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Economic Trends in Internet Exchanges

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Why am I giving this talk?

Why am I, an engineer, giving a talk on economics?

IXes are just Ethernet switches. The engineering is easy. But keeping people from breaking them by non-technical means seems to be more difficult than anticipated: CIX, CINX, CABASE, and others.

As an engineer, I don't like to see people break things I've built. Thus, I had to learn some economics.

Tools for thinking about Internet Exchanges in economic terms

- What are we, as ISPs, selling?
  - The right to modulate bits.
  - That right is a perishable commodity.
  - Where do we get the potentially-modulatable bits?

The right to modulate bits

Any Internet connection is a serial stream of time-slices.

Each time-slice can be modulated with a binary one or zero, one bit.

Each customer purchases potentially-modulatable bits at some *rate*, for example, 2mbps, which is 5.27 trillion bits per monthly billing cycle.

That's a perishable commodity

The quality (as opposed to quantity-per-time) characteristics of an Internet connection are *loss*, *latency*, *jitter*, and *out-of-order delivery*.

Loss increases as a function of the number and reliability of components in the path, and the amount of contention for capacity.

Latency increases as a function of distance, and degree of utilization of transmission buffers by competing traffic sources.

Jitter is the degree of variability in loss and latency, which negatively affects the efficacy and efficiency of the encoding schemes which mitigate their effects. Jitter increases relative to the ratio of traffic burstiness to number of sources.

Out-of-order delivery is the portion of packets which arrive later than other, subsequently-transmitted packets. It increases as a function of the difference in queueing delay on parallel paths.

All of **these properties become worse with time and distance**, which is a reasonable definition of a perishable commodity.

So where do we get the bits?

The value of the Internet is communication.

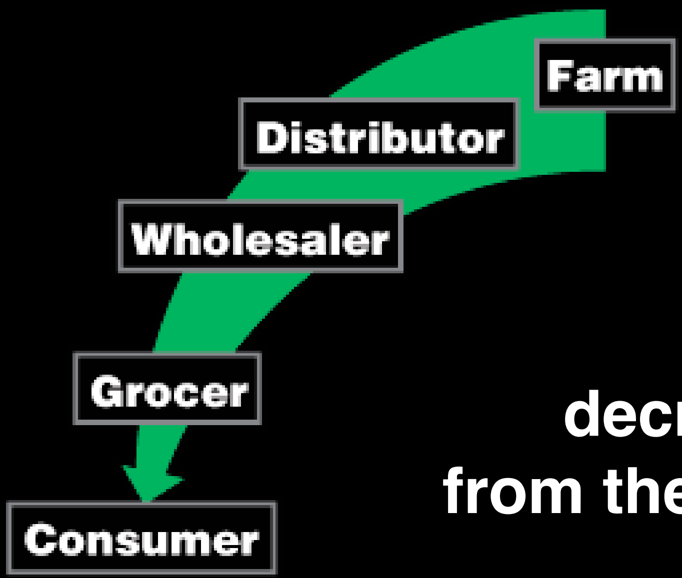
The value is produced at the point at which communication occurs between two ISPs, and it is transported to the customers who utilize it.

Thus, all the bits we sell come from an Internet exchange, whether nearby, or far away.

An analogy

Let's look at another perishable commodity with more readily observed economic properties... **Bananas**.

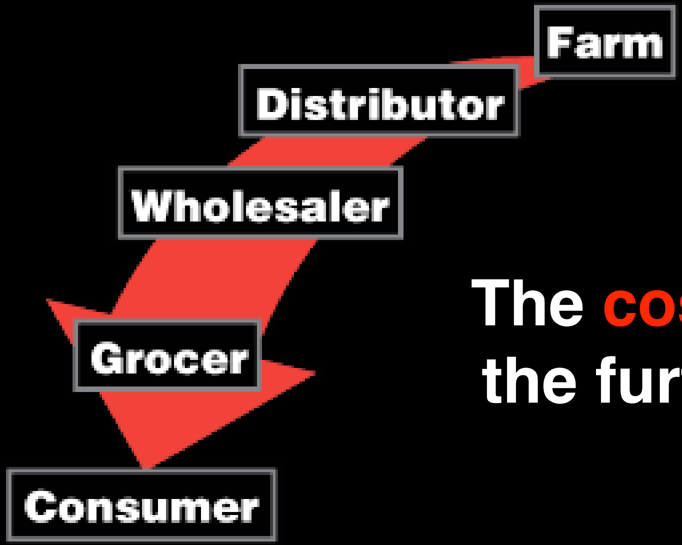
Value decreases with time & distance



The value of a banana decreases, the further it gets from the farm which produced it.

The shelf-life which the consumer can expect decreases, and eventually it becomes overripe, then rotten.

Cost increases with time & distance



The cost of a banana increases, the further it gets from the farm which produced it.

Salaries and hourly labor, warehouse leasing, petrol, lorry amortization, loss and spoilage, insurance, and other factors contribute additively.

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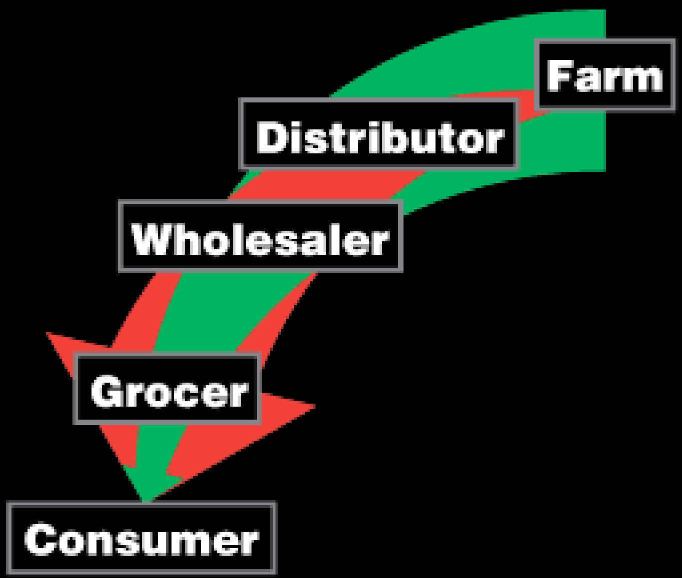
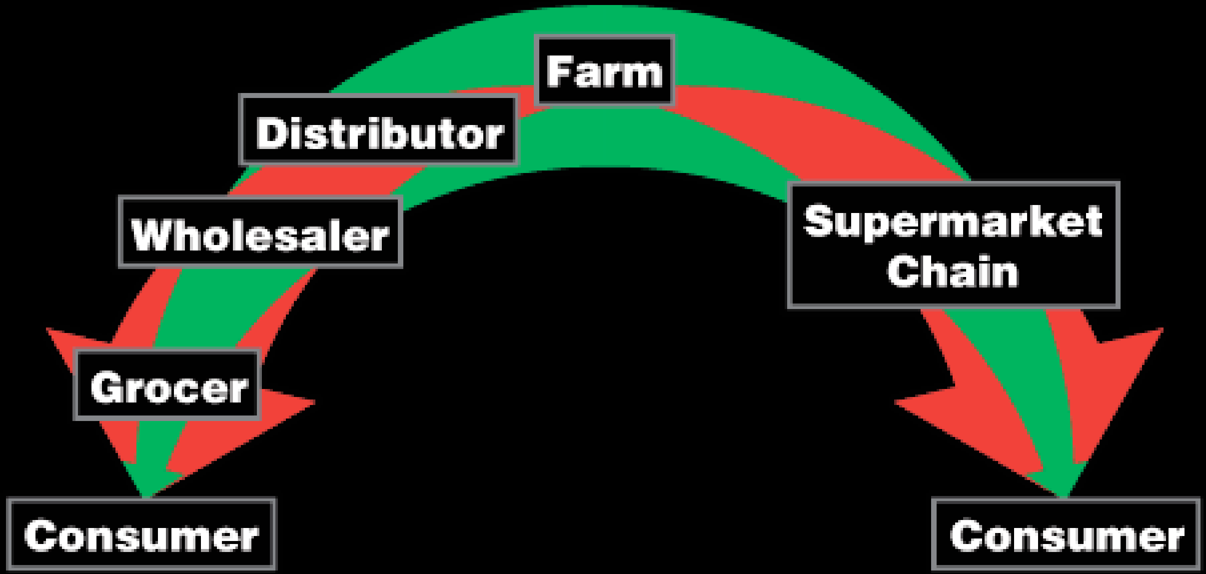
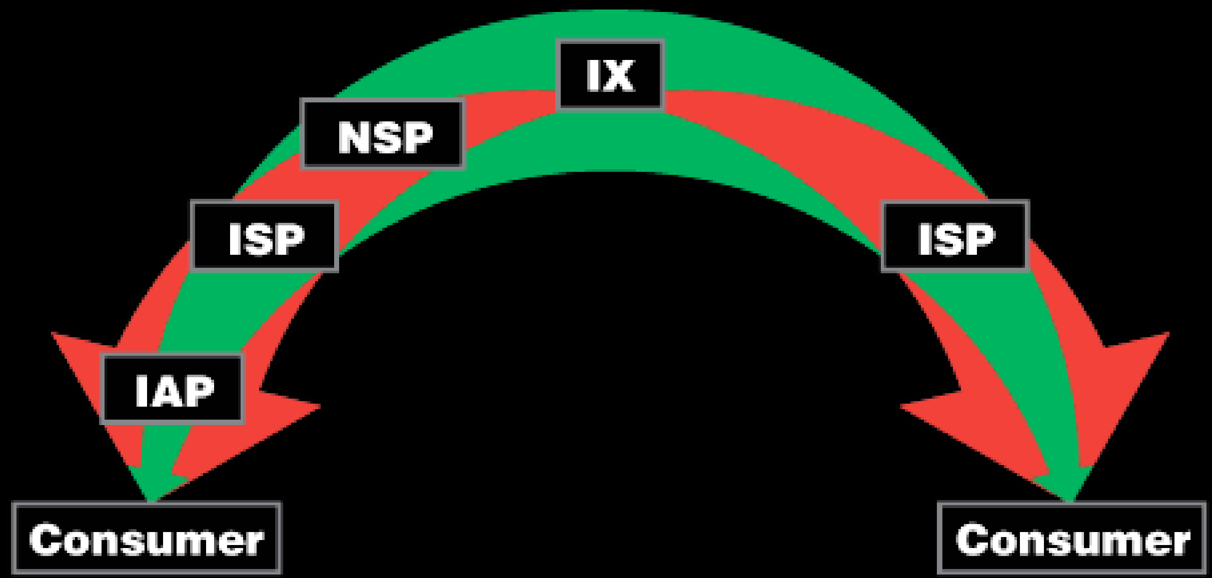




In a competitive environment, retail price is limited by competition, so time and distance influence the price more than the number of middlemen.

The problem is the same:



ISPs form a delivery chain, bringing perishable bits to the consumers who purchase them.

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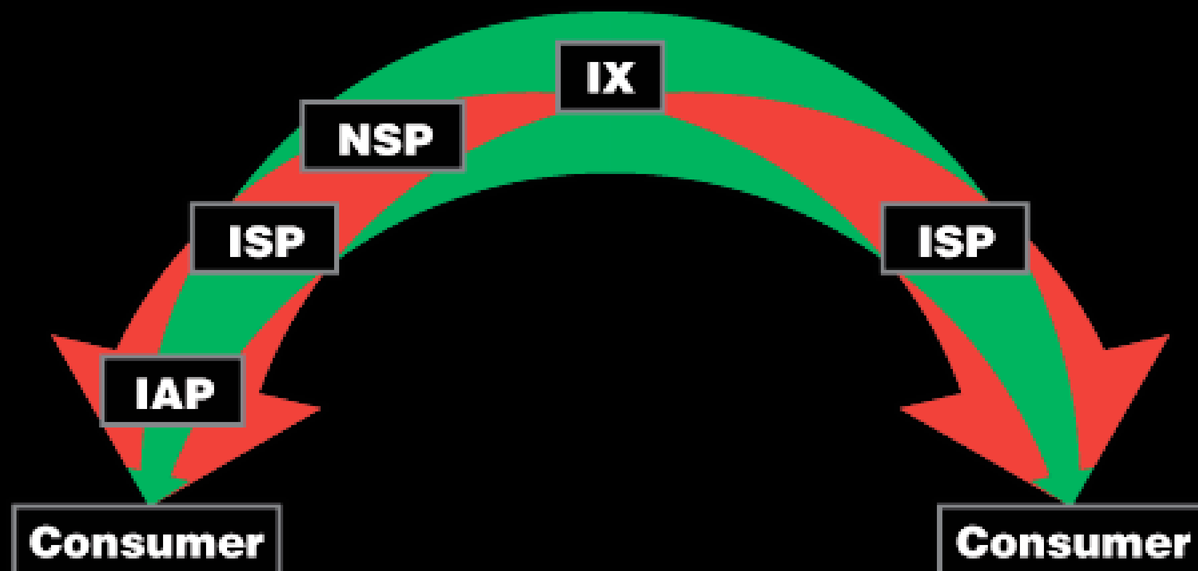
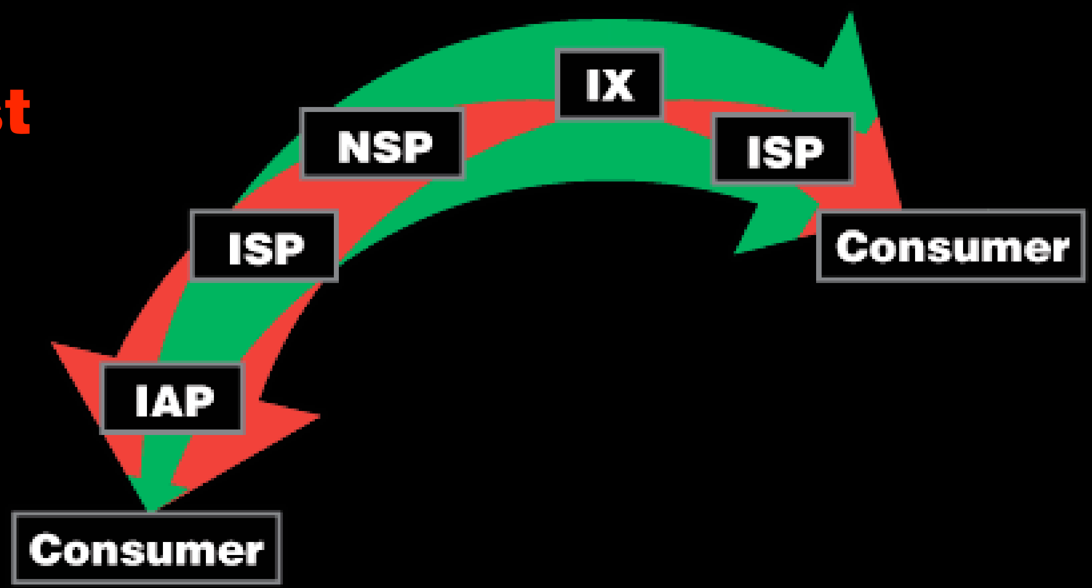
So how do we improve things?



Bring the customer nearer an IX...

High cost
Low value



Low cost
High value

...or bring an IX nearer the customer.

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So how do we recognize a successful exchange?

The purpose of an IX is to lower participating ISPs' average per bit delivery costs. (APBDC, see http://www.pch.net/resources/tutorials/average-per-bit-delivery-cost/ for a quick tutorial)

A cheap IX is probably a successful one.
An expensive IX is always a failure.
Reliability is just hand-waving by salespeople.

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The irony inherent in that

An efficient IX is an ISPs lowest-cost delivery method.

In order to shift latency-sensitive traffic toward the lowest-cost delivery method, it must also be the highest-capacity pipe.

Regardless of degree of utilization.

Thus many IX connections run at low utilization: apparent inefficiency.

So, with that background...

...let's take a short tour of the world, concluding with the Asia-Pacific region.

As we go, keep an economic perspective, and consider correlations between exchange locations and economic power.

Europe

Two Large Exchanges

Many, Many Smaller Exchanges

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Top European IXes

	Established	Participants	Traffic Volume
London LINX	1996	162	40 gbps
Amsterdam AMS-IX	1997	199	36 gbps
Stockholm NetNod	1997	35	13 gbps
Vienna VIX	1996	80	5 gbps
Frankfurt DE-CIX	1995	135	23 gbps
Milan MIX	2000	56	8 gbps
Gothenburg NetNod	2002	11	2 gbps
Prague NIX	1996	50	4 gbps
London XchangePoint	2001	166	6 gbps
Rome NaMeX	1995	19	2 gbps

North America

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Two Large Exchanges

Many Smaller Exchanges

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Top North American IXes

	Established	Participants	Traffic Volume
Palo Alto PAIX	1994	180	
Ashburn Equinix	1999	72	
Seattle SIX	1996	90	6 gbps
Miami NOTA	2001	89	5 gbps
New York IIX	1998	80	
Los Angeles LAAP	1995	75	
Chicago Equinix	2001	36	
San Jose Equinix	2001	37	
Portland NWAX	2002	15	
San Jose MAE-West	1994	100	

Africa

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Two Large IXes

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Eight Smaller IXes

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Satellite Only

African IXes

	Established	Participants	Traffic Volume
Johannesburg JINX	December 1996	15	45 mbps
Nairobi KIXP	February 2002	11	3 mbps
Maputo MozIX	July 2002	7	4 mbps
Kinshasa PdX	November 2002	4	1 mbps
Cairo CR-IX	December 2002	9	
Ibadan	March 2003	2	200 kbps
Kampala UIXP	July 2003	5	
Dar es Salaam TIX	January 2004	10	1 mbps
Mbabane SZIXP	June 2004	3	128 kbps
Kigali	July 2004	6	400 kbps

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Latin American & Caribbean Region

Two Large Exchanges

Nine Smaller Exchanges

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Three of those are in Brazil

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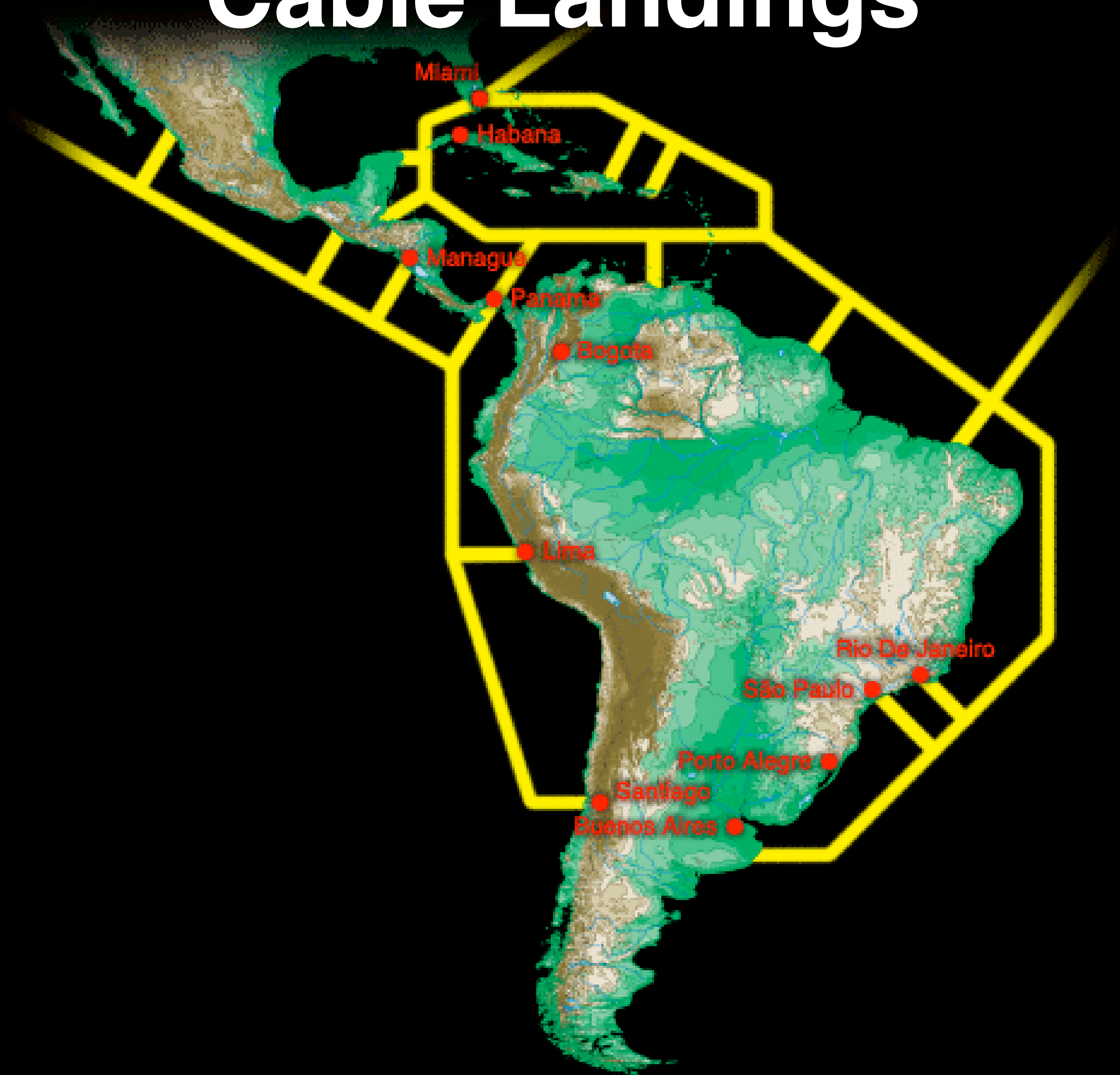

Latin American Exchanges

	Established	Participants	Traffic Volume
São Paulo	1998	37	900 mbps
Miami	September 2002	89	5 gbps
Porto Alegre	2000	15	160 mbps
Rio De Janeiro			
Buenos Aires			
Santiago			
Bogotá			
Habana	June 2001	5	50 mbps
Managua	April 2004	10	
Lima			
Panama			

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Asia-Pacific

Three Large Exchanges

Many Medium-Sized Exchanges

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Top Asian IXes

	Established	Participants	Traffic Volume
Seoul	1996	148	168 gbps
Tokyo	1996	252	75 gbps
Hong Kong	1995	69	13 gbps
Perth	1997	52	500 mbps
Beijing	2000	8	50 gbps
Jakarta	1997	70	100 mbps
Osaka	1998	30	5 gbps
Wellington	1996	123	
Singapore	2001	12	500 mbps
Taipei	1998	77	2 gbps
Auckland	2000	48	

Thanks, and Questions?

Copies of this presentation can be found
in Keynote, PDF, QuickTime and PowerPoint formats at:

http:// www.pch.net / resources / papers / asia-pac-ix-update

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