The Changing Structure of the Internet

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The Changing Structure of the Internet

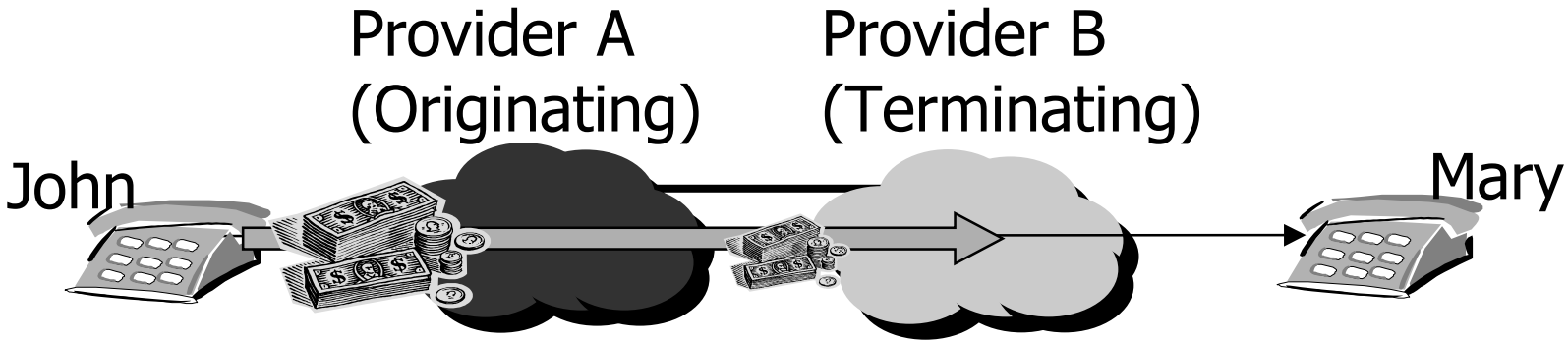
- **The Packet View**
- Cable Trends
- Network Metrics
- Trends in Internet Structure

The Packet View

- A comparison of inter-provider settlement arrangements, looking at the PSTN use of call accounting as a settlement mechanism, and comparing this to the Internet environment
- The comparison can be characterized as a shift from a transaction unit of circuits to packets

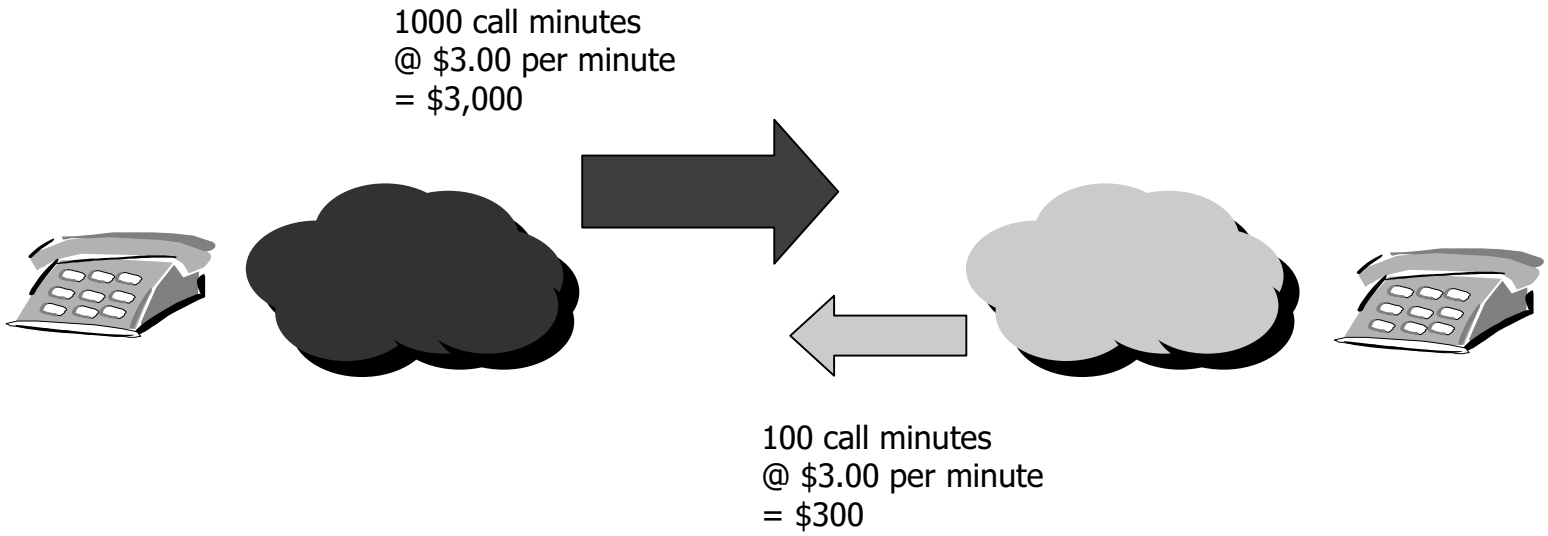
Call Model Settlements

- Every inter-provider circuit is used to support bilateral dynamic virtual circuits (calls)
- Each circuit is bilaterally funded
- Every call has an originator and a terminator
  - The originator pays the originating provider
  - The originating provider pays the terminating provider



Call Model Settlements

- Settlement balance based on call origination to termination imbalance using a common **call accounting rate**



Packets are Different

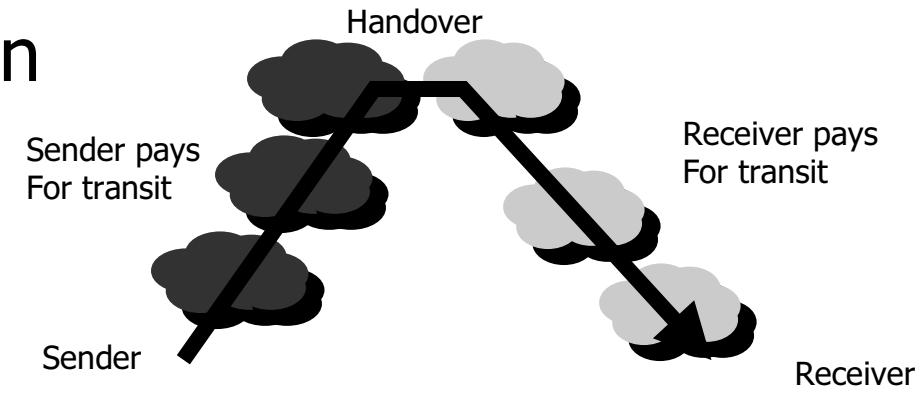
- Packet networks do not have such well defined transactions as paid calls
- It is appropriate to look at the components of inter-provider interconnection:
  - the interconnection ‘circuit’
  - the interconnection packet flow

The Packet-Transit Model

- Bilateral inter-provider carriage circuit is used to support bi-directional packet flow
- Each carriage circuit is fully funded by one provider or bilaterally funded
  - The circuit-based packet financial relationship is based on a larger set of structural criteria
- Packets passing across the circuit are either funded by the packet originator or packet terminator, or neither.

The Packet-Transit Model

- Every packet passing through a network has only two potential sources of funding: the sender and the recipient
- Every packet in the Internet today is bilaterally partial path funded:
  - Sender-pays, then
  - Hand-over, then
  - Receiver pays

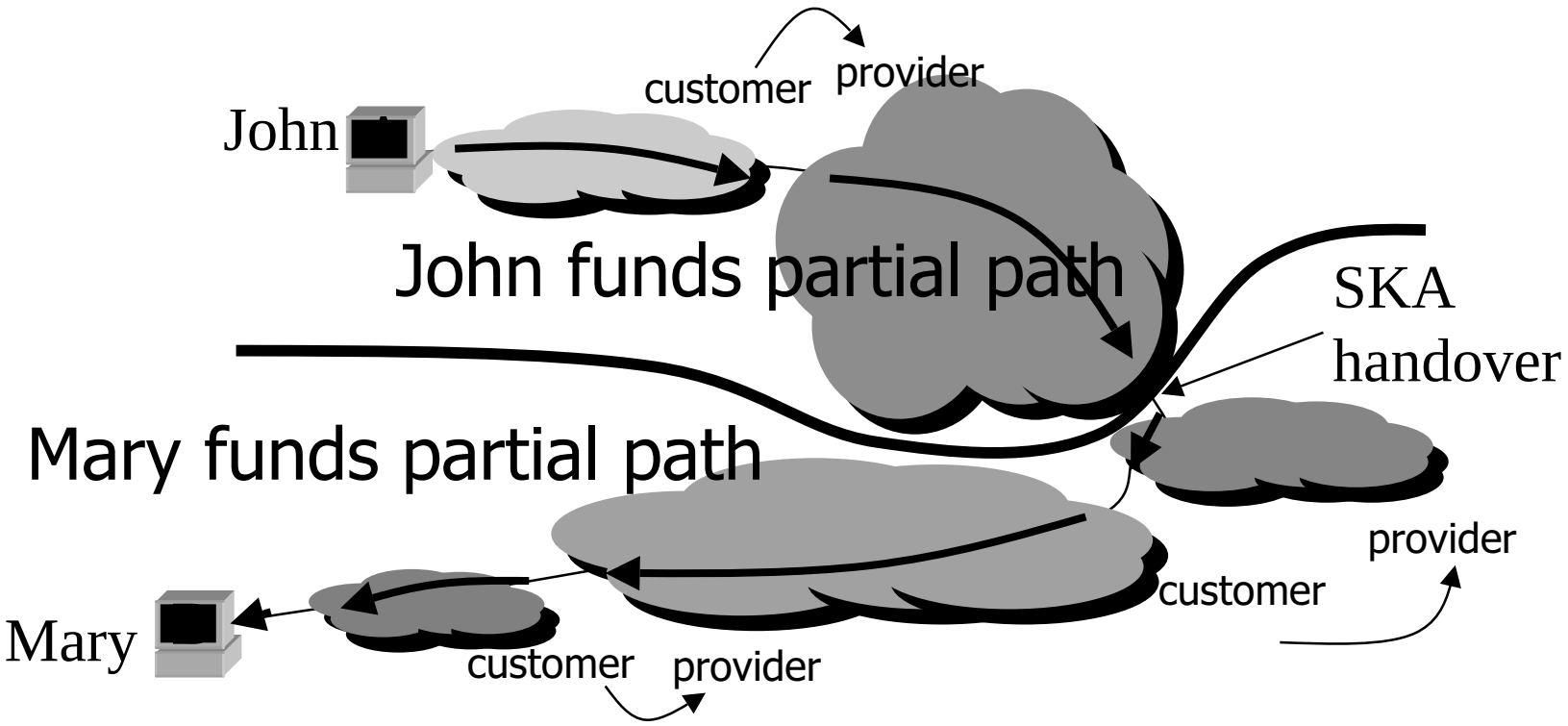


The Packet Transit Model

- The inter-provider relationships are not packet-dependant – they are statically negotiated and hold for **all** traffic passing across an inter-provider interface – in **both** directions
  - Sender-pays all infers
    - **Customer -> Provider relationship**
  - Handover infers
    - **Provider <-> Provider SKA peering**
  - Receiver-pays all infers
    - **Provider -> Customer relationship**

The Packet Transit Model

- Transit packet funding

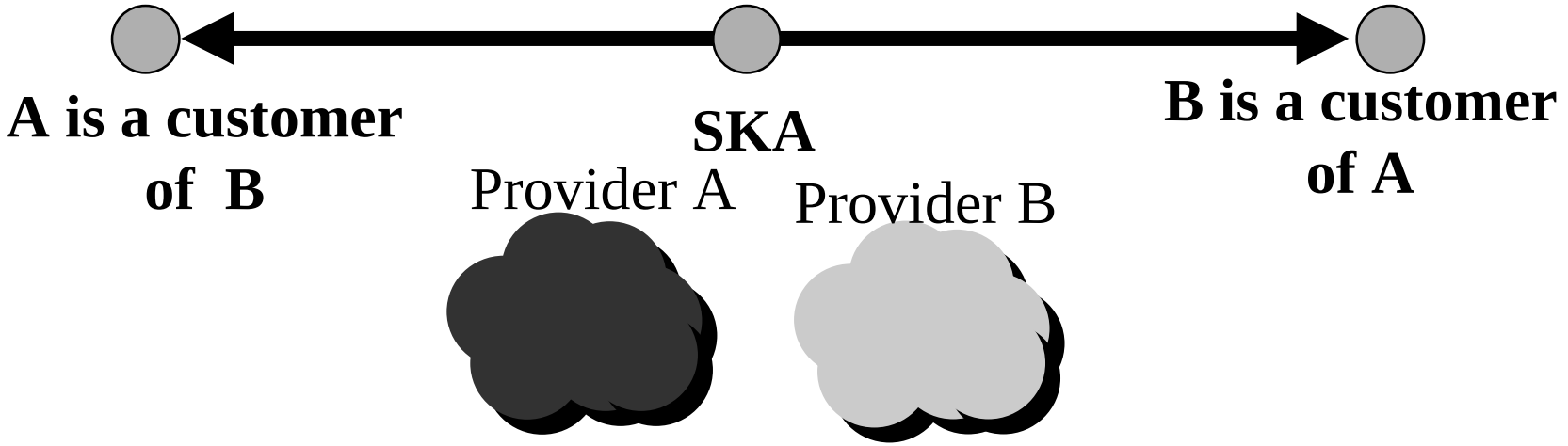


Packet-Based Interconnection

- Three major issues are relevant in an interconnection negotiation for packet handover:
  - The relative relationship between the two providers
    - Customer / Provider or Peer / Peer
  - The relative network location of the handover
  - Interconnection financial arrangement
- The resolution of the third issue is generally a function of the outcome of the first two issues

Internet Interconnection Outcomes

- The most stable outcome is a static bilateral agreement creating a provider / customer relationship, or SKA peer relationship between the two providers
  - i.e. there are only three stable outcomes



Interconnection Dynamics

- Every ISP wants to position itself within the inter-provider space so as to maximize revenue and minimize expenditure:
  - Every Customer wants to be a SKA Peer with its current provider
  - Every Peer wants to be a Provider to its current Peer
  - Every Provider wants to convert its current peers into Customers
- There are no objective metrics that determine the outcome any particular bilateral relationship. Each outcome is individually negotiated

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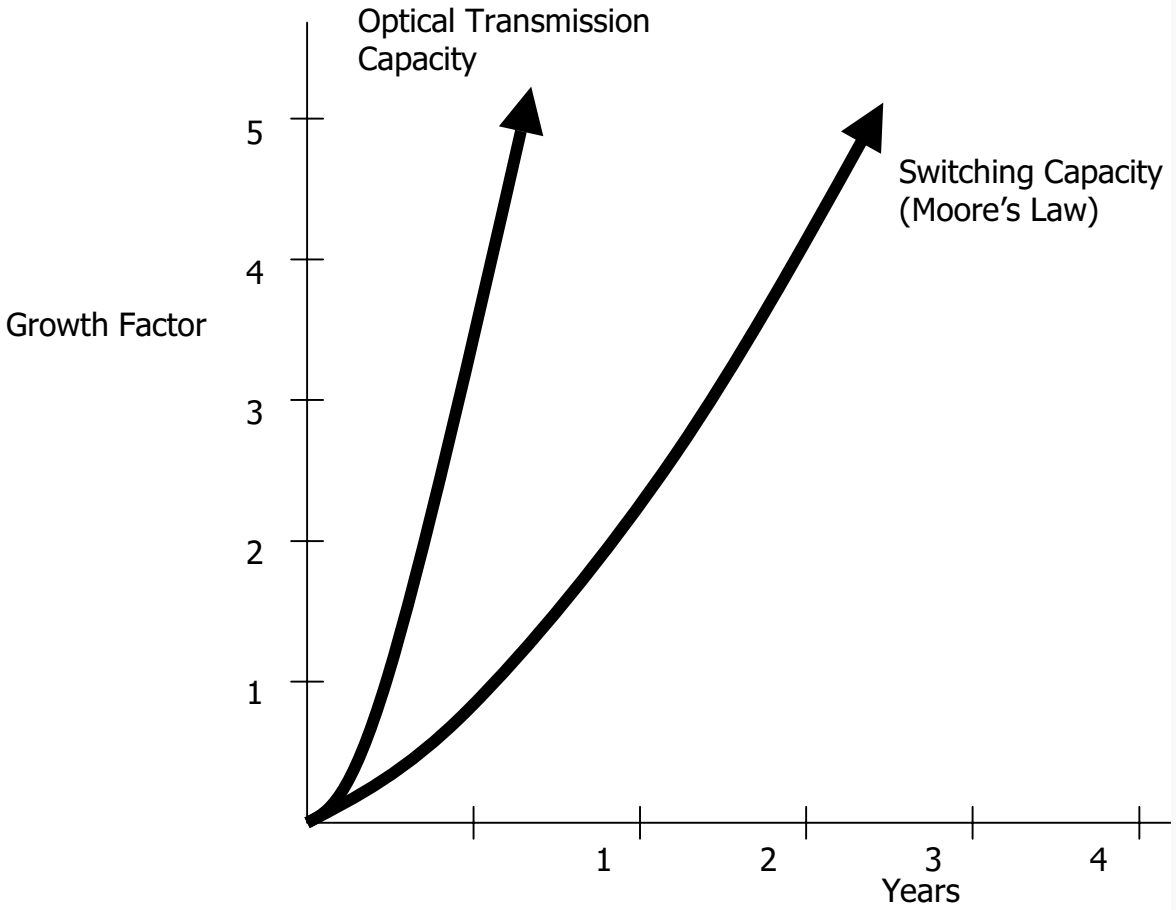
Technology Trends for Cable Systems



Part of the changing nature of the Internet is an outcome of the rapidly decreasing cost of packet carriage and packet switching.

As the unit cost of packet carriage declines the value of a Provider's transit service also declines.

This decline alters the balance between a transit provider and its current customers.

This section examines the changing cost structure of undersea cable systems as an example of a broader industry trend

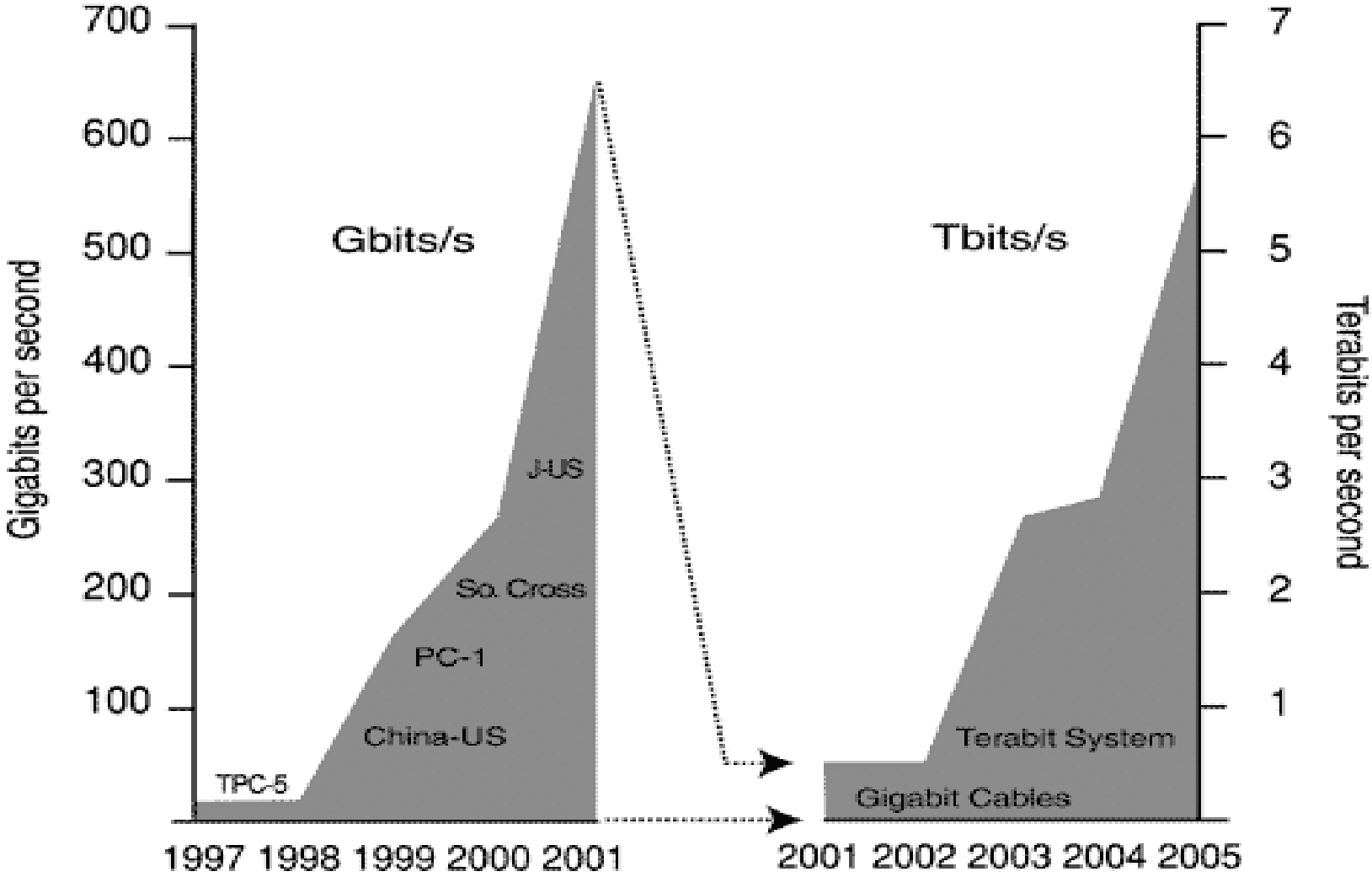
Technology Trends

- Undersea Cable Systems
  - Technology refinements, plus open competitive markets have created dramatic construction activity levels in recent years
    - This has changed the market from scarcity demand pull to considerable overhang in supply
    - This over-supply is creating price changes in the market…..

Asia-Pacific CABLES SUMMARY

Cable System	RFS	Fiber Pair	Initial Wavelengths per Fiber Pair	Wavelengths per Fiber Pair	Gbps per Wavelength	Upgraded Gbps per Wavelength	Total Capacity	Fully Upgraded Total Capacity
APCN	February-97	1	2	4	5	5	10	20
FLAG Europe-Asia	November-97	2	2		2.5	2.5	10	10
Guam-Philippines	March-99	2	1	4	2.5	2.5	5	20
SEA-ME-WE-3	September-99	2	4	8	2.5	2.5	20	40
Pacific Crossing - 1	December-99	4	2	16	2.5	10	20	640
China-US CN	January-00	4	8		2.5	2.5	80	80
Japan-US CN	February-00	4	8	64	2.5	2.5	80	640
Southern Cross	October-00	3	8	16	2.5	2.5	60	160
EAC	December-00	4	2	64	10	10	80	2560
North Asian Cable	June-01	4	8	64	10	10	320	2560
Australia - Japan	July-01	2	4	32	10	10	80	640
SAT-3/WASC/SAFE	October-01	2	8	16	2.5	2.5	40	80
							805	7450

Asia-Pacific CABLES SUMMARY



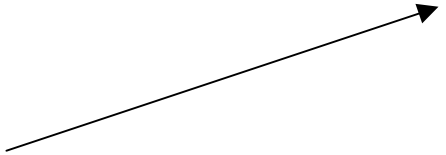
Cable Supply Models

- The unit of capacity that is purchased from the cable system has increased 1,00-fold over 4 years
  - Up to 1998: Retail T1/E1, T3
  - 1999 – Wholesale T3/STM-1 available everywhere
    - IRU or Capital Lease + O&M
  - 2000: Wholesale STM-4c available
  - 2001: Wavelength (2.5G/10G) offering

Cable Price Movements

Capacity between Tokyo and the West Coast

Example Capacity Prices				
Year	Data Rate	onthly Lease	IRU / Capital Lease	**Unit Price**
1997	E1	$ 54,000	n.a.	$ 27,000
1998	DS3	$ 540,000	n.a.	$ 12,000
1999	DS3	$ 320,000	n.a.	$ 7,111
2000	OC3	$ 200,000	$ 8,000,000	$ 1,290



$ / Mbps / Month

The Tug of War of the Cost of Cable

For suppliers: The first system to connect bandwidth-starved points may capture sales at a much higher price than when the rest of the bandwidth barons (private or consortium) join in.

For Buyers: The opposite strategy holds true: If you don't like bandwidth prices now, wait a bit. They will likely change soon enough.

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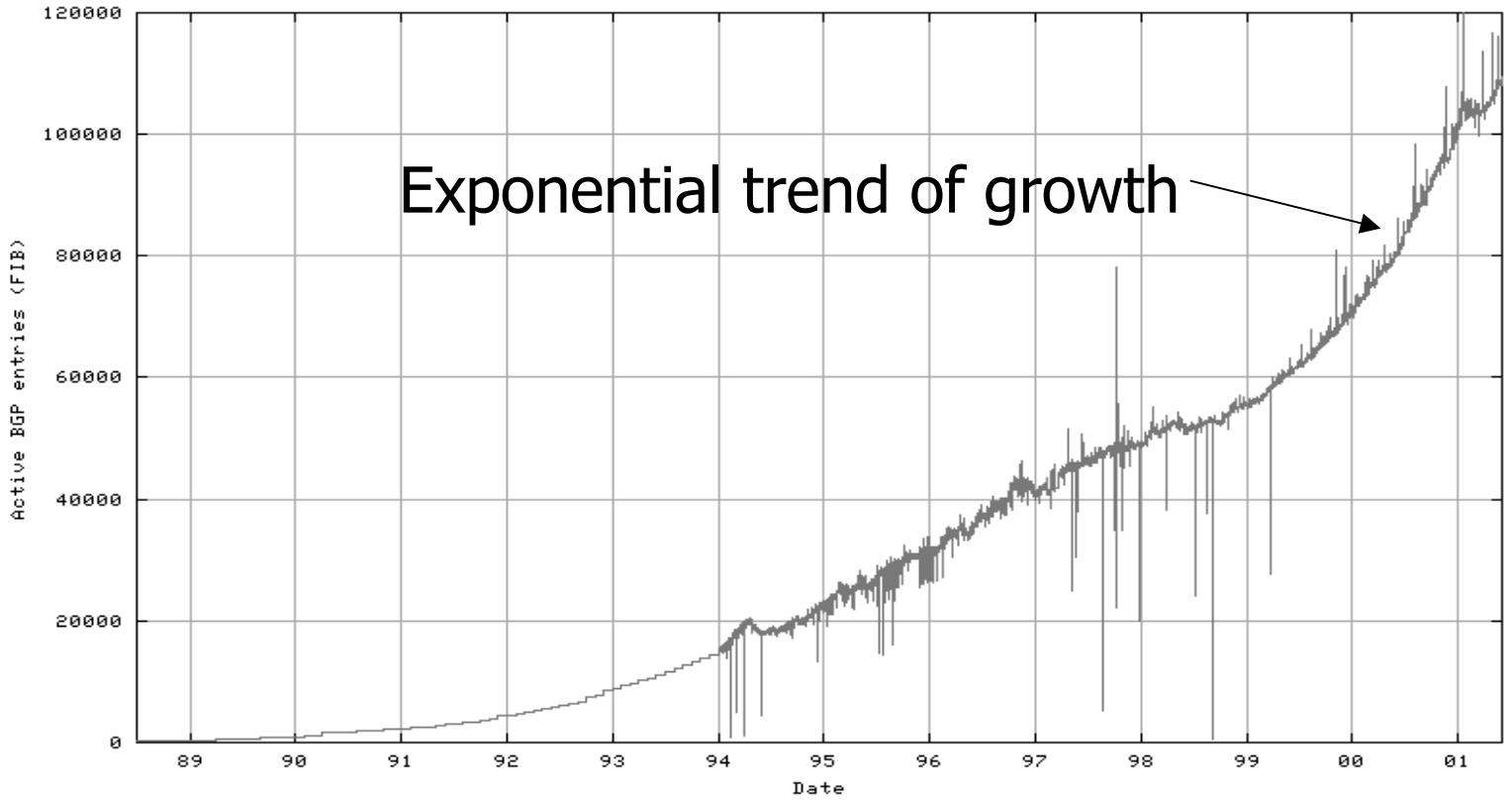
Internet Metrics

- Methodology:
  - Routing information is an abstract picture of the inter-provider topology of the network
  - Take regular ‘snapshots’ of the Internet’s global routing table
  - Changes in the topology and structure of the inter-provider Internet are reflected by trends in aspects of the routing system

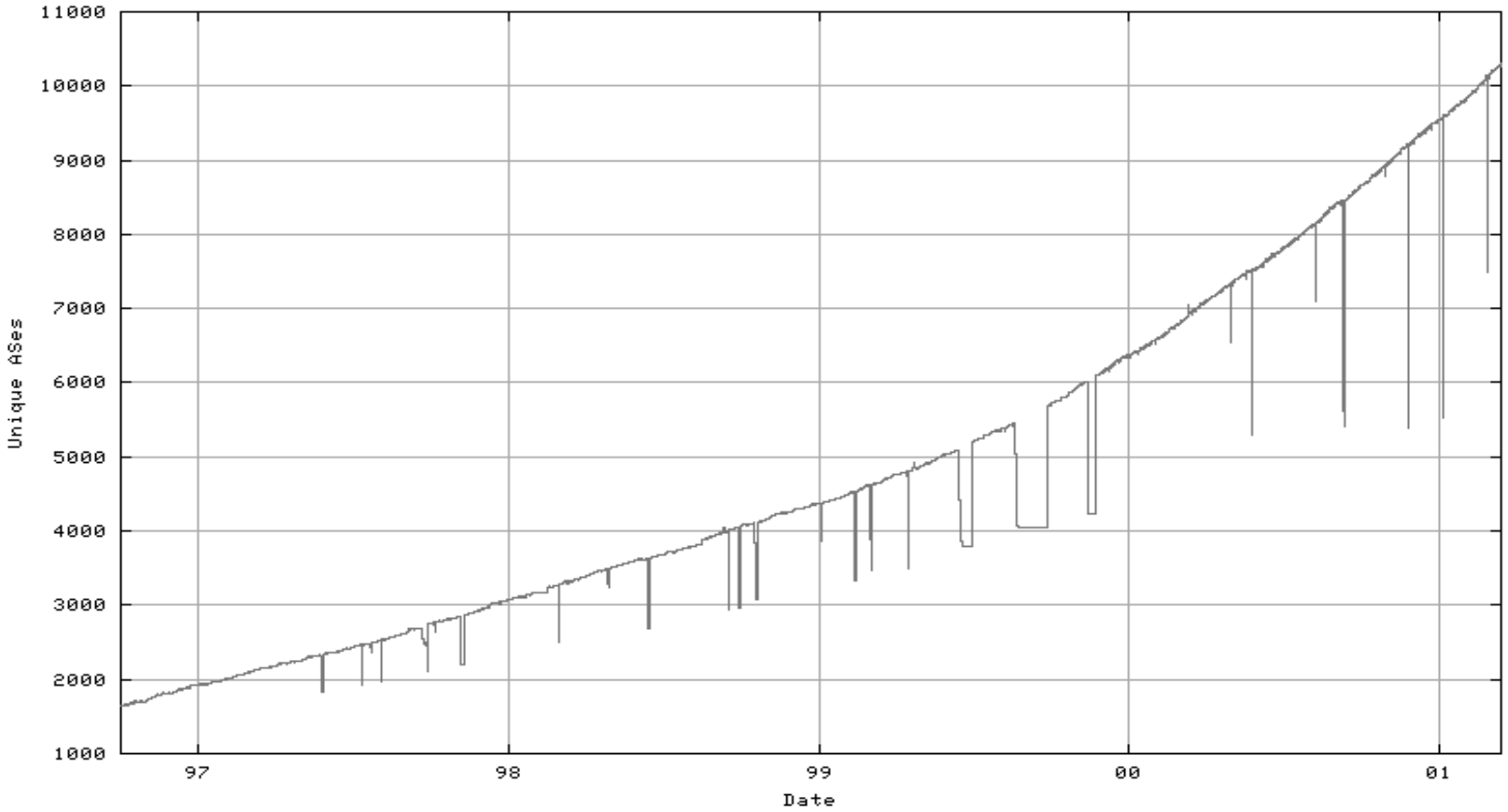
Internet Metrics

- Number of routing entries is growing exponentially



Internet Metrics

- Number of distinct IP Network Providers is growing exponentially

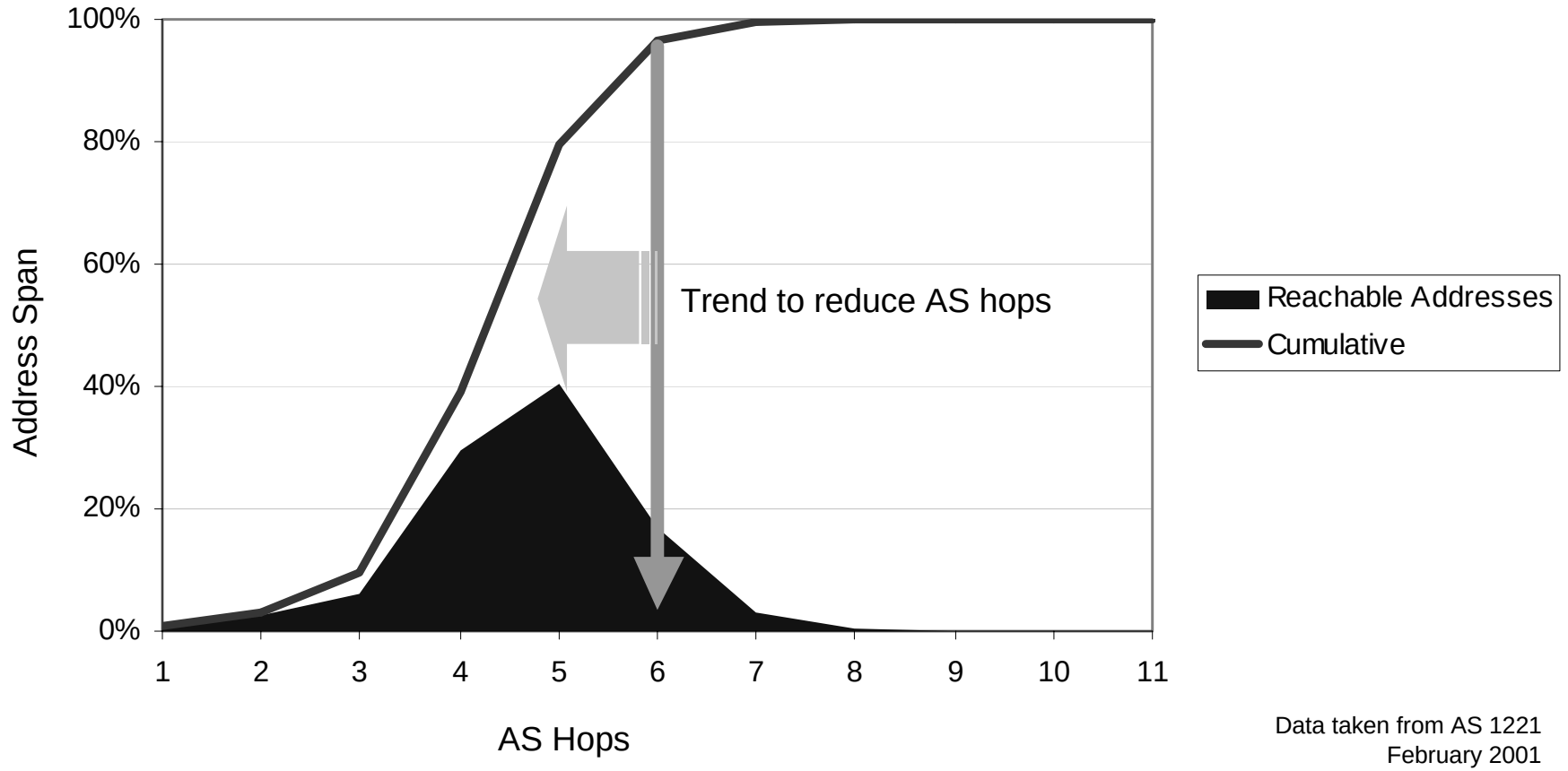


Internet Metrics

- There are an increasing number of distinct ISP providers within the global routing tables
- Each ISP appears to have a distinct set of interconnection policies
- Carriage costs are declining faster than provider's transit costs
  - Each ISP can improve their financial position by increasing the number of peer connections and reducing their transit requirements

Internet Metrics

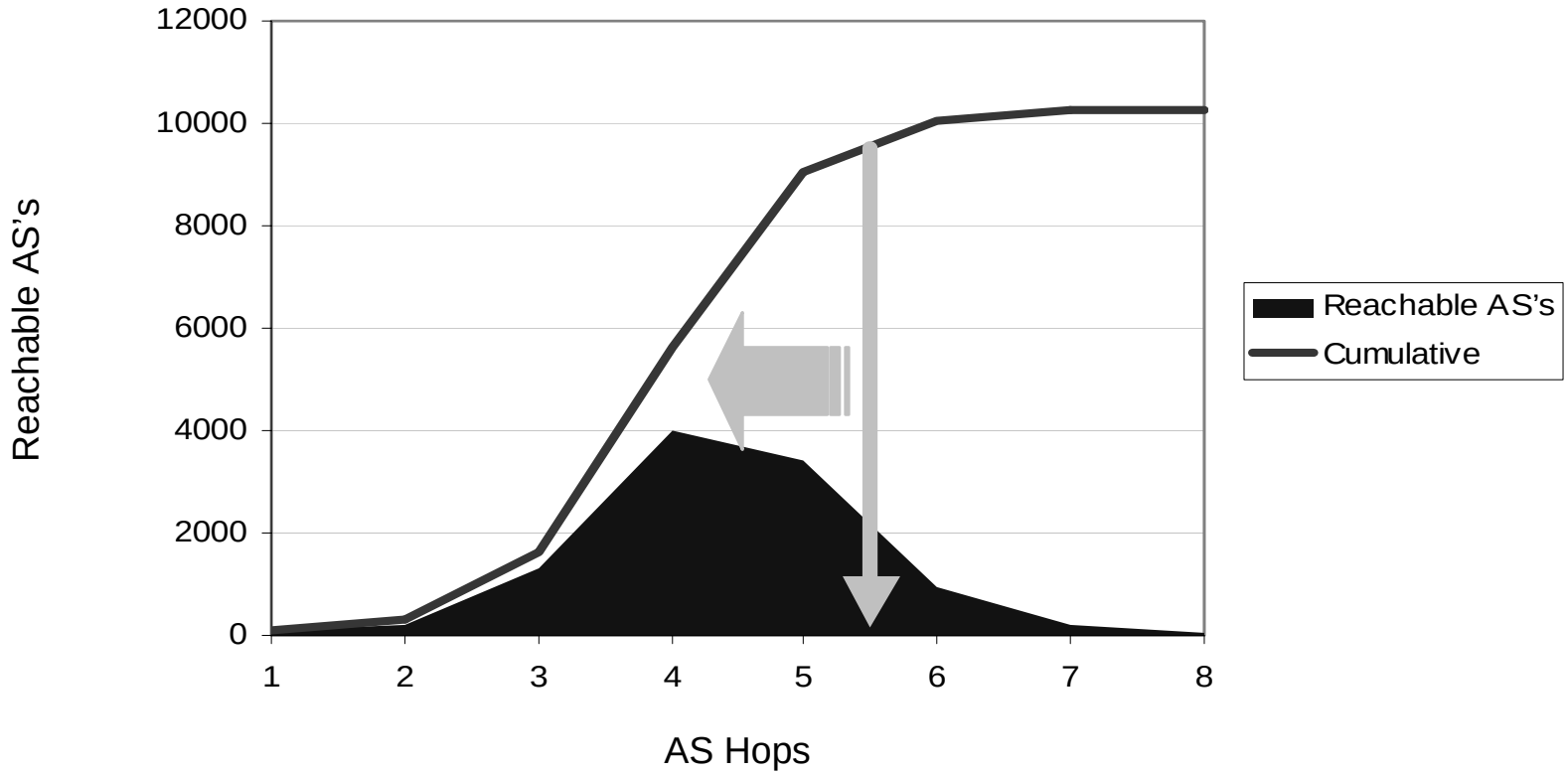
- Reachability by AS hops is getting smaller



Data taken from AS 1221
February 2001

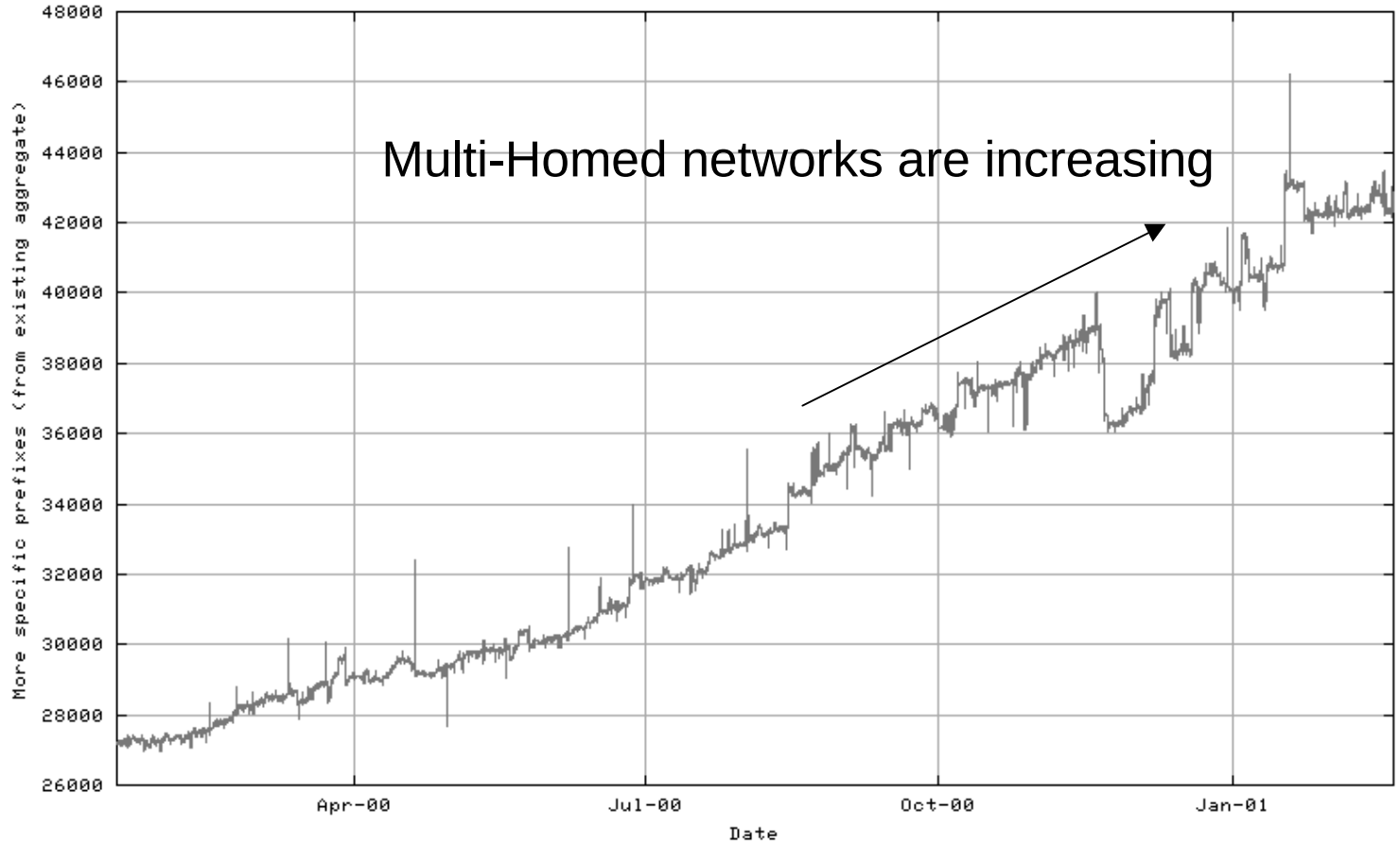
Internet Metrics

- AS Reachability by AS hops is also getting smaller



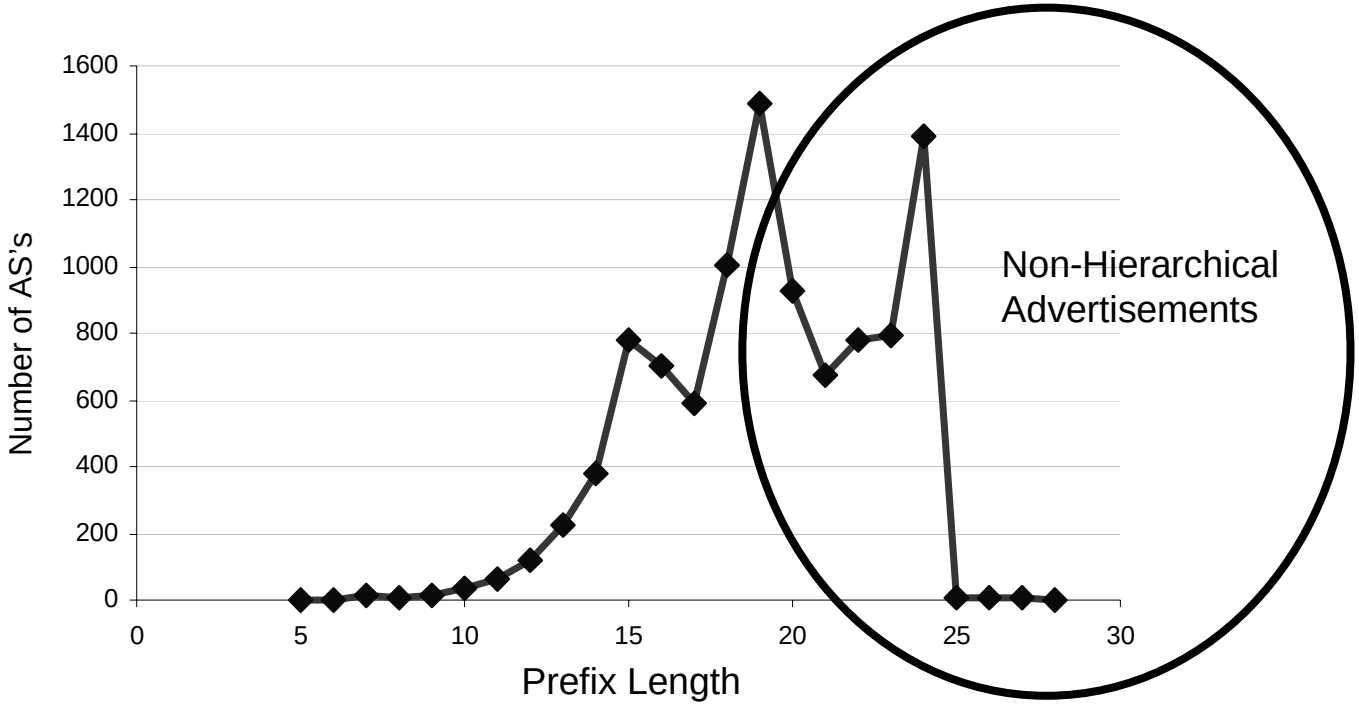
Internet Metrics

- More Specific advertisements are growing exponentially



Internet Metrics

- Distribution of originating address sizes per AS
- Address advertisements are getting smaller



Internet Metrics

- The time series data of ‘density of interconnection’ shows an increasing number of neighbors for each distinct network
- The network structure is becoming more heavily ‘meshed’

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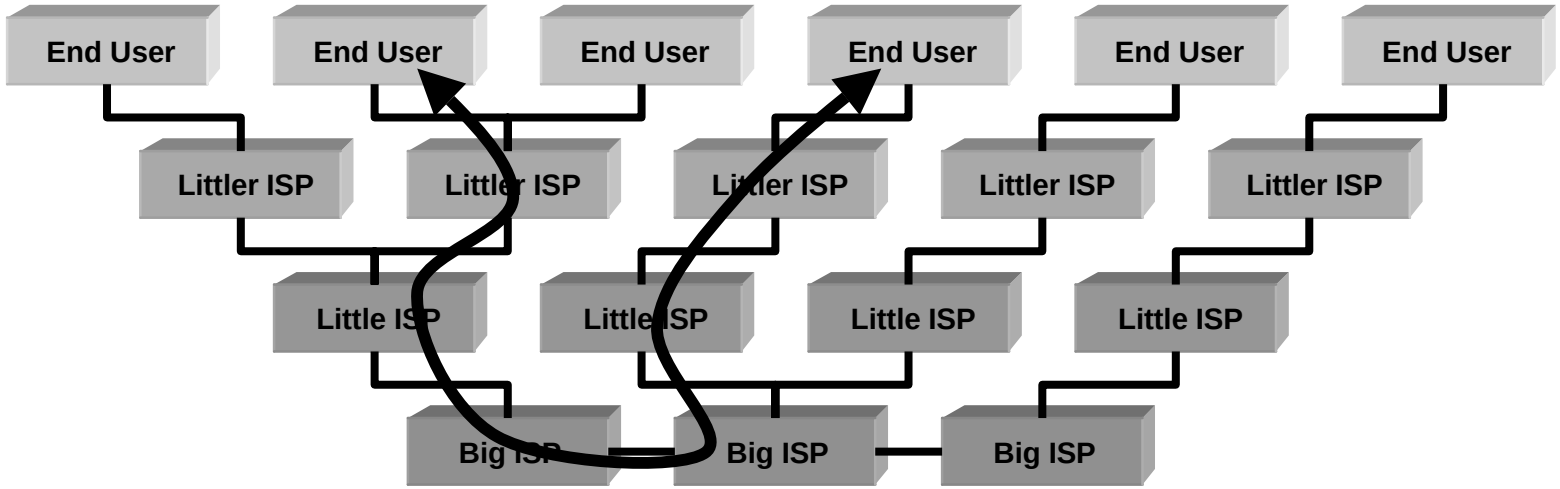
The Hierarchical View

- The ‘traditional’ view of the Internet saw the Internet described as a hierarchy of providers

- Segmentation of Internet Providers into a number of ‘tiers’
- Each ISP purchases service from a single provider at the next higher tier
- Each ISP sells service to multiple customers at the next lower tier

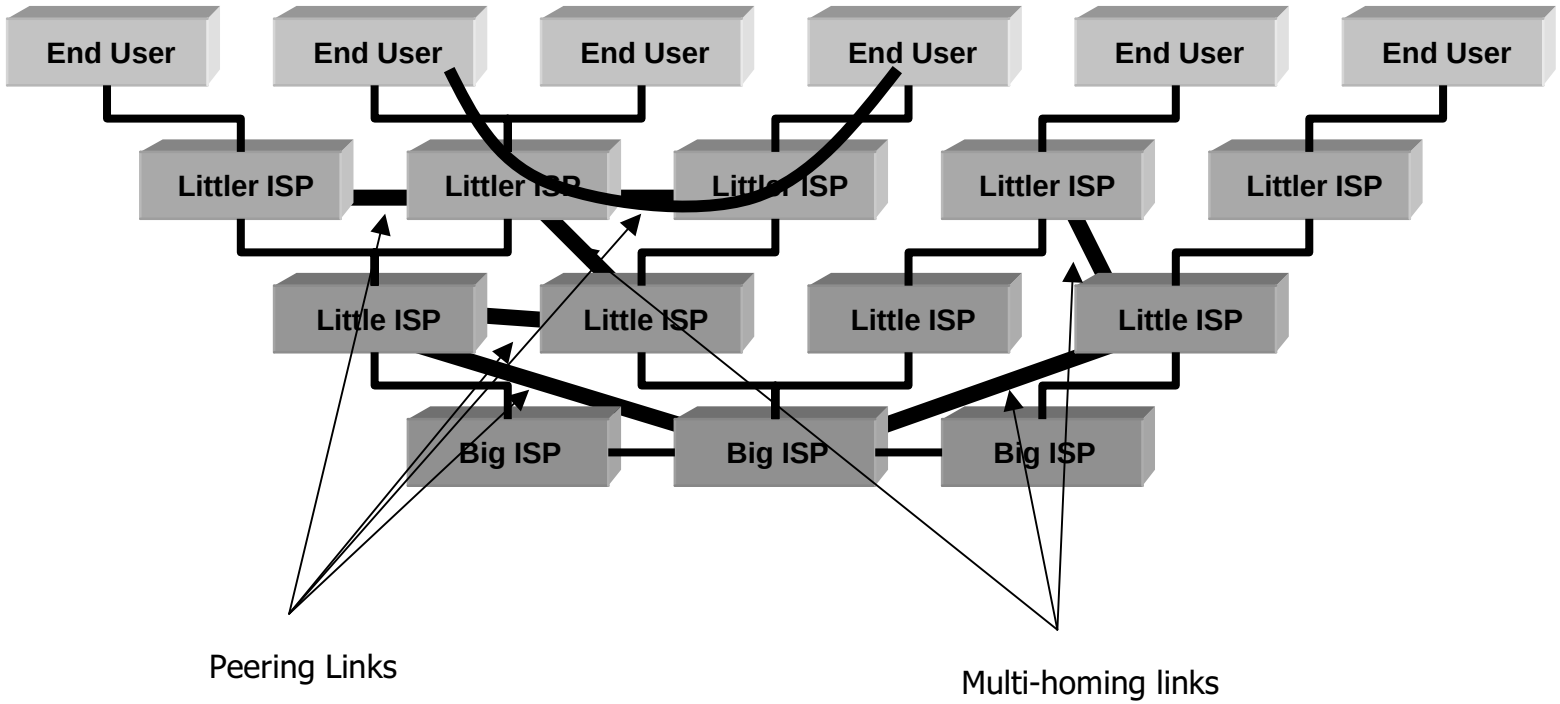
The Hierarchical View



Hierarchical Evolution – Tiers and Multi-homing

- This hierarchy has been evolving due to competitive pressures in the provider market and opportunities for lateral peering
- May use 2 or more upstream providers (multi-homing)
- May use SKA peering within a tier

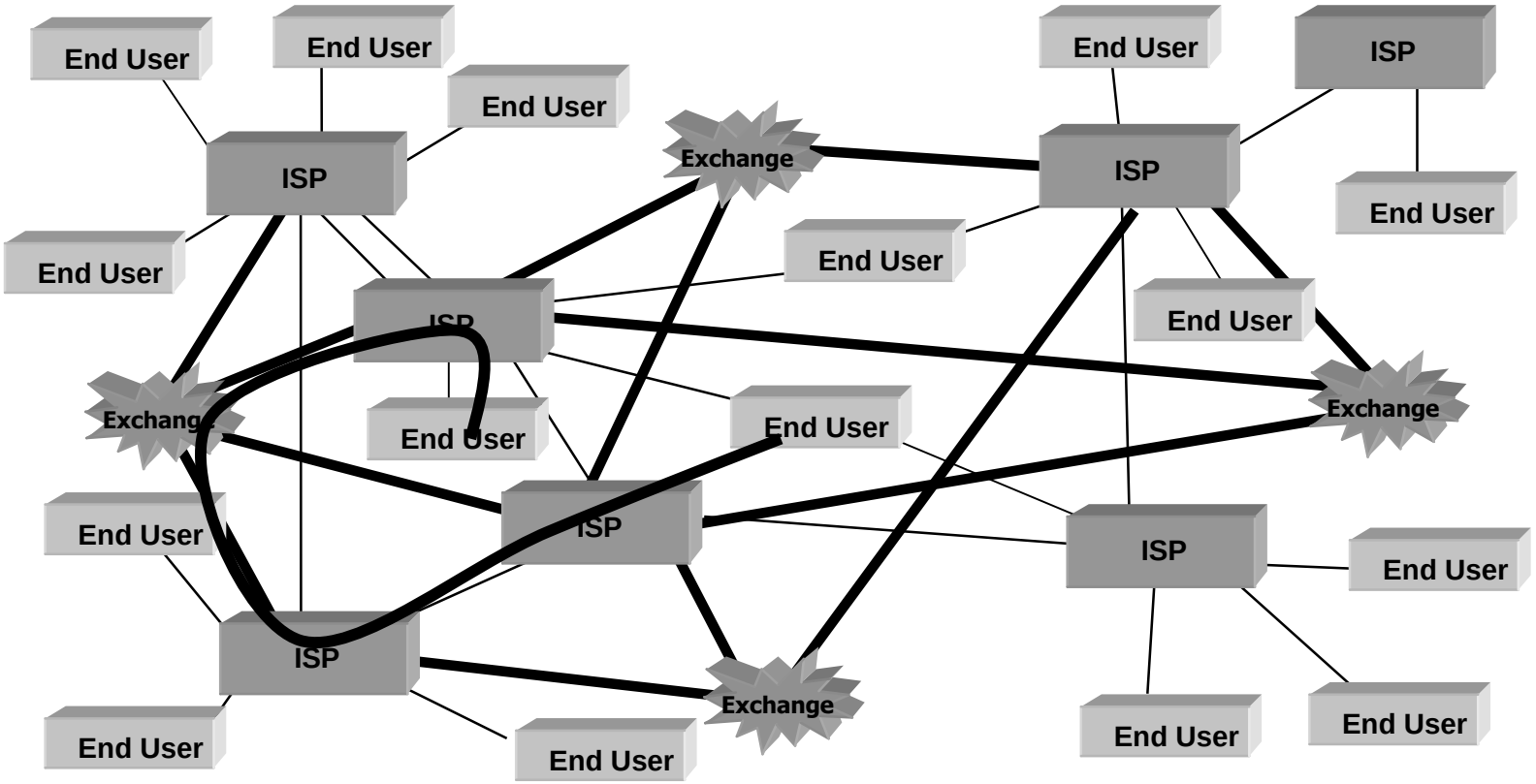
Hierarchical Evolution – Tiers and Multi-Homing



Non-Hierarchical Evolution

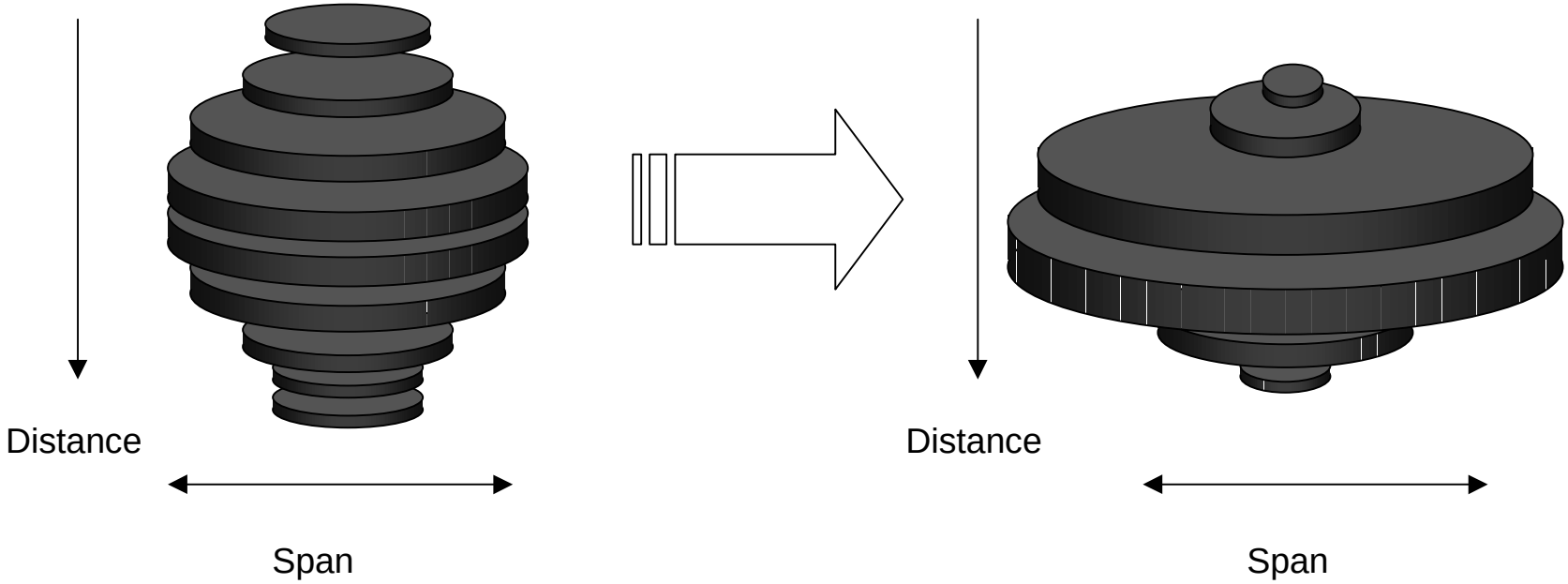
- May peer across tier levels
- May use ‘paid peering’ as a form of limited provider-based transit services
  - (the use of ‘peering’ in the service name is purely cosmetic – the outcome is a provider service without third party transit)
- May use a ‘settlement metric’
  - (again the term is normally cosmetic – in most cases it can be regarded as a conventional service tariff)

Non-Hierarchical Evolution: Today's Internet



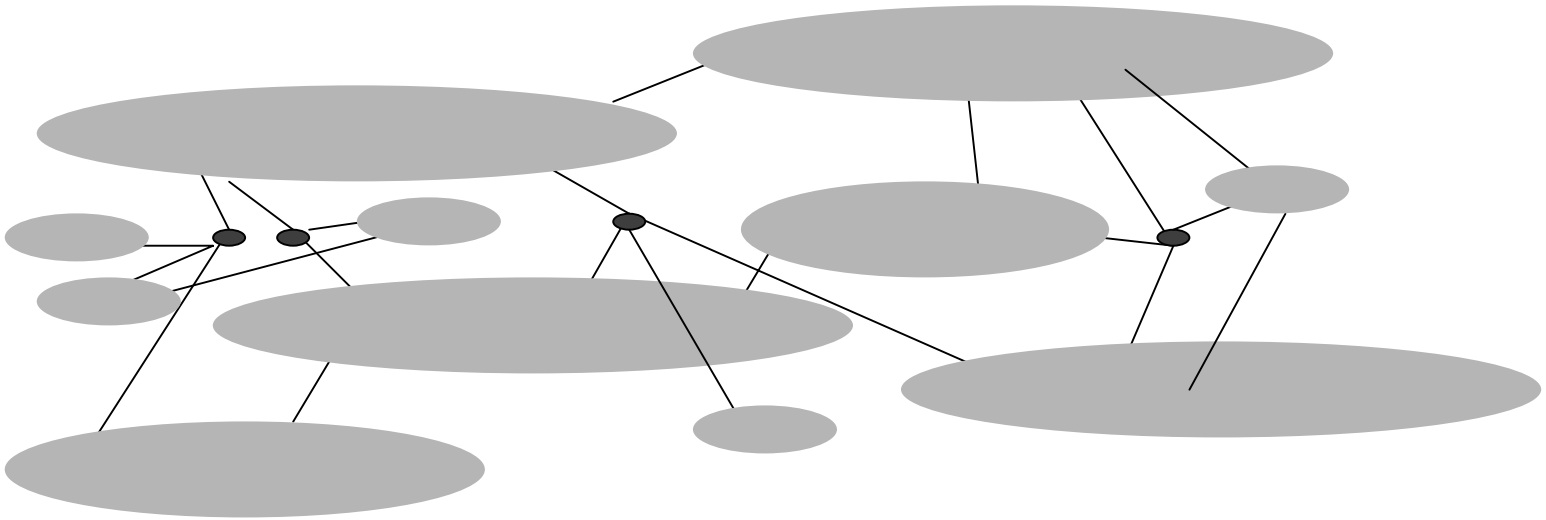
Internet ‘Shape’

- The network is becoming less ‘stringy’ and more densely interconnected
  - i.e. Transit depth is getting smaller



Internet ‘Shape”

- The network is becoming less strictly hierarchical
- Regional ‘globbing’ is evident
- Multi-point interconnection is widely used



Interconnection Trends

- **Multiple upstream contracts are commonplace**
  - An open competitive market for upstream transit is evident
  - Upstream transit services are becoming a commodity service
- **Substitutability exists through peering**
  - Widespread interconnection is a substitute for a large proportion of upstream services
  - Deregulation, increasing communications requirements, decreasing unit cost of communications, interconnection marketplaces all make interconnection cheaper
  - transit service costs are being forced down to match substitution costs
  - There is some lag in the transit market, opening the opportunity for still further interconnection

The Larger Picture

- **Communications costs are declining**
  - as a result of technology, deregulation and market response to the changing supply / demand ratios
- **The network is now more densely interconnected**
  - less relative reliance on a small collection of Tier 1 transit service providers and related financial arrangements
- **Substitutability exists for hierarchical paid upstream transit services**
  - Through use of peering points, multiple upstream services, wider network reach

The Larger Picture

- IP packet transmission is becoming a commodity market with IP transit and circuit services becoming directly comparable

- The evolving Internet content market is rapidly becoming the most critical issue in terms of value transfer

The Larger Picture

- While the content market is increasing in value, it is important to distinguish value and volume in the context of the content market.
- High volume, replicated content has a low unit value to individual consumers
- Point-to-point individual services, while low volume, represent the highest value segment of the content market
  - As evidenced by the rise of SMS volumes as compared to call minutes on mobile phone networks
- Volume is not the same as Value in the Inter-Provider Internet