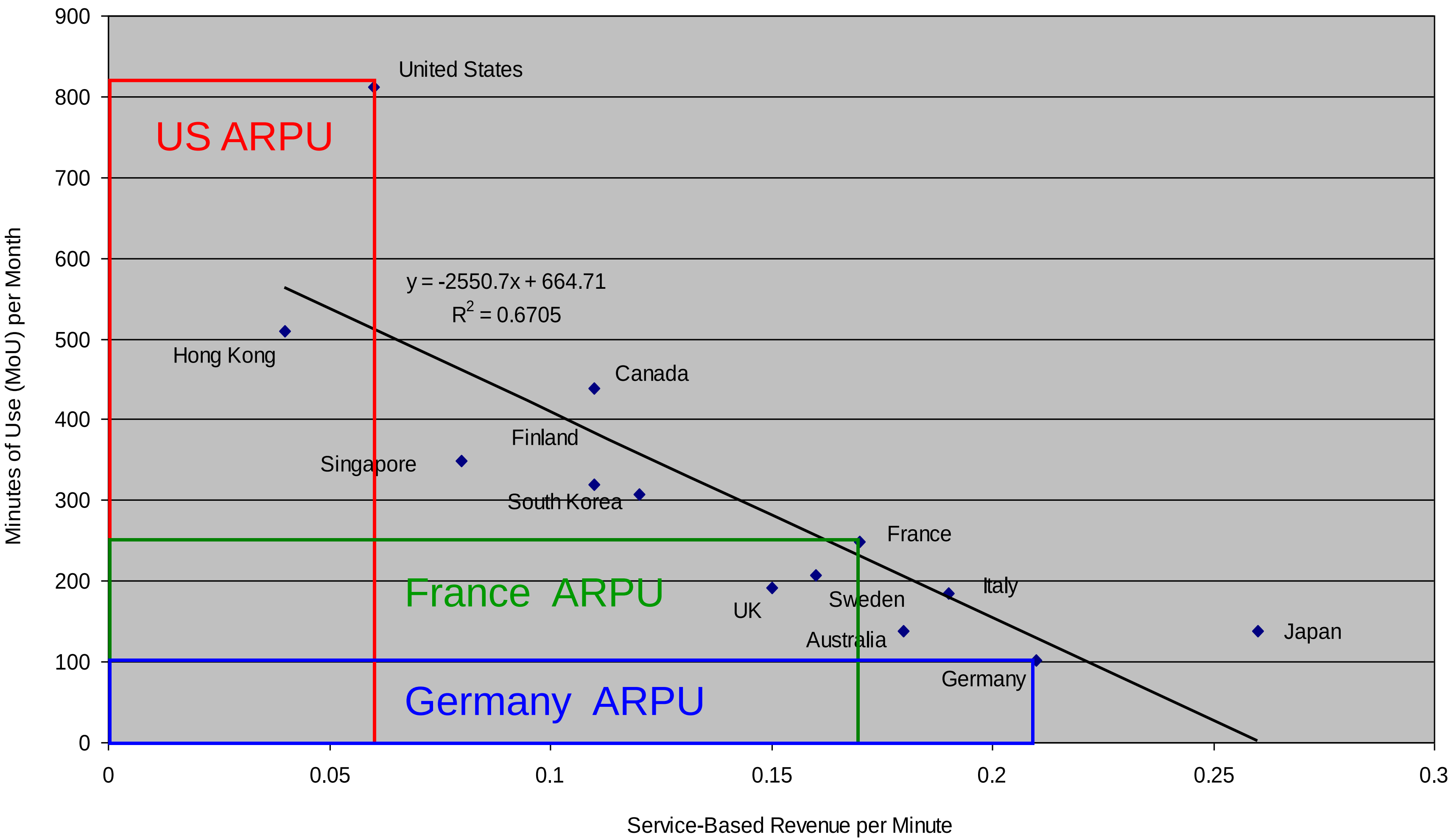
Economic background; Wholesale and retail



Economic background; Wholesale and retail



Economic background; Wholesale and retail



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Economic background; Wholesale and retail

- Lower MTRs tend to result in a lower service based revenue, with a highly significant coefficient of +0.71, and lower retail price with a coefficient of not less than +0.56. (Source: WIK)
- Lower MTRs (operating through the mechanism of lower retail prices) tend to result in greater consumption of mobile services (greater call initiation) in terms of minutes of use per month per subscription. Long term elasticity (in the range of -0.52 to -0.61) is much greater than short term elasticity (-0.097). (Source: WIK)
- CAVEAT: Correlation is not causation, but we think that the causal links are clear enough.

On-net Off-net price discrimination

- Most MNOs charge less at retail for calls to their own customers (on-net calls) than for calls to other MNOs.
- For on-net calls, the MNO faces the real marginal cost of termination, not the (inflated) MTR.
- On-net off-net price discrimination favors MNOs with large shares of subscribers.
  - For a “large” MNO, many calls remain on-net.
  - For a “small” MNO, most calls must go off-net, and therefore face the high MTR as an incremental cost.
- For any MNO, it is challenging to price below the MTR. The more you sell, the more you lose.
- A low or zero MTR enables competitors to price aggressively, and constrains on-net off-net price discrimination.

- NGN: Concepts and challenges
- IP interconnection
- Voice interconnection: Economics, implications, challenges
- Implications of declining voice call Termination Rates (TRs)
- Quality of Service (QoS)
  - The role of QoS in the Internet
  - Why so little QoS differentiation between network operators?
  - QoS and network neutrality
- Evolving the system?
- Concluding remarks

What is QoS in an IP-based NGN?

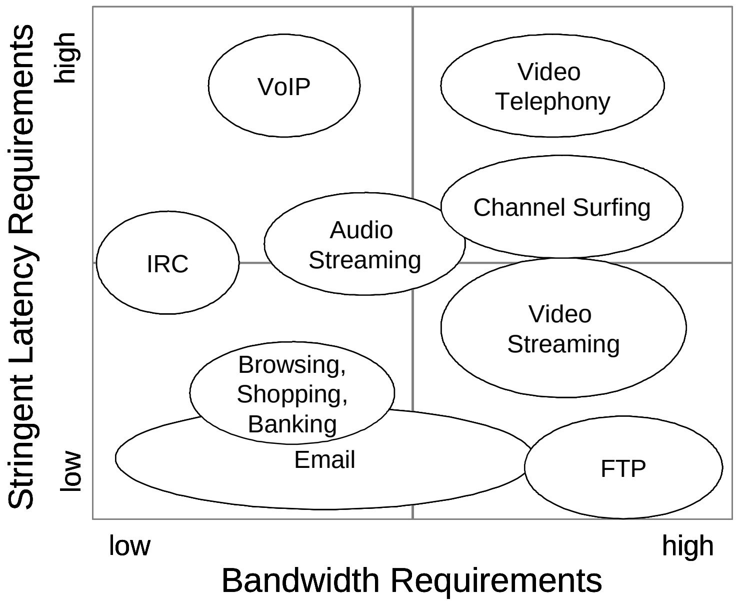
- In traditional fixed telephone networks, there tended to be a great deal of concern about blocking probability, much less about voice quality once the call was allowed to complete.
- In an IP-based system under load, packets can routinely be queued for transmission, or dropped if the queue is too long.
- These delays are not a failure mode – they are a normal aspect of Internet Protocol operation.
- What factors are most critical to the Quality of User Experience in such an environment?

What is QoS in an IP-based NGN?

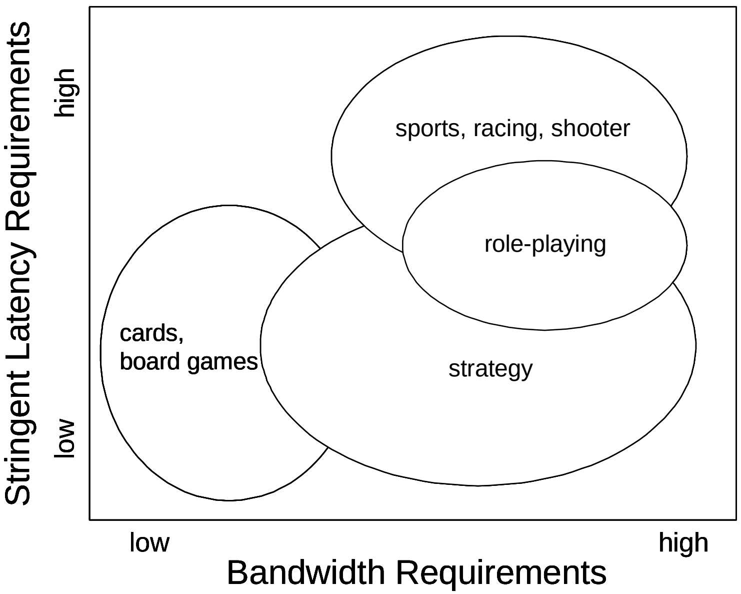
- **Bandwidth:** the maximum number of bits that a transmission path can carry.
- **Propagation delay:** The time that a packet requires, as a function of the length of all transmission path and the speed of light through that particular transmission path.
- **Queuing delay:** The time that a packet waits before being transmitted. Both the average delay and variability of delay (jitter) matter, since the two together establish a confidence interval for the time within which a packet can be expected to arrive at its destination.
- **Packet loss:** The probability that a packet never reaches its destination. This could be due to transmission errors, but errors are quite rare in modern fibre-based fixed networks. More often, packets are lost because the number of packets waiting for transmission is greater than the available storage capacity (buffers).

Differentiated Quality of Service (QoS): Application Needs

General Applications



Gaming Applications

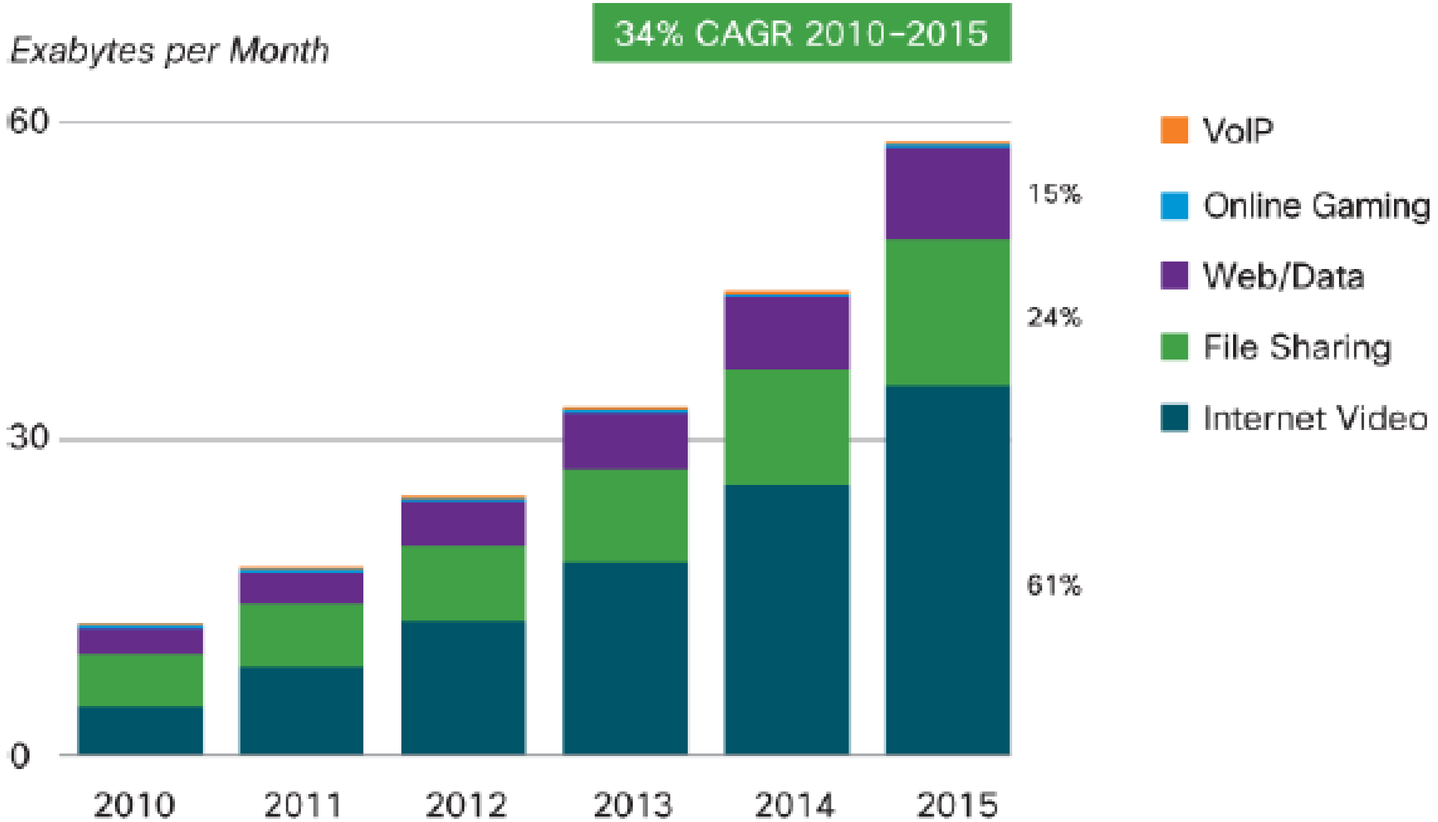


- Real time bidirectional audio: stringent requirements
- Email: liberal requirements
- Streamed audio and video: fairly liberal requirements. (Channel surfing?)

Differentiated Quality of Service (QoS): Application Needs

- For voice, if delay exceeds about 150 milliseconds, both sides may begin to speak at once.
- Not all video is delay-sensitive.
  - For real-time videoconferencing, similar considerations apply to delay; however, bandwidth requirements are far greater.
  - For streamed video, if it is permissible to wait a second or two at the outset, a jitter buffer can accommodate typical delays.
  - Interconnection is not relevant to all video. Much video is originated close to the end-user (within the end-user’s own network, in order to save transmission costs.
- Certain interactive games may be highly delay-sensitive.
- Data applications tend to be less sensitive, but some (e.g. web-browsing) are more delay-sensitive than others (e.g. e-mail).

The relative weight of VoIP and Internet video



Source: Cisco (2011).

Differentiated Quality of Service (QoS)

- At a technical level, QoS is not fundamentally hard.
  - DiffServ is technically trivial.
  - MPLS in a single network is technically trivial.
  - Cross-provider MPLS is only marginally harder.
  - Even RSVP is not that hard. My former company, BBN, had working production RSVP-compliant networks in 1995!
- In terms of the basic economics, QoS is not fundamentally hard.
- Differentiated QoS *within* a network is, in fact, commonplace.
- Nonetheless, there is no significant roll-out of differentiated QoS *between* networks.

➢ ***WHY NOT?***

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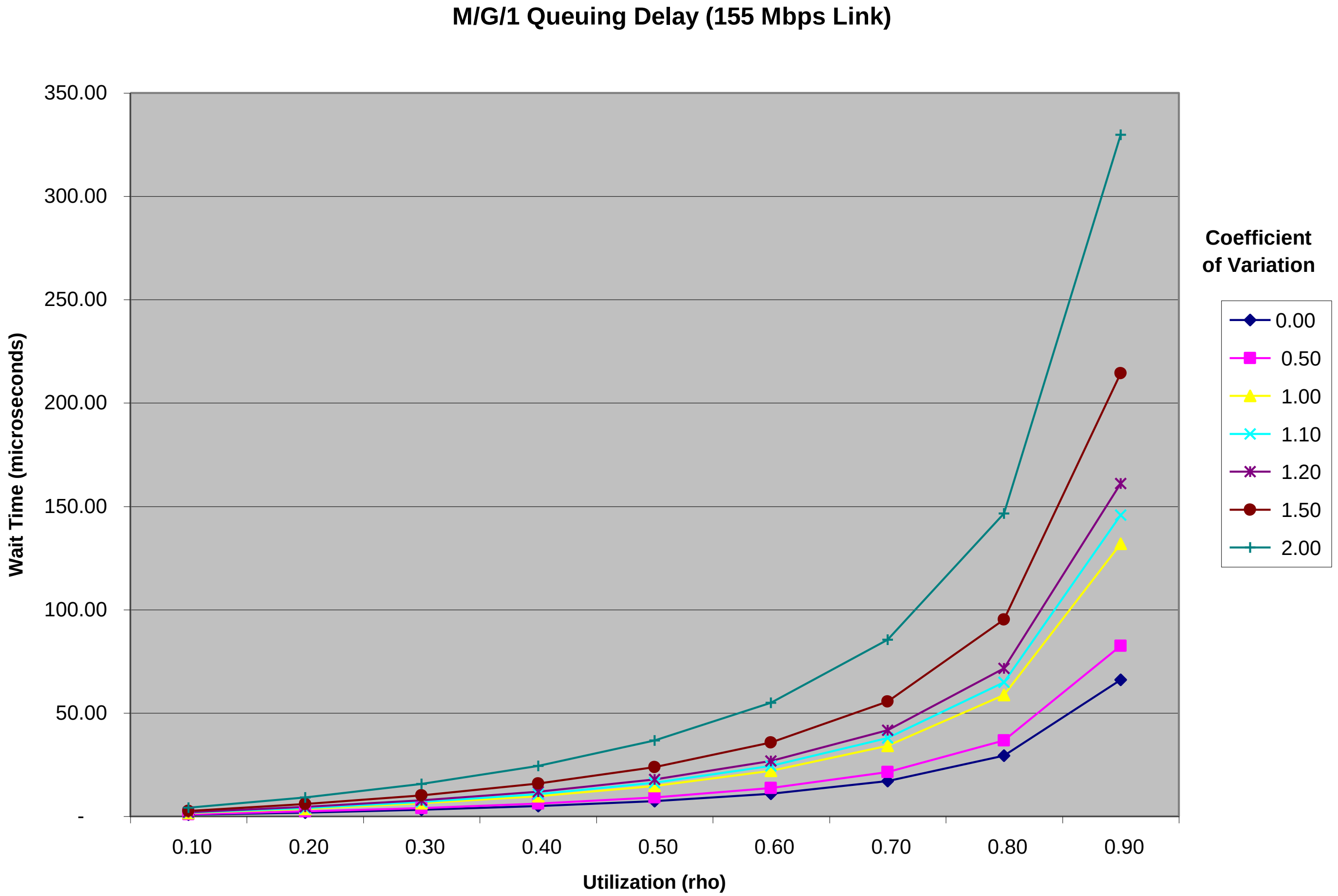
Economic theory and QoS issues: Differentiated Quality of Service (QoS)



M/G/1 queueing analysis of the performance ***of a single link***

(with clocking delay of 50 µsecs (284 byte packets) and a 155 Mbps link)

Differentiated Quality of Service (QoS)

- As we have seen, per-hop delay, even in a network with 90% load, is about 1,000 times less than the 150 millisecond delay "budget" for real-time bidirectional voice.
- IMPLICATION: Most of the time, and under normal conditions, variable delay in the core of the network is unlikely to be perceptible to the users of VoIP or other delay-sensitive applications.
- FURTHER IMPLICATION: Consumers will not willingly pay a large premium for a performance difference that they cannot perceive.
- Packet delay is more likely to be an issue:
  - For slower circuits at the edge of the network
  - For shared circuits (e.g. cable modem services)
  - When one or more circuits are ***saturated***
  - When one or more components have failed
  - When a *force majeure* incident has occurred

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Differentiated Quality of Service (QoS)

- In the US, and to a somewhat lesser degree in Europe, there has been an intense debate over *network neutrality*.
- Network neutrality has many different meanings. All relate to some form of traffic or pricing discrimination that is felt to be unwarranted.
- The debate is closely linked to notions of differentiated Quality of Service.

“The chief executive of AT&T, Edward Whitacre, told *Business Week* last year that his company (then called SBC Communications) wanted some way to charge major Internet concerns like Google and Vonage for the bandwidth they use. "What they would like to do is use my pipes free, but I ain't going to let them do that because we have spent this capital and we have to have a return on it," he said.”

NY Times, March 8, 2006

Economic background of network neutrality

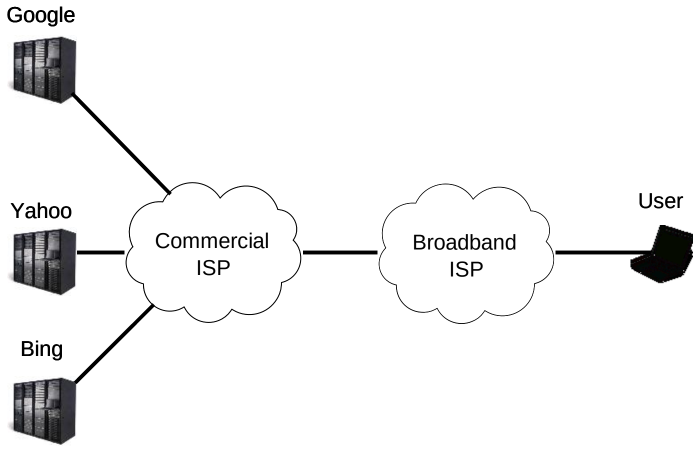
- Quality differentiation
- Economic foreclosure
- Two-sided (or multi-sided) markets

Quality differentiation

- Quality differentiation and price differentiation are well understood practices.
- In the absence of anticompetitive discrimination, differentiation generally benefits both producers and consumers.
- We typically do not consider it problematic if an airline or rail service offers us a choice between first class and second class seats.

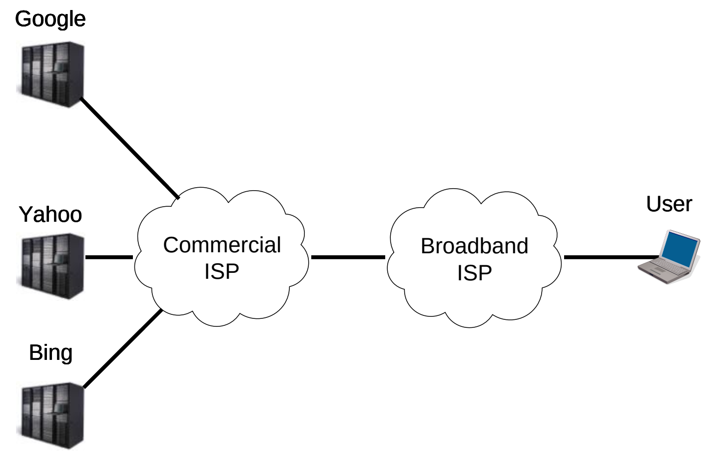
Economic foreclosure

- When a producer with market power in one market segment attempts to project that market power into upstream or downstream segments that would otherwise be competitive, that constitutes economic foreclosure.
- Foreclosure harms consumers, and imposes an overall socio-economic deadweight loss on society.



Two-sided markets

- The Internet as a whole can be thought of as a two-sided market, with network operators serving as a platform connecting providers of content (e.g. web sites) with consumers.
- Under this view, some disputes are simply about how costs and profits should be divided between the network operators and the two (or more) sides of the market.
- The Internet is clearly *not* a monolithic platform. Interests of the various ISPs are not aligned.



Two-sided markets

- To say that the Internet as a whole can be viewed as a two-sided market analysis does not in and of itself tell us how payments should ideally be allocated between the sides of the market.
- This would depend on a detailed analysis of externalities and demand elasticities (which changes over time).
- Some argue that consumer-facing ISPs are not making enough money to finance the migration to Next Generation Access.
- This argument could very well be backwards. If the problem is that the marginal willingness-to-pay of consumers for ultra-fast bandwidth is just €5 per month, the reall problem is arguably a lack of high bandwidth high value content.

Differentiated Quality of Service (QoS)

- Network neutrality has manifested differently in Europe than in the U.S, because:
  - The European broadband market has a richer competitive structure than that of the U.S.
  - The European regulatory framework, in conjunction with European competition law, provides much more comprehensive mechanisms for dealing with potential harms.
- In the US, rules are in place. The degree to which they will be enforced and enforceable remains to be seen.
- In Europe, the issue bears watching, but a major intervention (beyond the changes already implemented in 2009) does not appear to be warranted.

- NGN: Concepts and challenges
- IP interconnection
- Voice interconnection: Economics, implications, challenges
- Implications of declining voice call Termination Rates (TRs)
- Quality of Service (QoS)
- Evolving the system?
- Concluding remarks

Implementing inter-provider QoS

- Although the technology is reasonably straightforward, little practical experience in enforcing QoS across IP-based networks.
- It is not due to a lack of standards – there are too many standards, not too few.
- Classic problem of introducing change into a technological environment:
  - Network effects – no value until enough of the market has switched.
  - Long, complex value chains.
  - Costs and complexity of transition.
- Analogous problems have slowed IPv6 and DNSSEC.

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Implementing inter-provider QoS

- Efforts to extend Quality of Service (QoS) across network operators have failed to catch fire for many reasons:
  - **Scale:** Bilateral peering arrangements will tend to be acceptable to both network operators only when the networks are of similar scale, or more precisely when both networks can be expected to be subject to similar cost drivers for carrying their respective traffic.
  - **Traffic balance:** Where traffic is significantly asymmetric, cost drivers are likely to also be asymmetric.
  - **Monitoring and management:** There are many practical challenges in determining whether each network operator has in fact delivered the QoS that it committed to deliver.
  - **Financial arrangements:** There has been no agreement as to how financial arrangements should work. In particular, there has been enormous reluctance on the part of network operators to accept financial penalties for failing to meet quality standards.

Implementing inter-provider QoS

- Many efforts over the years to define inter-provider QoS standards.
- One of the best and most practical was organised by MIT, with substantial industry participation.
- The following values from the MIT white paper would appear to be resonable for IP interconnection suitable for real time bidirectional voice:

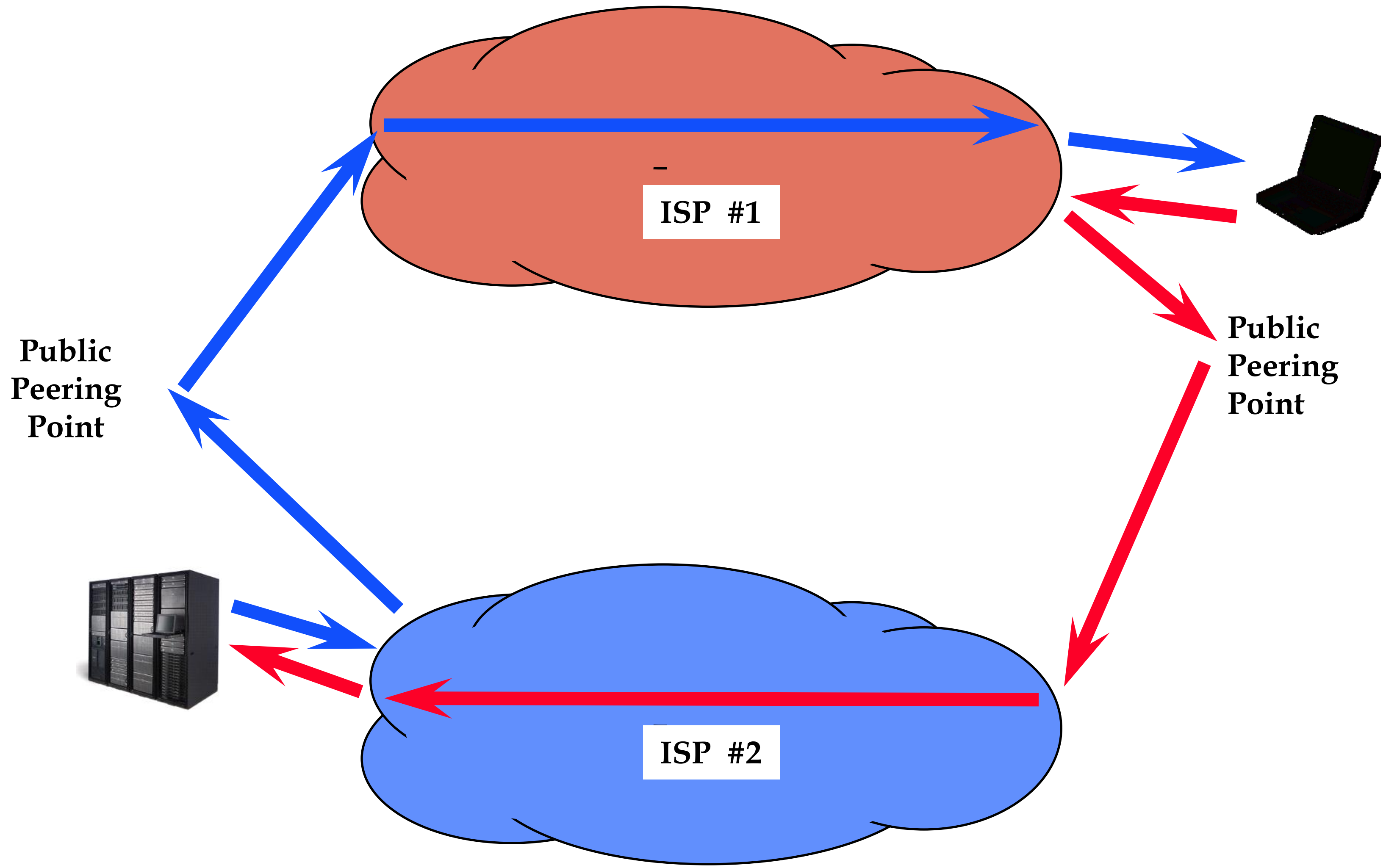
Delay:	100 msec
Delay Variance:	50 msec
IPPM Loss Ratio:	1 x 10-3 (One Way Packet Loss)

- The MIT WG white paper also explains how to measure these, and how to allocate end-to-end requirements to multiple networks. IPPM probes could be suitable.
- A challenge: No network operator will want another to operate probes within its network.

Implementing inter-provider QoS

- As part of the functional/operational separation of Telecom New Zealand, there were commitments
  - To interconnect with competitors using IP
  - To support a suitable QoS for VoIP in those interconnections
- The first of these is in place.
- For the second, Telecom New Zealand made a quite interesting proposal, based on their methodology for the first of these.

Peering and Shortest Exit



Implementing inter-provider QoS: TNZ offer

- Division of New Zealand into 29 interconnection areas;
- Willingness to interconnect with any network operator of any size (without settlement payments for IP traffic) to interchange data with TNZ customers within that interconnection area, provided that the access-seeking network operator has made arrangements to get its traffic to the interconnection area;
- Availability of IP traffic transit arrangements from TNZ at reasonable wholesale prices to get the traffic to the desired interconnection area;
- A fair process for achieving physical interconnection within an IP interconnection area if desired;
- Two classes of services offering performance better than “best efforts”; but
- No specific penalties or payments if traffic is delivered with quality less than that committed.

Implementing inter-provider QoS

- Telecom New Zealand proposal should be workable.
- Technically, it is nearly identical to the means by which the largest backbones interconnect globally. It differs only in geographic scale.
- Economically, it is similar to (apparently sound) proposals by Ingo Vogelsang and Patrick de Graba.
- Deals simply and elegantly with size differences among network operators.

Concluding observations

- Interconnection continues to be critical to the business success of all network operators (and their end-user customers).
- The migration to IP-based NGNs has shaken up “traditional” interconnection in profound ways.
- Technological considerations do not solely drive the evolution of interconnection arrangements – and they probably should not.
- One might expect voice and data interconnection to converge, but there has been little movement to date.
- New, fully IP-aware interconnection arrangements have been slow to emerge.
- There have, however, been a few interesting developments that might ultimately prove their worth.

A few of my papers

With Pieter Nooren and Jonathan Cave, “Network Neutrality”, a study for the European Parliament, 2011, at: http://www.europarl.europa.eu/activities/committees/studies/download.do?language=en&file=36351

With Christian Growitsch and Christian Wernick, "The Effects of Lower Mobile Termination Rates (MTRs) on Retail Price and Demand", at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1586464.

With Dieter Elixmann and Christian Wernick, "Next Generation Networks (NGNs)", a study for the European Parliament, available at: http://www.europarl.europa.eu/activities/committees/studies/download.do?language=en&file=27911

Marcus et al., Interconnection in Next Generation Networks (NGNs), study for OSIPTEL (Peru), 2009.

With Dieter Elixmann, and numerous senior experts, *The Future of IP Interconnection: Technical, Economic, and Public Policy Aspects*, a study prepared for the European Commission, available at: http://ec.europa.eu/information_society/policy/ecomm/doc/library/ext_studies/future_ip_intercon/ip_intercon_study_final.pdf.

“IP-based NGNs and Interconnection: The Debate in Europe”, *Communications & Strategies*, November 2008, http://www.idate.org/fic/revue_telech/831/CS72_MARCUS.pdf.

With Dieter Elixmann, “Regulatory Approaches to Next Generation Networks (NGNs): An International Comparison”, *Communications and Strategies* number 69, first quarter 2008.

With Dieter Elixmann, Antonio Portilla Figueras, Klaus Hackbarth, Péter Nagy, Zoltán Pápai, and Mark Scanlan, *The Regulation of Next Generation Networks (NGN)*, 10 May 2007, a study for the Hungarian NHH, available at: http://www.nhh.hu/dokumentum.php?cid=15910.

With Dieter Elixmann, Christian Wernick, and the support of Cullen International, *The Regulation of Voice over IP (VoIP) in Europe*, a study prepared for the European Commission, 19 March 2008, available at: http://ec.europa.eu/information_society/policy/ecomm/doc/library/ext_studies/voip_f_f_master_19mar08_fin_vers.pdf.

“Network Neutrality: The Roots of the Debate in the United States”, *Intereconomics*, Volume 43, Number 1, January 2008. See: http://www.springerlink.com/content/g37k162urx11/?p=1a363b658dfb4d95accaecba21b38d5f&pi=0.

wik CONSULT

wik-Consult GmbH
Postfach 2000
53588 Bad Honnef
Tel 02224-9225-0
Fax 02224-9225-68
eMail info@wik-consult.com
www.wik-consult.com