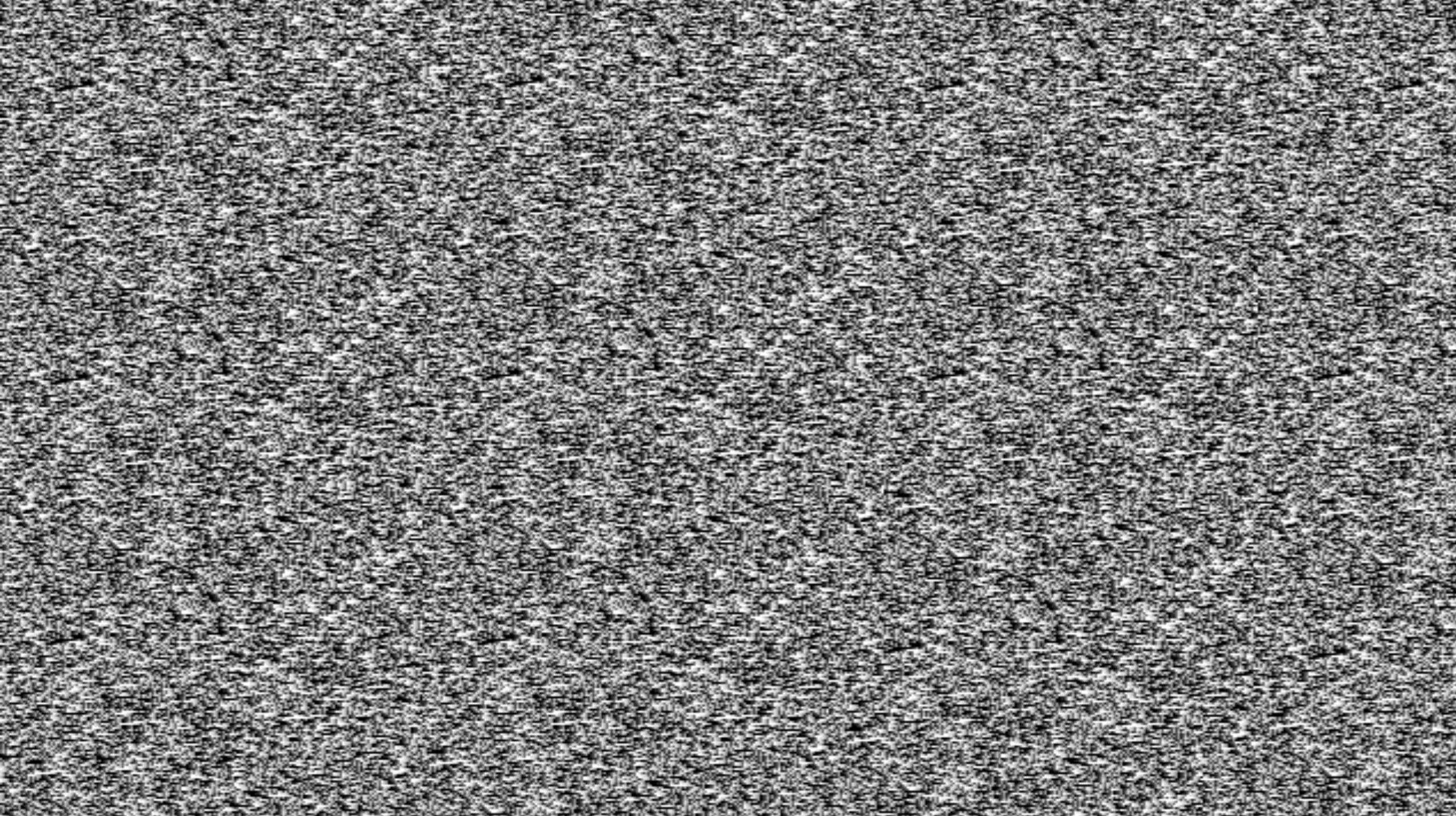


Interconnection and Peering: Then and Now

Geoff Huston
APNIC

Lets roll back the clock to 1998

And look at what was being said about interconnection, peering and exchanges 20 years ago



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Interconnection Issues

Geoff Huston



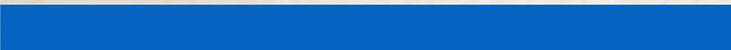
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Internet Service Providers



- Many providers in every market
- Many provider profiles - from small local business to global corporation
- Many diverse objectives in entering the ISP market
 - niche market opportunity
 - leverage of core activities
 - revenue opportunity
 - capital gain opportunity
 - risk dilution






The Financial Model of Interconnection

- 
- **Transit** is a customer / provider relationship where the customer ISP pays the provider (transit) ISP
 - **Peering** is a “Sender Keep All” relationship where neither ISP pays the other

These are the only models of Interconnection between ISPs in the Internet

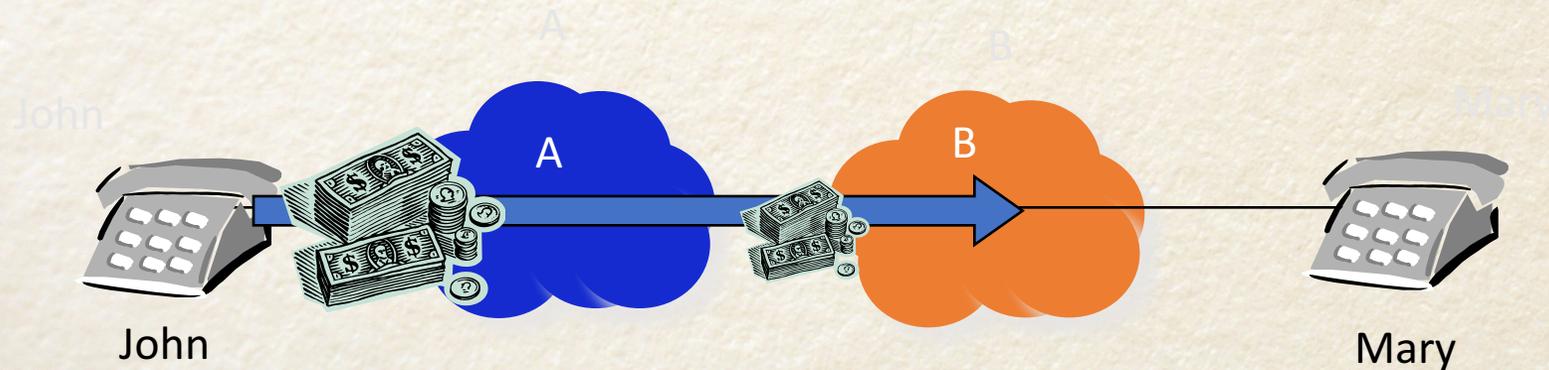
Why?



Follow the Money

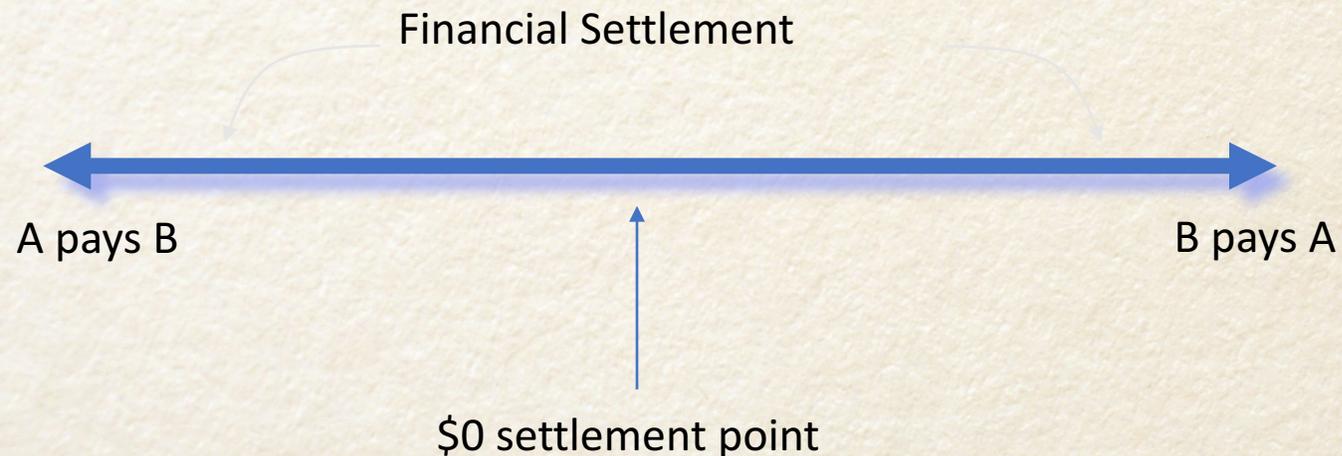
In a conventional multi-provider service the money flow is easy to identify. For example in the telephone network:

- John initiates the transaction
- John pays his local provider A for the entire end-to-end transaction charge for the end-to-end service
- A pays B an “interprovider charge” for B to terminate the transaction
- B terminates the transaction at Mary without charging Mary



Settlements - Who pays who?

- The inter-provider financial relationship will vary for each individual transaction
- The net outcome is balanced through financial settlement





Settlements- Who pays who?

• • •

This assumes:

- each transaction has a measurable value
- each transaction is individually accountable
- each transaction is funded by the end clients in a consistent fashion
 - initiator direction pays or
 - responder direction pays

There is no incentive for setting efficient inter-provider settlement rates in this model when the parties are operating as local monopolies



Enter the Internet . . .

- 
- In the Internet there is no readily identifiable uniform service transaction
 - There is no “call” or similar compound service transaction
 - There is no “caller” and no “recipient”
 - Customers pay their ISP to both send and receive IP packets on their behalf
 - What happens when customers in different network exchange packets?
 - Could we map each service transaction to the transit of a single packet (packet accounting)
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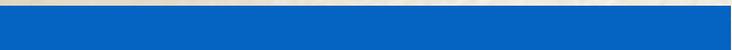

 IP Packet Accounting is a failure!

...

IP packets

- have a vanishingly small value
- have no readily identifiable transaction context
- may not be delivered
- have no ability to accumulate a uniform model of 'incremental value'

Inter-Provider IP packet accounting models

- accrue benefits to inefficient carriers and penalise efficient carriers
 - this is the opposite of what benefits consumers!
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Can we drop per-service settlements?



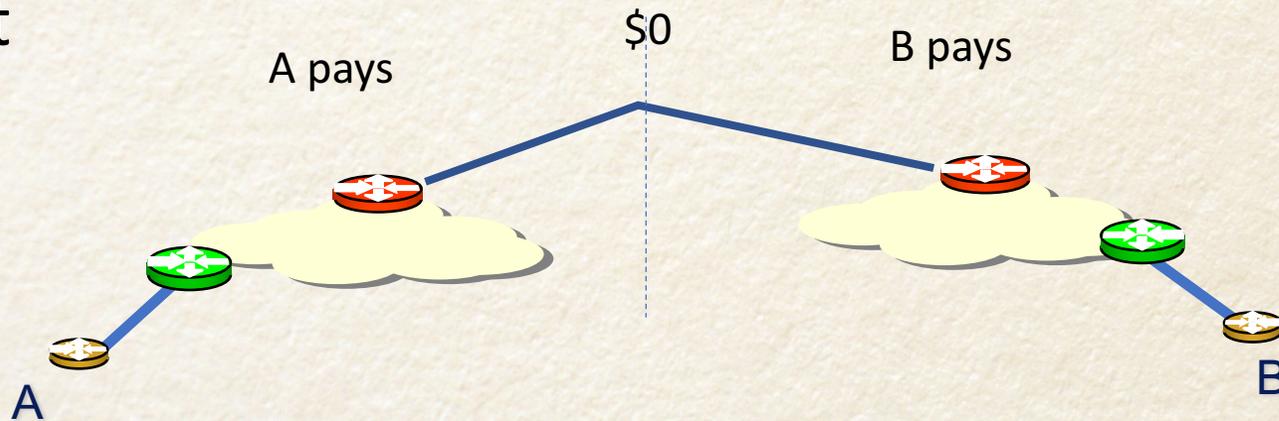
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The retail model of the Internet is an “access” service, not a usage service

- Customers are charged a flat fee for access to the Internet, rather than a charge per sent or received packet, or for variable fees based on the routes miles incurred by the packet
- Any stable inter-provider connection model needs to be an abstraction of the retail model
 - Otherwise the differences create opportunities for leverage which generates inefficiencies

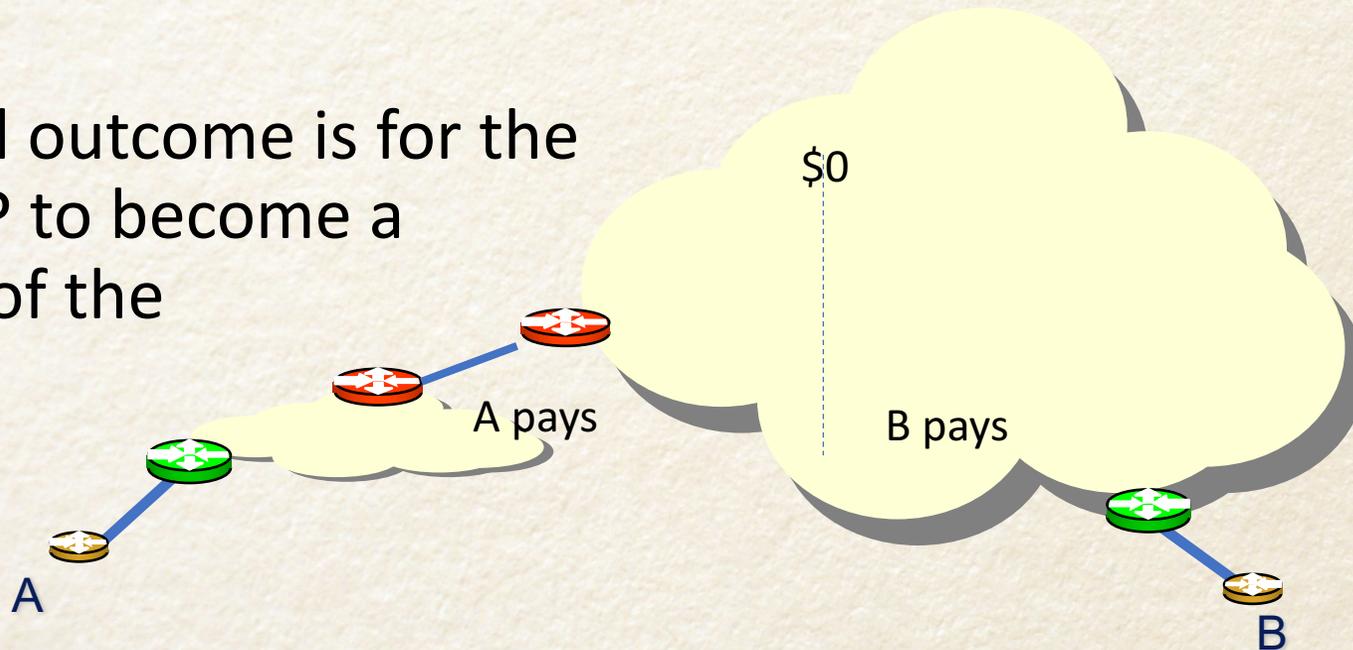
Two Party Peering

- In a simple case of two ISPs that have similar size, then each customer is meeting their ISPs costs incurred in carrying the packet
- There is no net imbalance that calls for inter-provider financial settlement



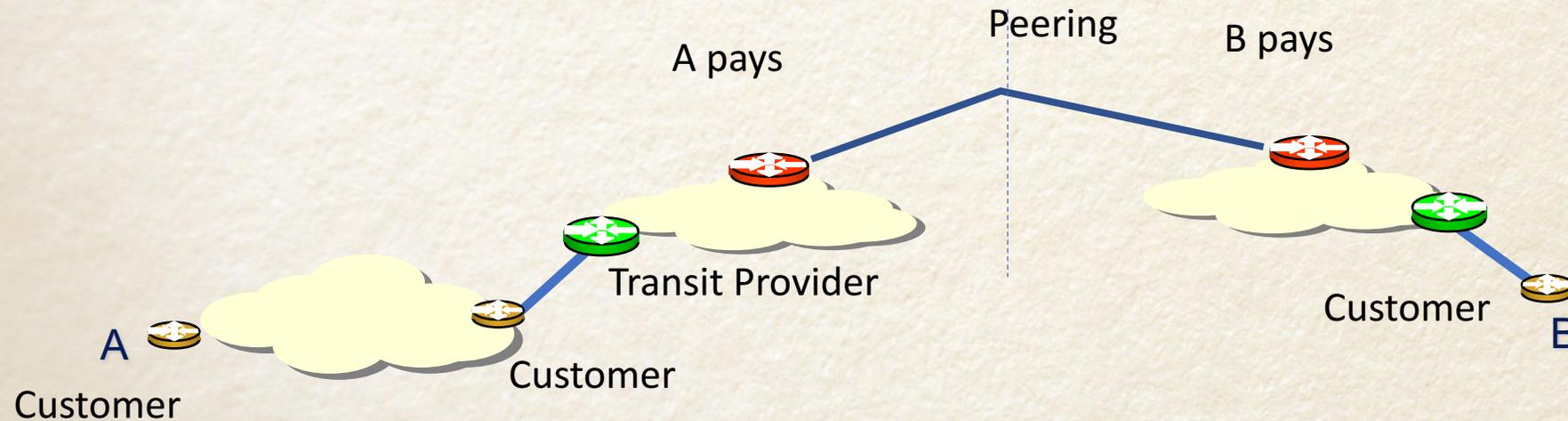
Two Party Tiering

- When the two ISPs are of dissimilar size then peering will not be seen as fair, as the smaller ISP is leveraging the size of the larger
- The typical outcome is for the smaller ISP to become a customer of the larger ISP



Multi-Party Interconnection

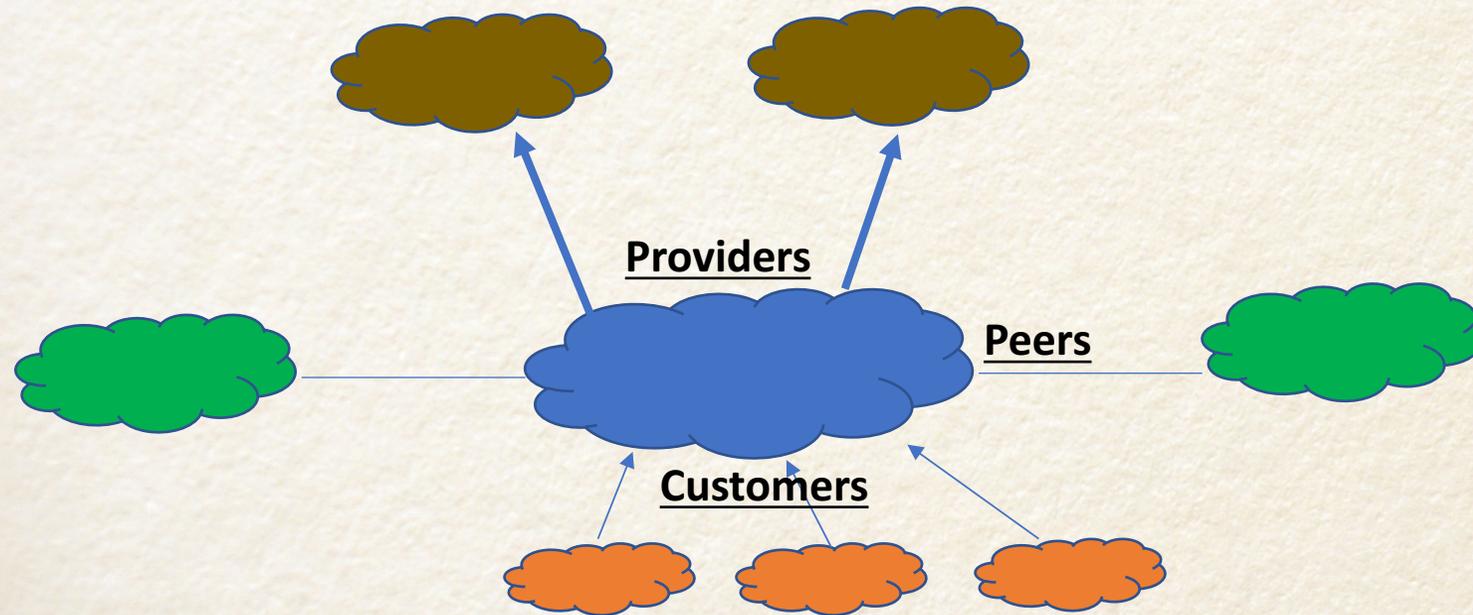
- The two ISP model can be generalised to multiple parties by using the same two concepts of:
 - Customer/Provider, where the customer pays the provider
 - Peering, where there is no financial settlement



The Interconnection Model

...

Each ISP may have multiple relationships:





The Financial Interconnection Model

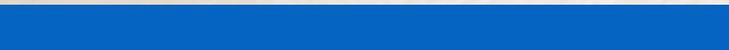


The financial flow in this model is extremely simple:

Customers pay to Providers

Providers receive payments from Customers

Peers don't pay each other



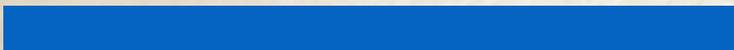


The Routing Interconnection Model



The route advertisement flow in this model is extremely simple:

- Routes learned from customers are re-advertised to other customers, peers and upstreams
- Routes learned from Peers are re-advertised only to Customers
- Routes learned from upstreams are re-advertised only to Customers





Negotiated Relationships

- 
- Every ISP interconnection is either a relationship of provider/customer or SKA peer
 - It's up to the parties to reach an agreement between themselves
 - There are no fixed rules, so its possible to see interconnection as a market in its own right
 - But there are informal “guidelines”
- 
- 


 Universal Peering is a poor strategy

• • •

- Unless you have nothing to lose!
- Risks
 - *Leverage* where a smaller ISP can leverage the network base of a larger ISP without paying
 - Disincentive to invest when others can on-sell the network service without incurring the cost of service provision
- Both parties have to perceive equal benefit in order to peer
 - If unequal parties are forced to peer the larger party is placed at a commercial disadvantage



Aggregation Wins

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- Every customer wants to be a peer
- Every peer wants to be a provider

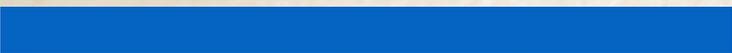
- Bigger is better
 - ISPs that aggregate through mergers and takeovers can obtain access to a more advantaged position with respect to their peer ISPs



The Internet - as we know it



- The competitive ISP industry tends to equilibrate on the lowest local cost structures
- There are no objective criteria to identify who is the provider and who is the customer
- underlying carriage tariffs shape Internet-based 'locality'
- Within each locality ISPs tend to SKA peer - or not
 - bluff is a critical component of the peering game
- Strict tiering blurs because of the confusion over value identification
 - is content of equal value to transit?





The Problem - as we see it

How to interconnect many component networks while:

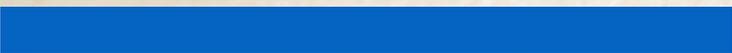
- minimizing local cost everywhere by:
 - localizing transit traffic
 - matching diverse import, export and transit policies
 - avoiding super dense traffic black holes
 - maintaining stability and quality
 - both technical and financial
 - staying within the bounds of available technologies
 - and also adding thousands more component networks



The Role of the Exchange

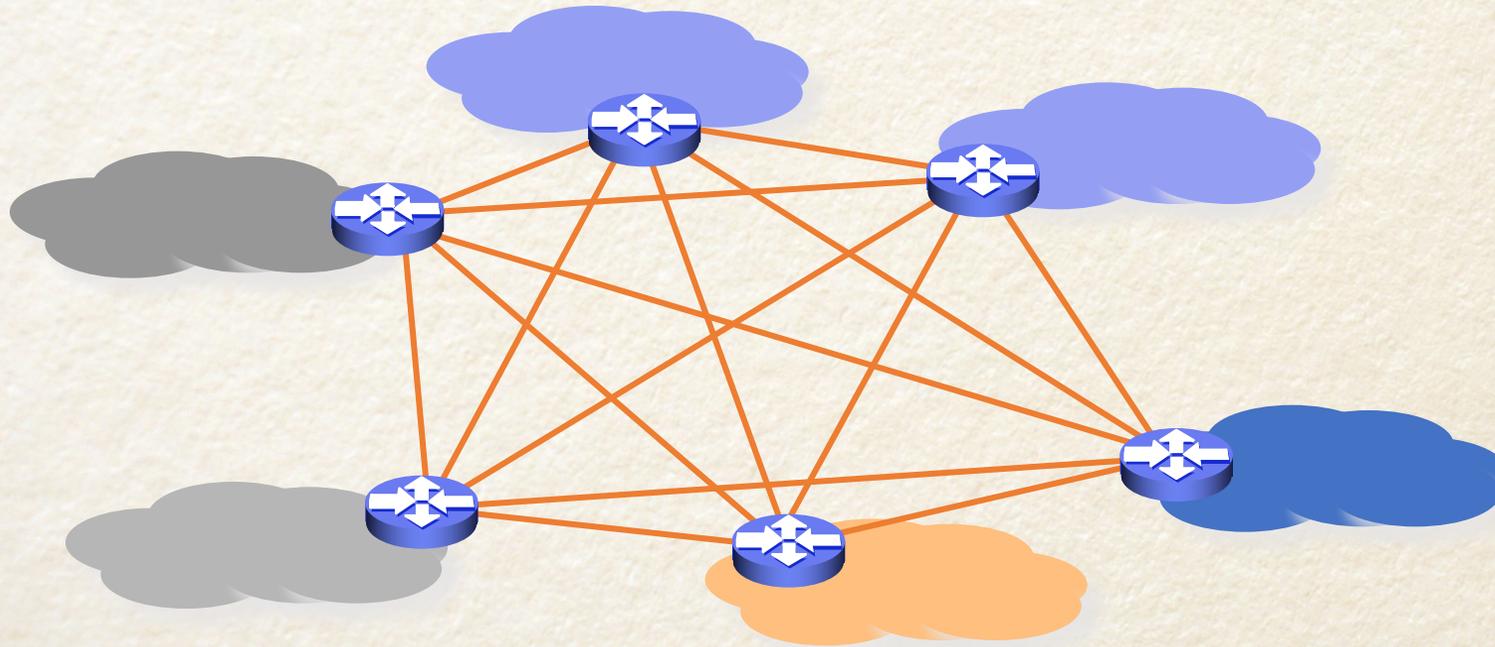


- An examination of the rationale for public Internet exchanges



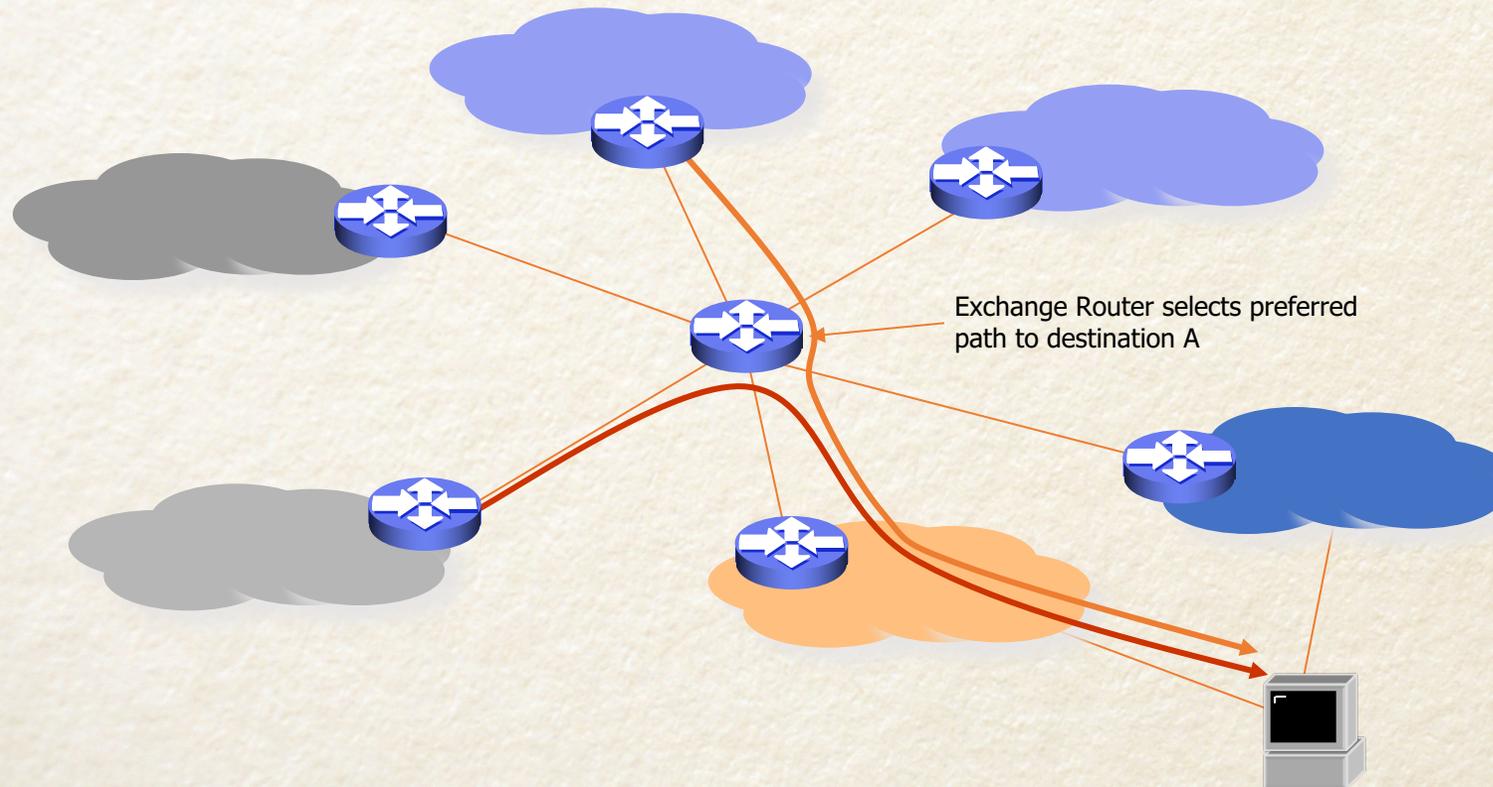
The N-squared problem

- N^2 circuits, N^2 peerings
- questionable scaling properties



The Exchange Router

- Simple unilateral exchange policy
- Router-based exchanges impose transit policy

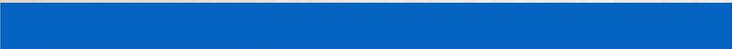
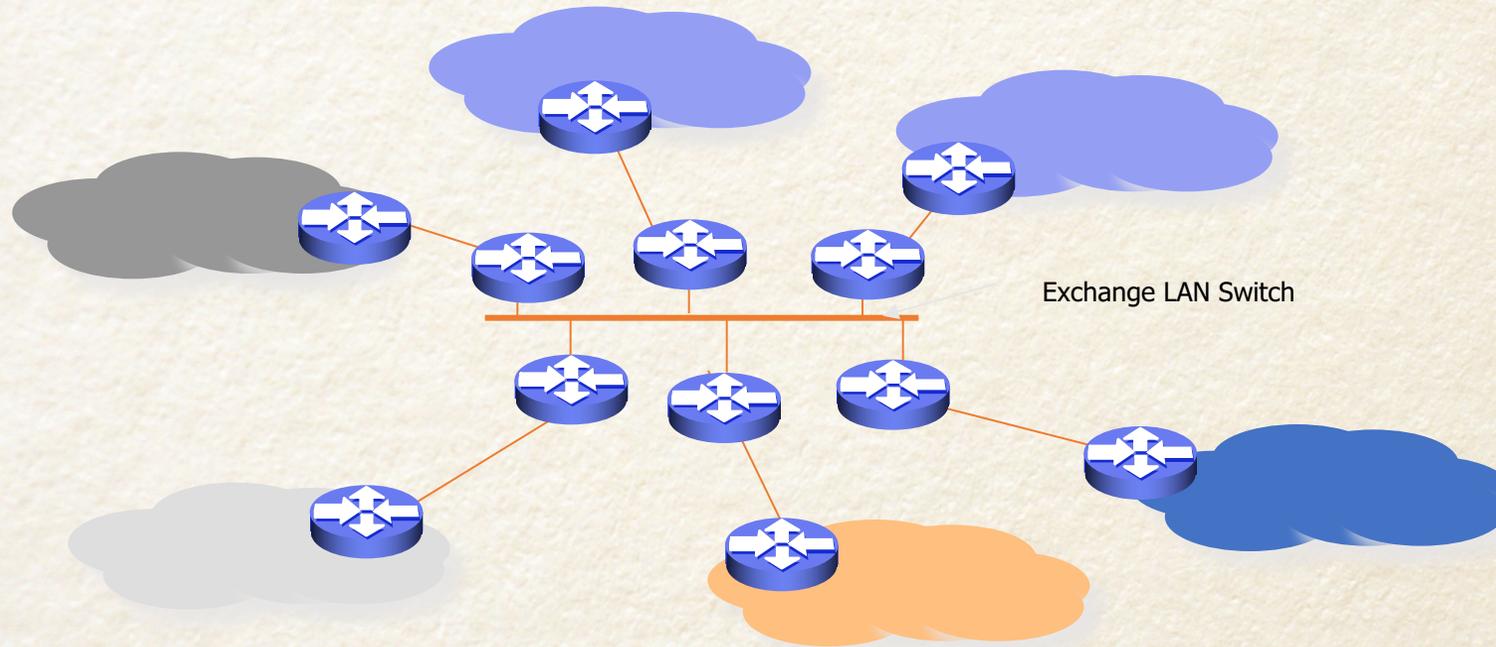


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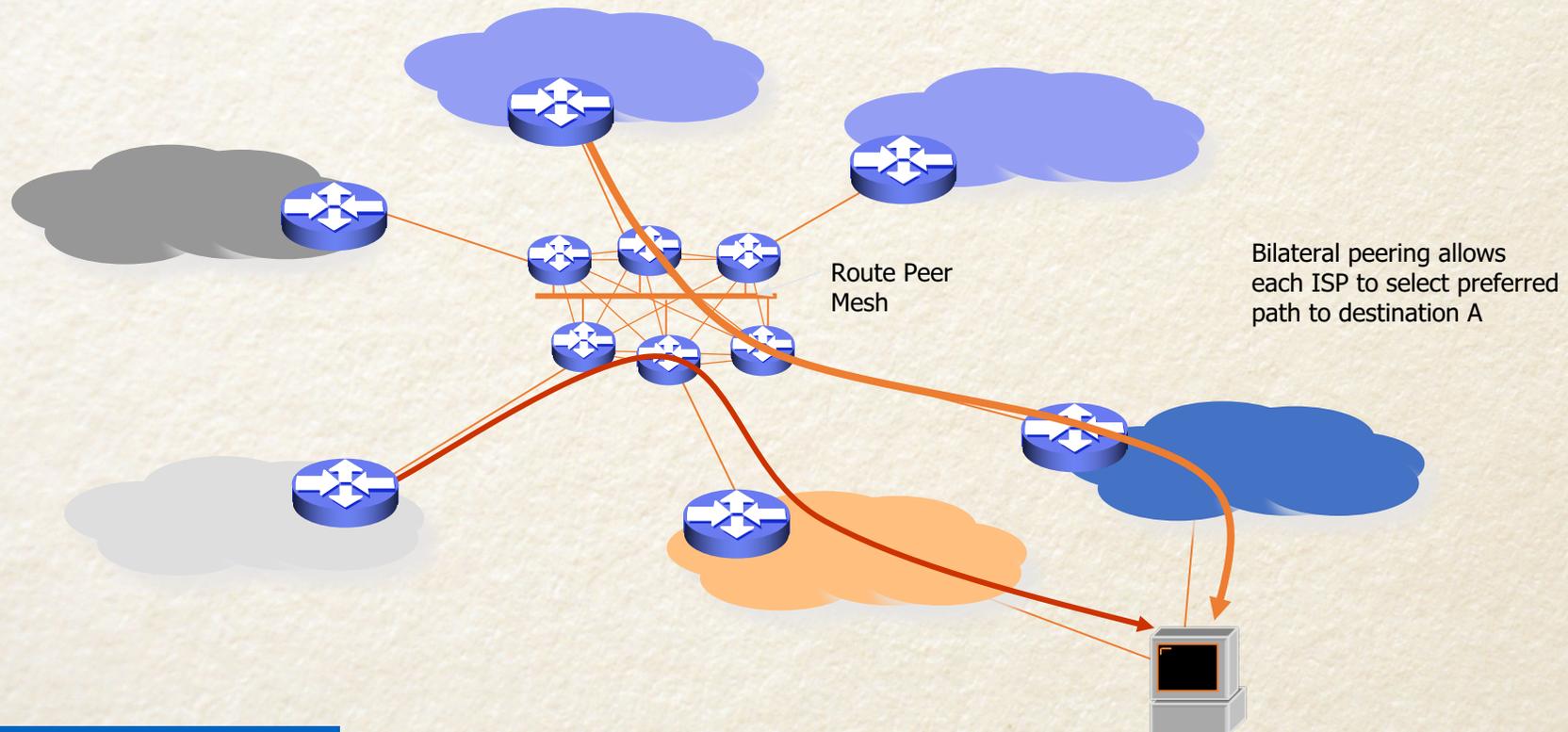
The Exchange Switch



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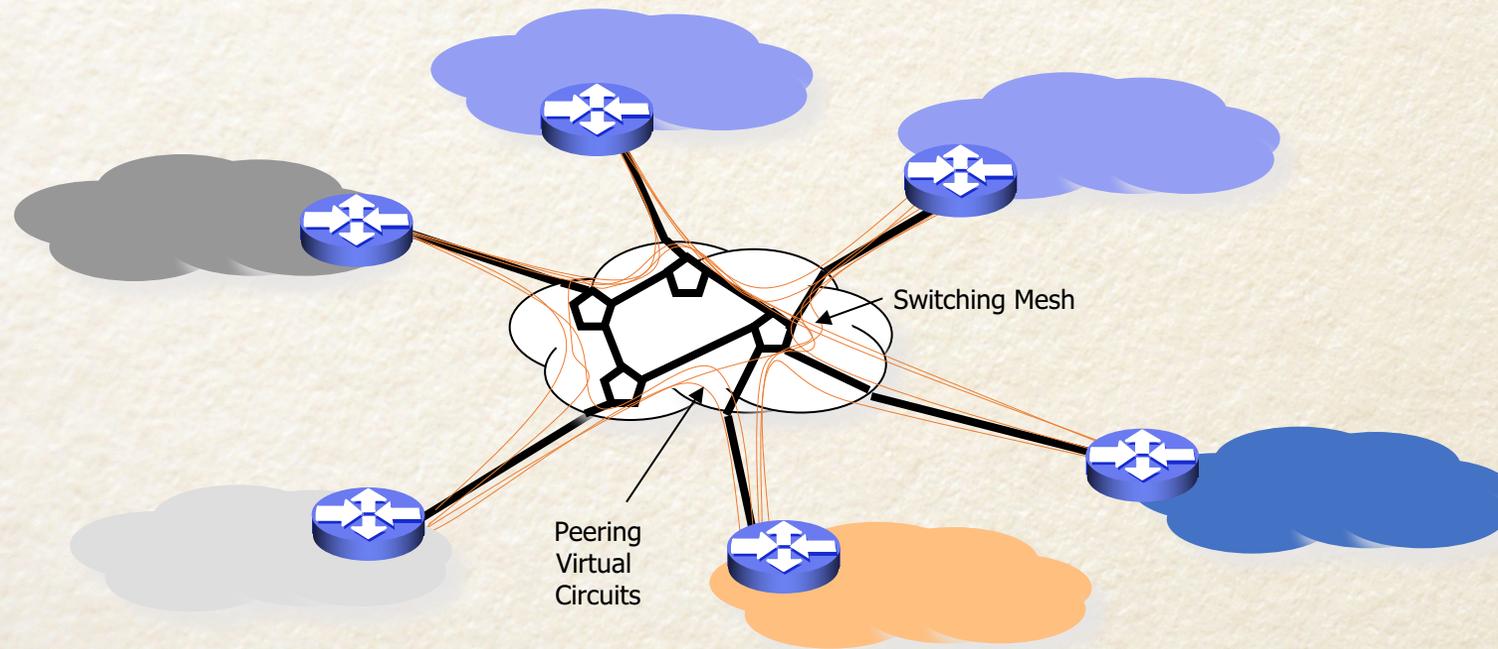
The Exchange L2 Switch

- An L2 switch does not implement routing policy
- Routing policy is then the outcome of bilateral agreements



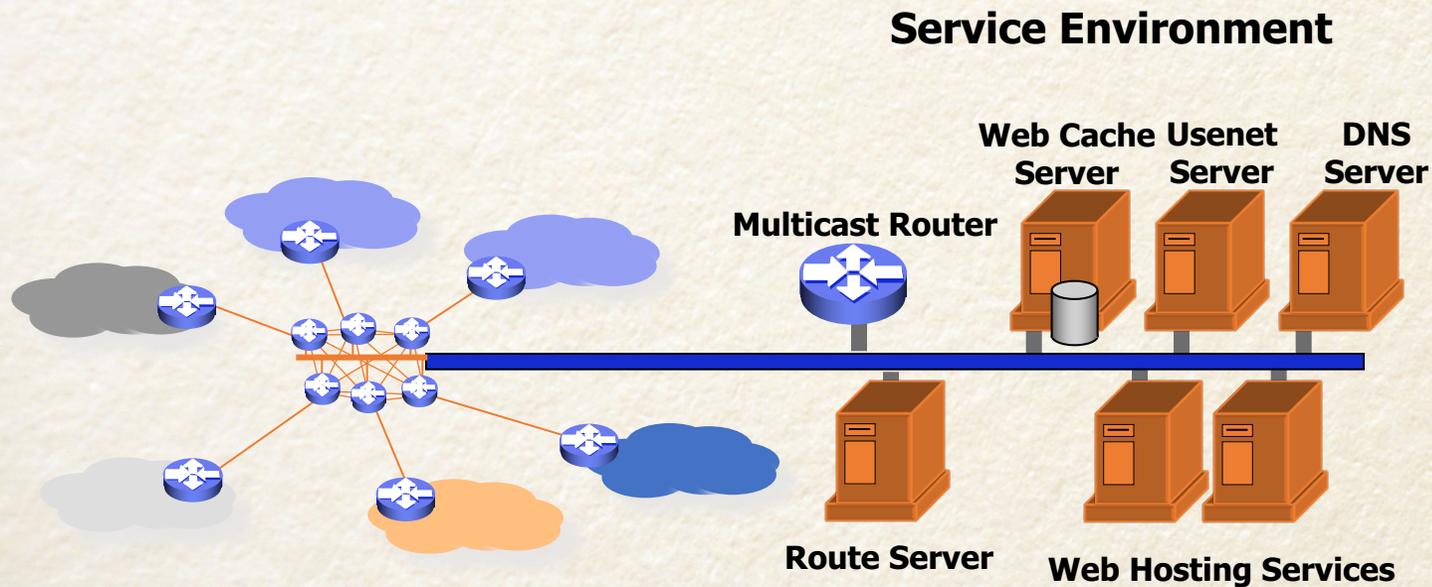
The Distributed Exchange

- Use of L2 virtual circuits to support bilateral peering eliminates the need for co-location



... Adding Value to the Exchange

- exchanges represent a very efficient centralized service launch point





Today's Environment

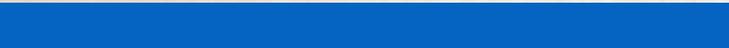
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- Natural tendency to aggregate within the ISP industry
 - Economies of scale of operation
 - Access to more advantageous SKA peering agreements
 - Risk factors
 - reduction of competitive pressure
 - collective action on industry peering arrangements
 - collective action on retail pricing

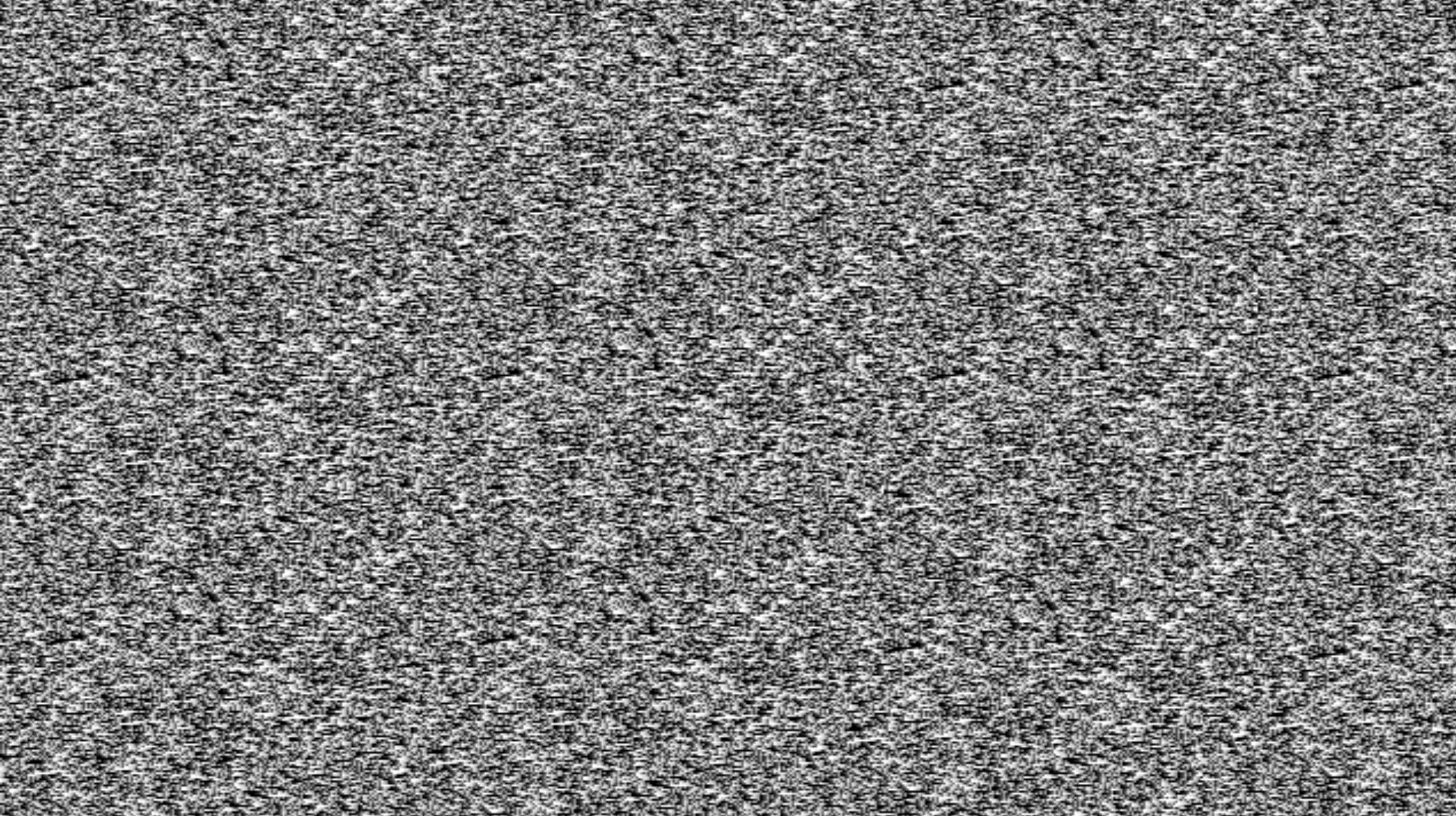


Futures



- Aggregation will continue and the market will coalesce into a small number of very large provider cartels
- The regulator has a huge problem in attempting to hold back the inevitable!





Let's shift forward from 1998 to 2017

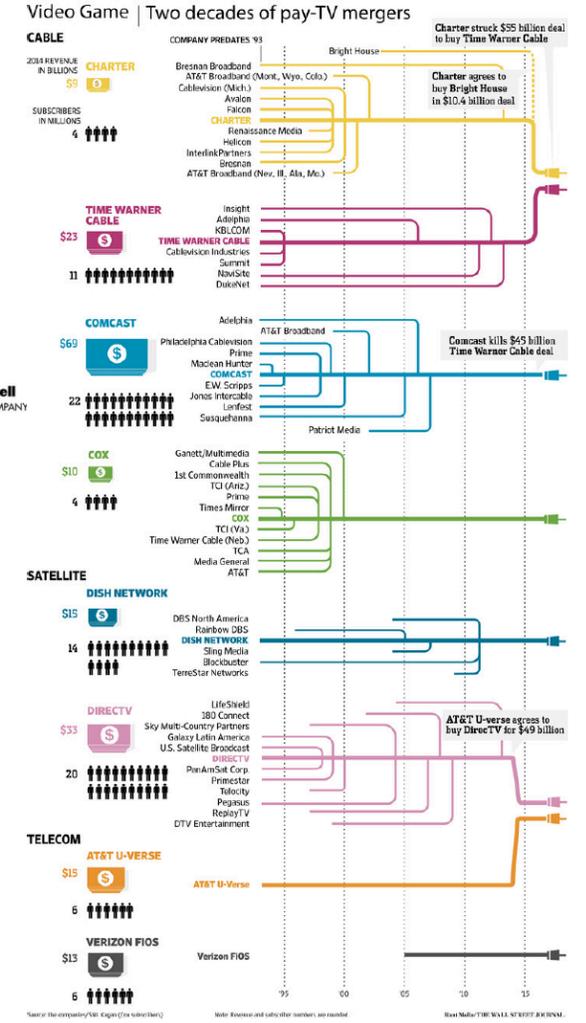
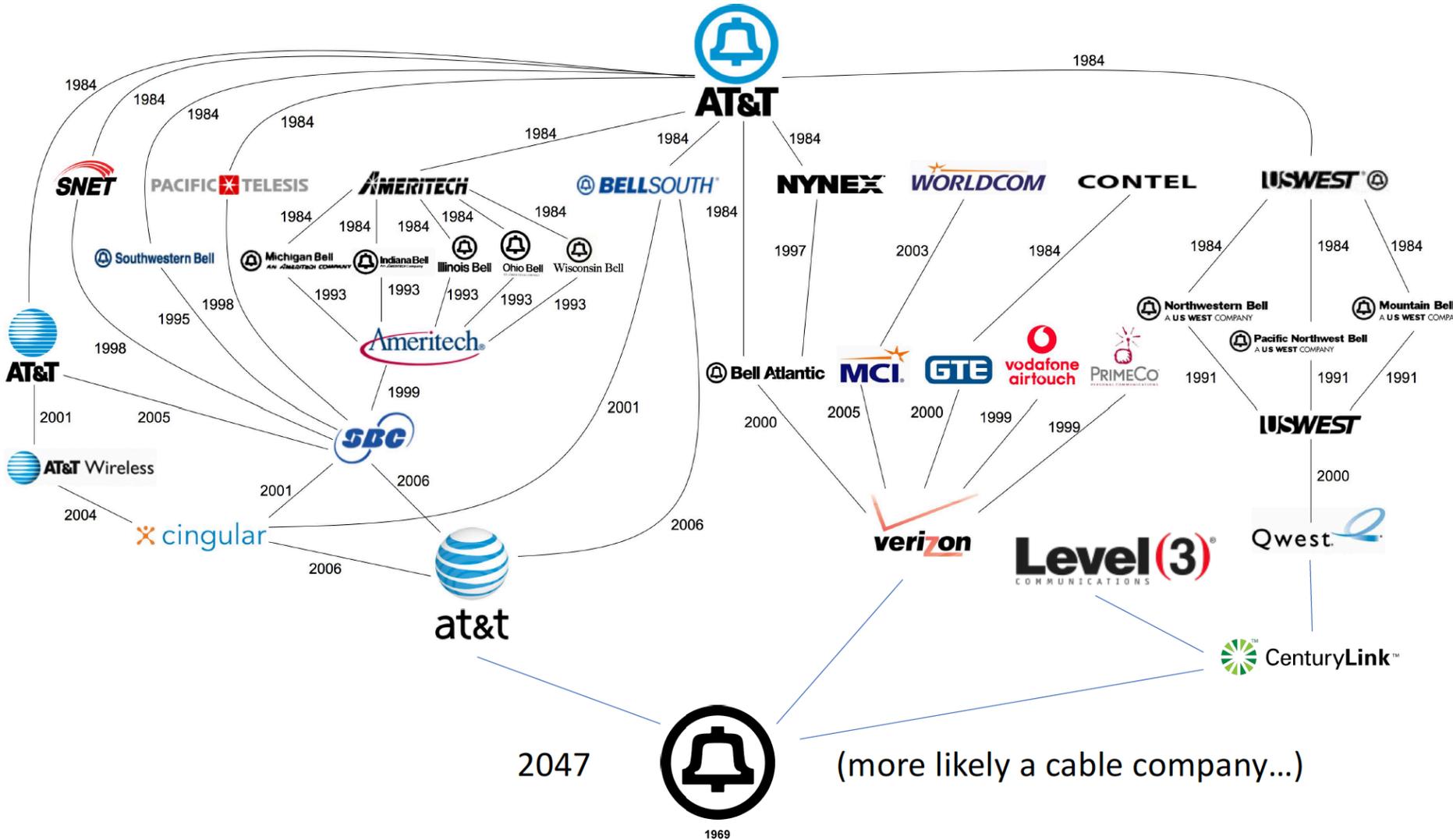
The last mile has changed:

- It's no longer dial-up and DSL and cable
- It's DSL, cable and fibre in the fixed line access
- But its mobile last mile systems that totally dominate the access landscape today
 - So much so that, economically speaking, fixed line access systems represent the digital slums of the Internet, with all the associated issues faced when allowing common access infrastructure to run down

Let's shift forward from 1998 to 2017

- Competitive ISPs still exist
 - but there is been a very large culling of the small to medium ISP sector, so the competitive pressure between ISPs is expressed in different ways

The telecom industry is consolidating (US)



Let's shift forward from 1998 to 2017

Carriage Prices have plunged

- Partly due to fibre optic evolution, partly due to market consolidation and economies of scale
- Unit prices for Internet access have fallen on a per Mbps scale
- Continual pressure both market-based and regulatory-based to further drop prices

Lessons Learned (1)

The rules of the Peering Game haven't changed

- Peering works when the parties bring approximately equal value to the relationship
 - Peering fails when one party relies on the other
 - Peering is stable when neither party needs it more than the other
 - Paradoxically, peering is at its most stable when neither party needs to peer with the other!
-
- At its heart, the peering game is still a game of bluff and leverage!

Lessons Learned (2)

Regulatory intervention often creates more harm than good

- This is a volume-based service enterprise where larger entities can access dramatically lower unit prices than smaller entities
- Regulatory intervention creates investment risk, where the normal market pressures are distorted by the regulatory tilt
- It creates disincentives for further capital investment in infrastructure by the major private actors in a market, leaving the space to under-capitalized and inefficient smaller operators
- This also creates perverse incentives to corrupt the regulatory structure

Lessons Learned (3)

Increased Competition does not necessarily result in increased market efficiency

- In a service activity that exhibits economies of scale, smaller providers will be unable to compete on price
- Artificially sustaining the continued existence of inefficient providers through regulatory protections leads to an inefficient market, with higher prices passed onto consumers

Today's Internet

The ISP transit market is failing

Rapid technology changes in fibre and silicon capability depress costs for new entrants

Incumbents are forced to operate on low or negative margins to stay competitive on older technology platforms

Incumbents form defensive cartels to collectively raise barriers to entry

Regulatory stance typically favors incumbents over challengers

Today's Internet

- The rise and rise of Content Distribution Networks as specialized actors
 - If you can bring valued content close to consumers then the role of Internet carriage is devalued – carriage is marginalised
 - Which means that the levels of diversity and competition in carriage is less important to the overall Internet service market and its efficiency

- To borrow another slide from 1998:

The Bottom Line

- Continued operation of a strongly competitive diverse national ISP carriage market is probably the wrong answer.
- The money is NOT in IP. Regulatory intervention at the IP level is stunningly dangerous to any national economy.
- Intense IP provider aggregation is coming, but it may not matter as much any more. The largest revenue margins are in content service, not packet plumbing.

Today

- Inter-ISP traffic exchange is a marginal activity – the obvious money lies in content distribution – which means ISP peering is no longer as important to the ISPs
- Exchange Operators are strongly motivated to attract CDNs to their facilities in order to attract access ISPs to colocate in their premises
- Access ISPs are strongly motivated to connect to an exchange point in order to secure access to CDNs, not to other ISPs
- Today's IXPs are little more than aggregate CDN access points

Tomorrow

- Market actors tend to avoid intermediaries if they can improve their position through bypassing the intermediary
- So CDN operators are pushing further and closer to the edge with caches to sit inside the ISPs' access network
- Content delivery is moving inexorably closer to the consumer
- The longer term role of ISPs and IXPs in this environment is very unclear at present

Audiens Cave

- Much of this material is based on my direct experience in the context of the Australian environment and its evolution of the past 25 years, and my observations of similar trends in North America and Western Europe
- But these paths differ both by region and in time:
 - Infrastructure base
 - Public and Private Investment profile
 - Geography
 - Regulation
 - Consumer preferences
- So I'm not sure how much of this is directly relevant to you – that's something you need to work out for yourself!

Interested? Further Reading:

“The internet has been quietly rewired”

<https://qz.com/742474/how-streaming-video-changed-the-shape-of-the-internet/>

“Interdomain Traffic”, Craig Labowitz

<https://jon.oberheide.org/files/sigcomm10-interdomain.pdf>

“A Better Way to Organize the Internet: Content-Centric Networking”

Glenn Edens, Glenn Scott

<https://spectrum.ieee.org/telecom/internet/a-better-way-to-organize-the-internet-contentcentric-networking>