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Packet Clearing House

The Economic Significance of Internet Exchange Points

Version 0.9

July, 2007

Bill Woodcock

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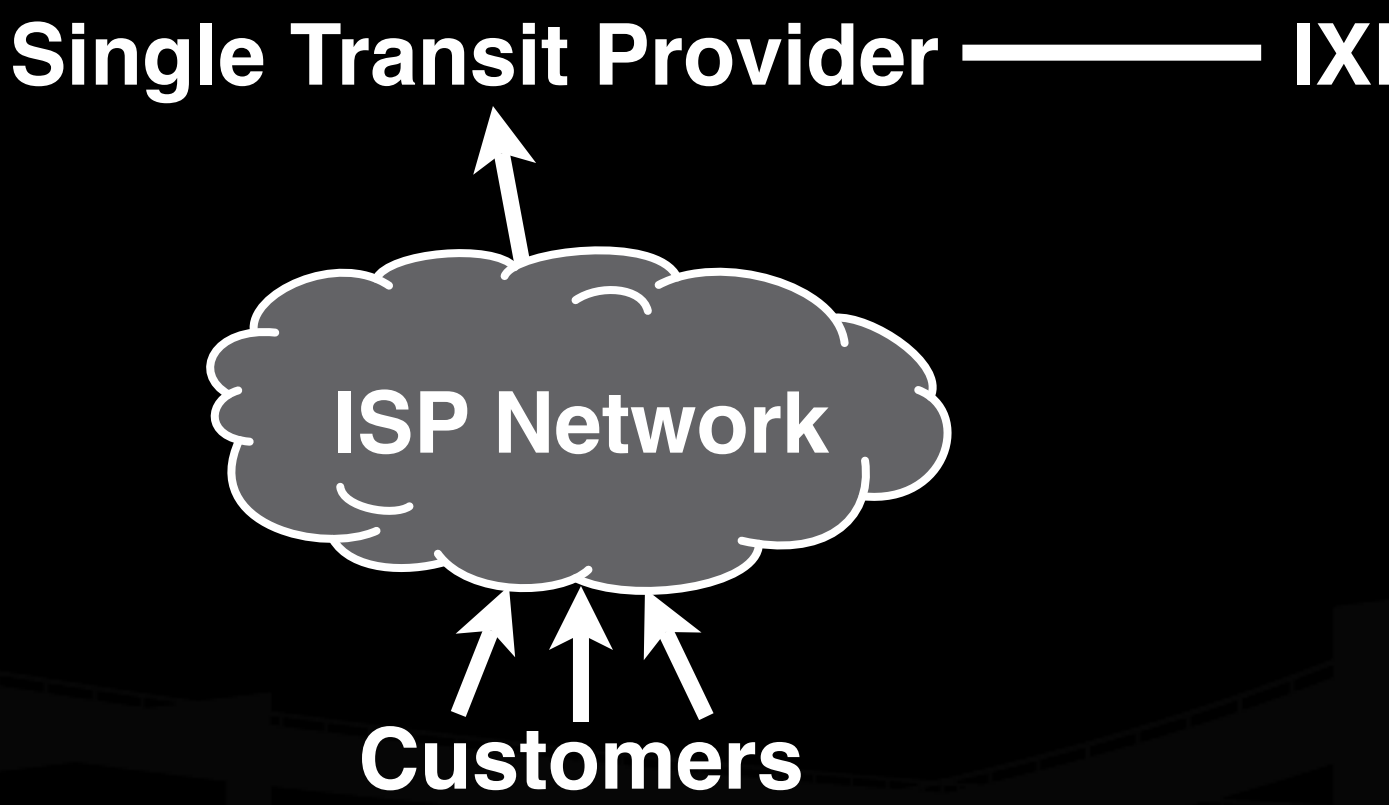
ISP Lifecycle: Simple Aggregator



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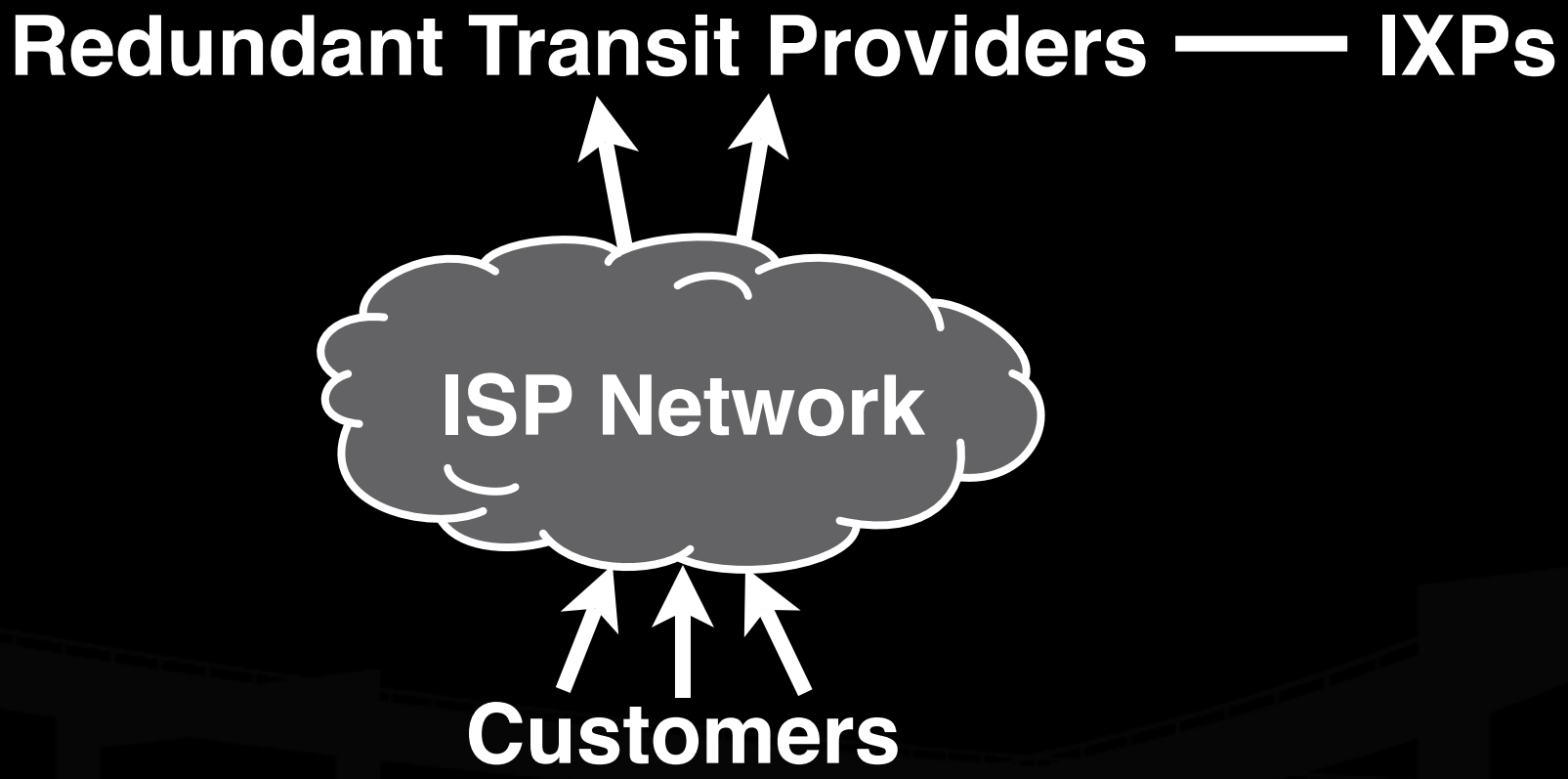
ISP Lifecycle: Redundancy and LCR



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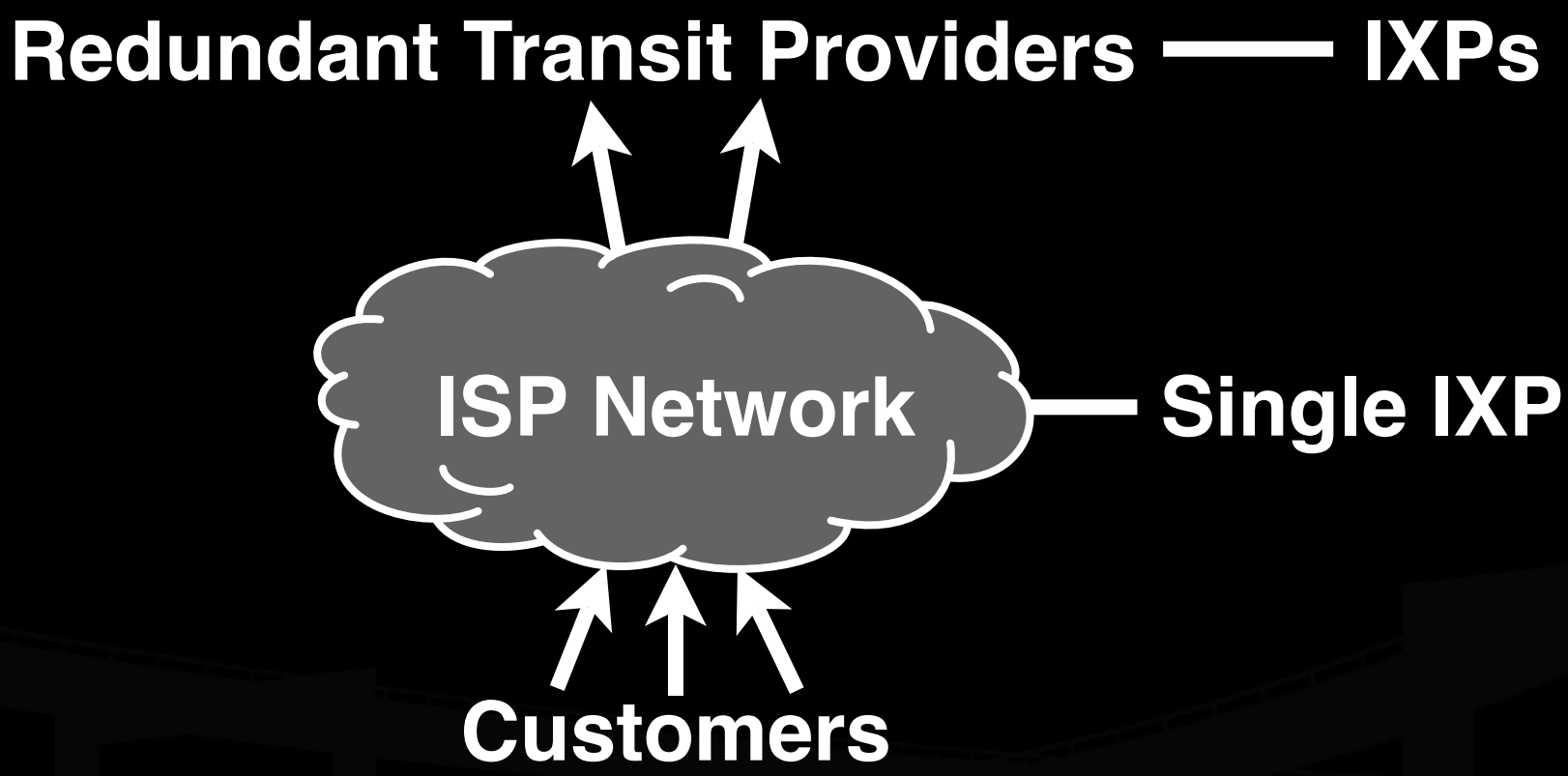
ISP Lifecycle: Local Peer



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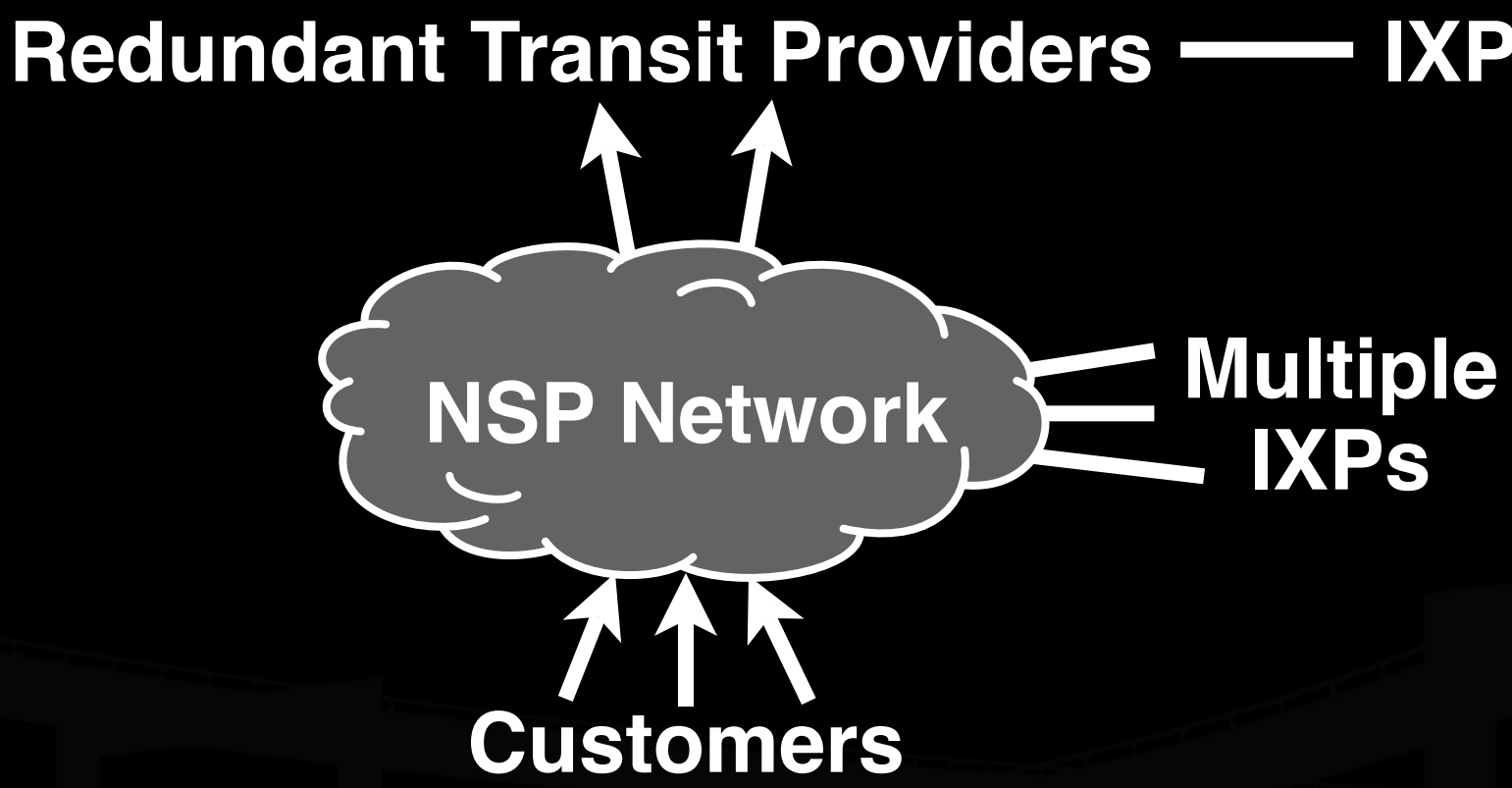
ISP Lifecycle: Network Service Provider



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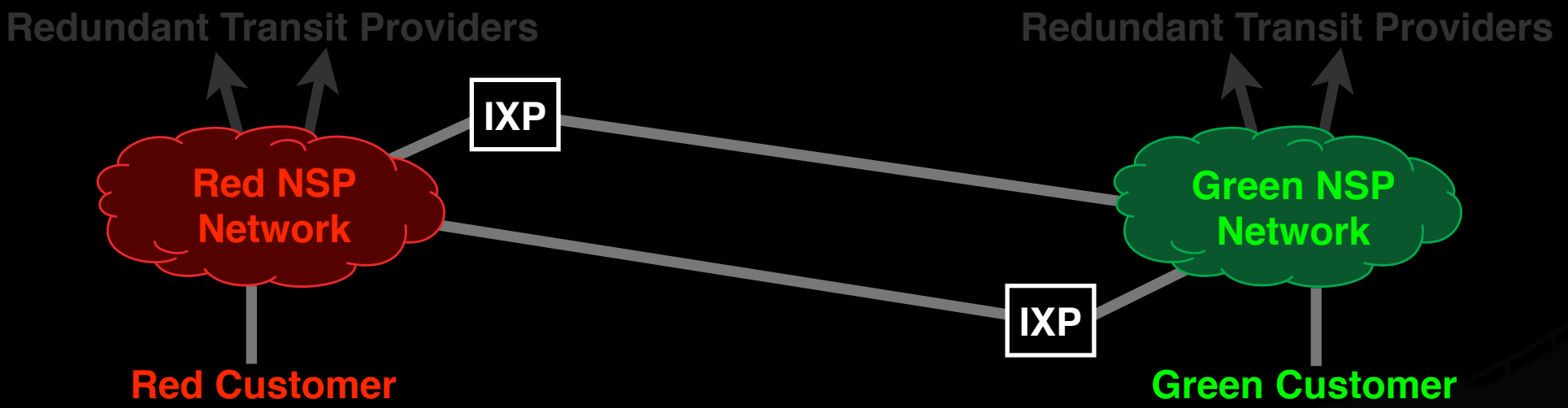
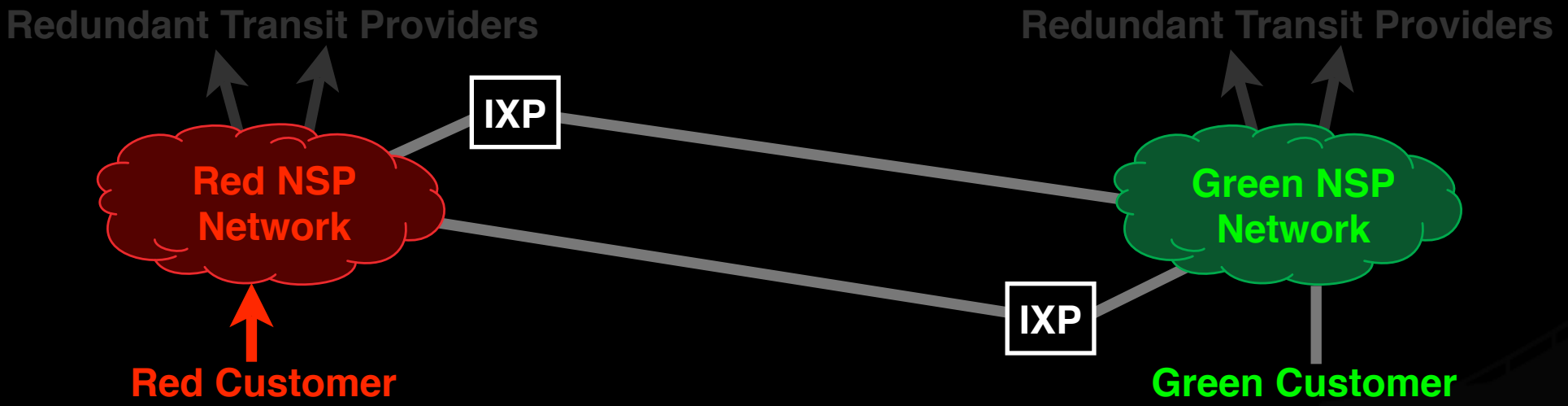
Hot Potato Routing



Hot Potato Routing

Red Customer sends to Green Customer via Red NSP



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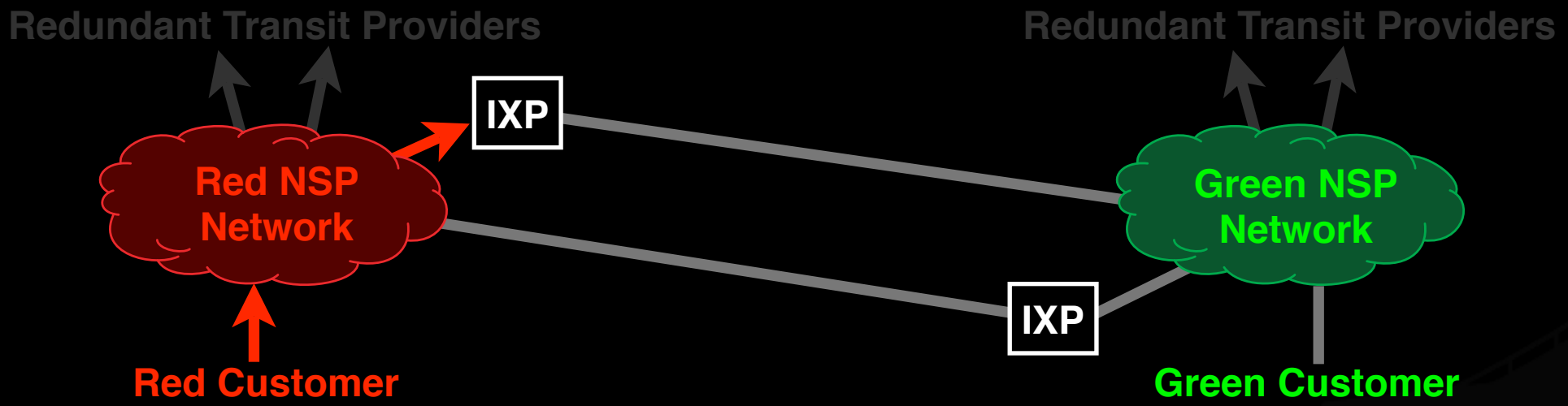
Hot Potato Routing

Red NSP delivers at *nearest* IXP



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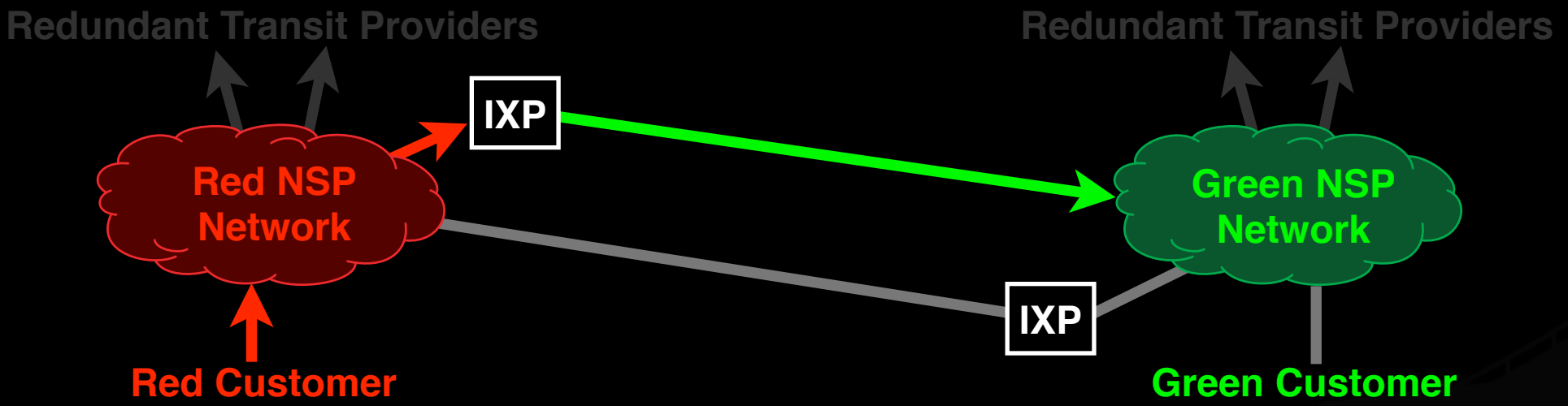
Hot Potato Routing

Green NSP backhauls from distant IXP



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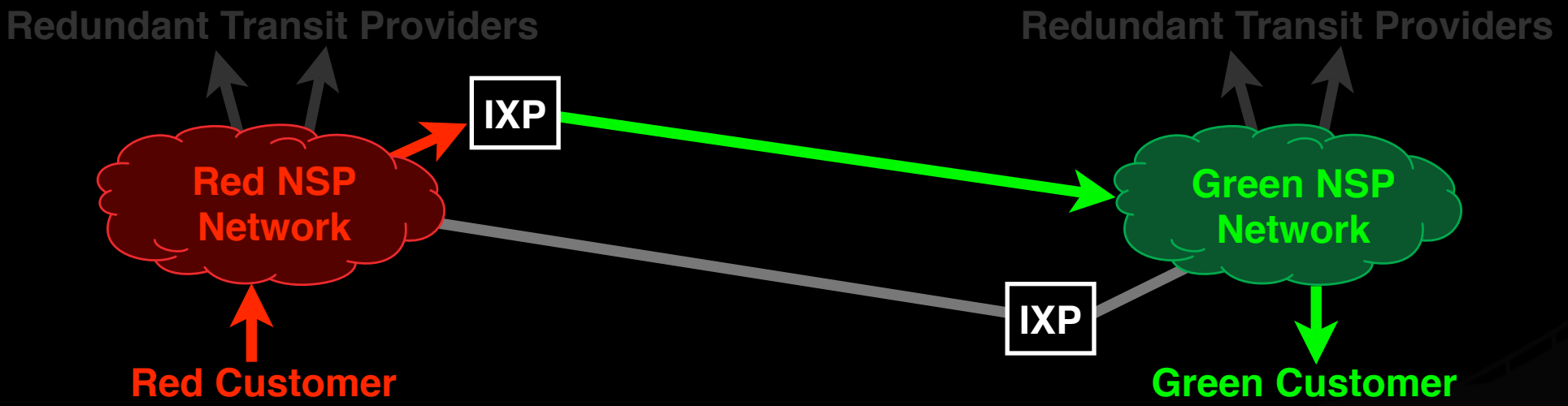
Green ISP delivers to Green Customer



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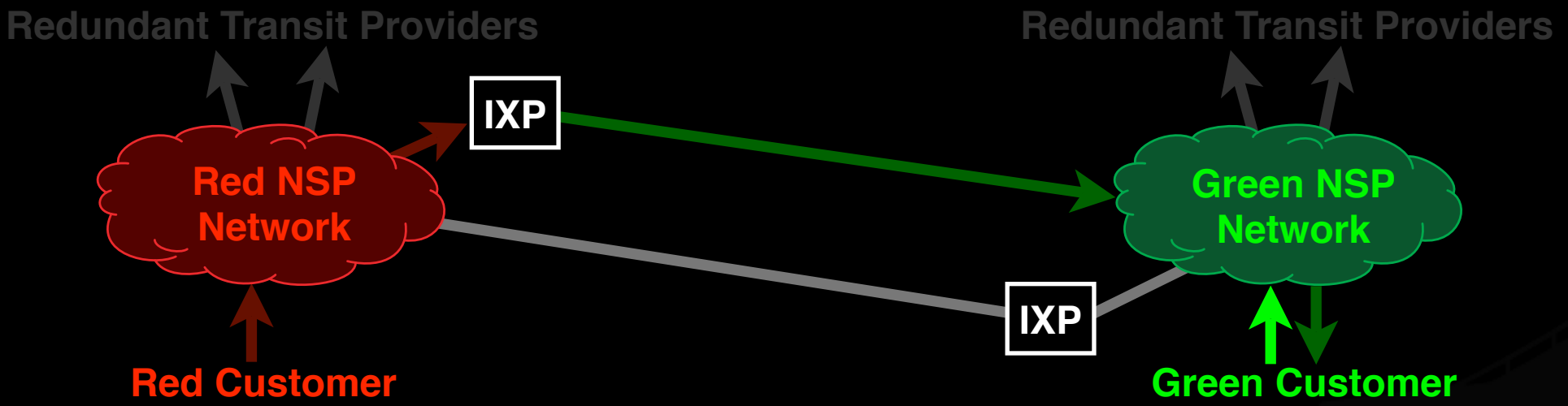
Green Customer replies via Green NSP



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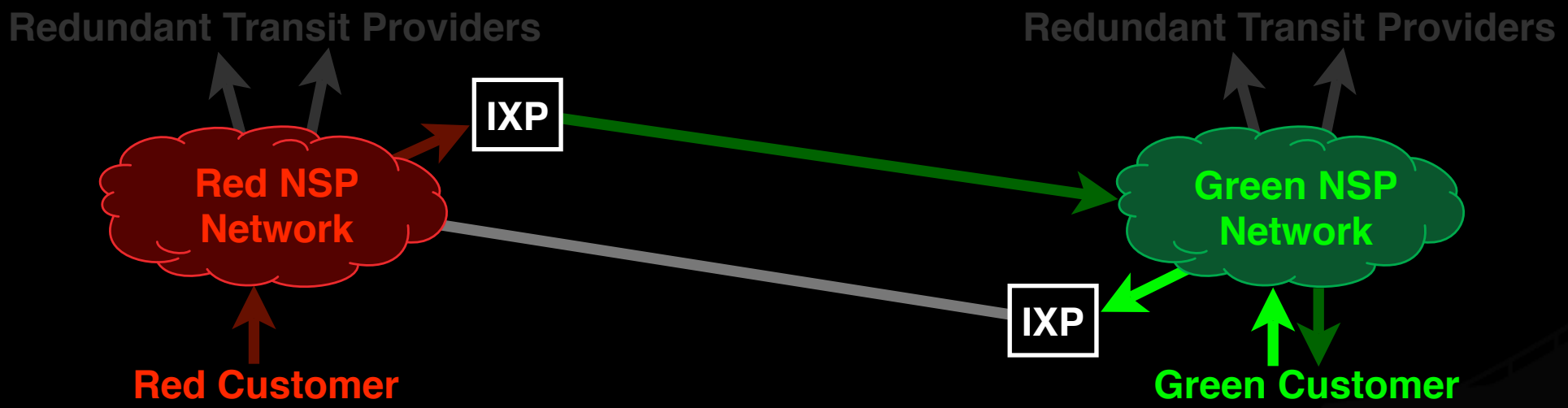
Hot Potato Routing

Green NSP delivers at nearest IXP



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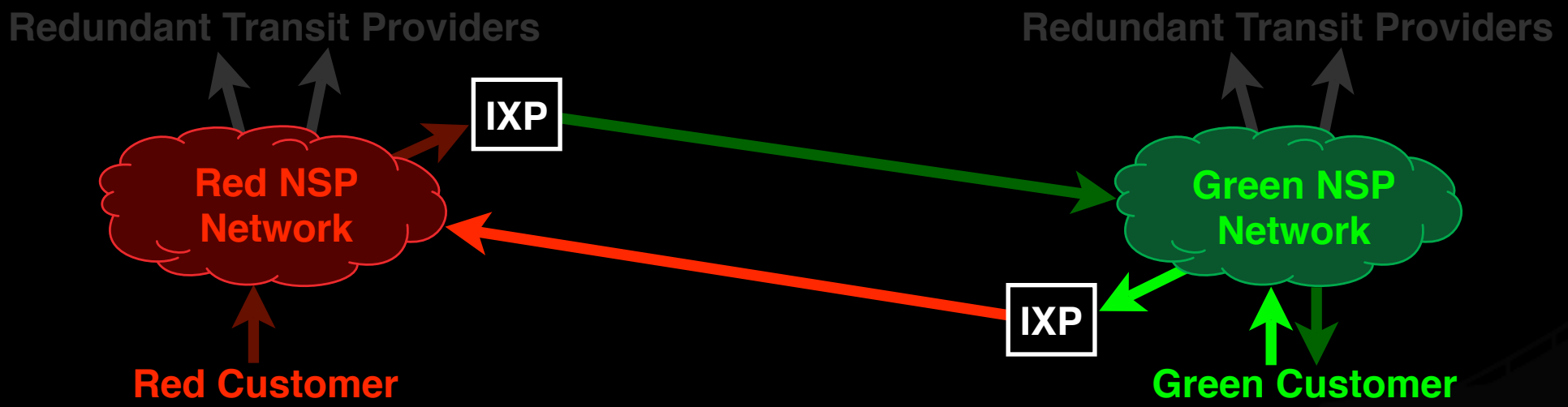
Red NSP backhauls from distant IXP



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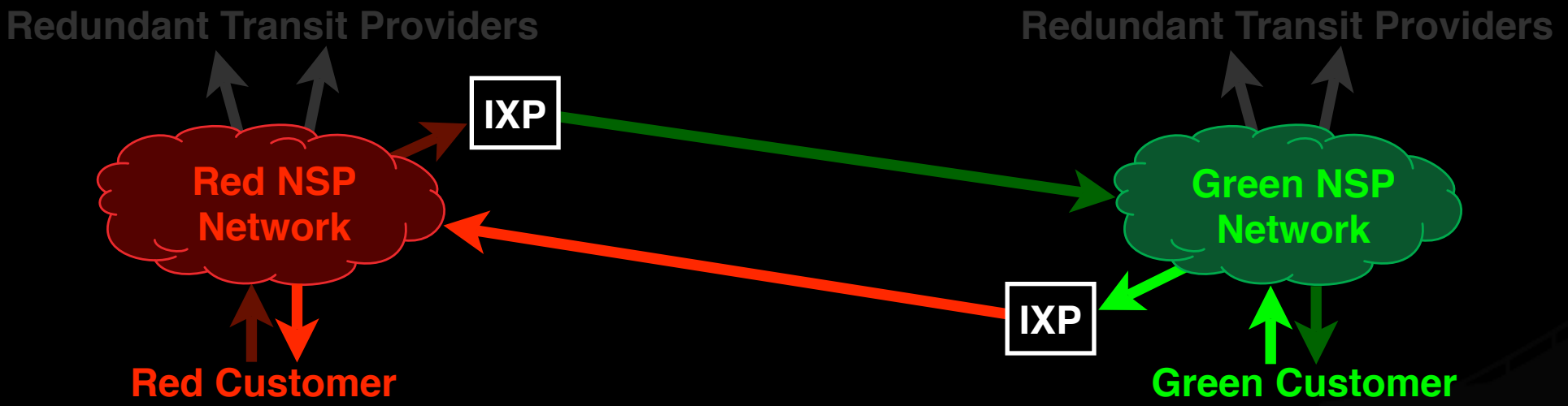
Hot Potato Routing

Red NSP delivers to Red Customer



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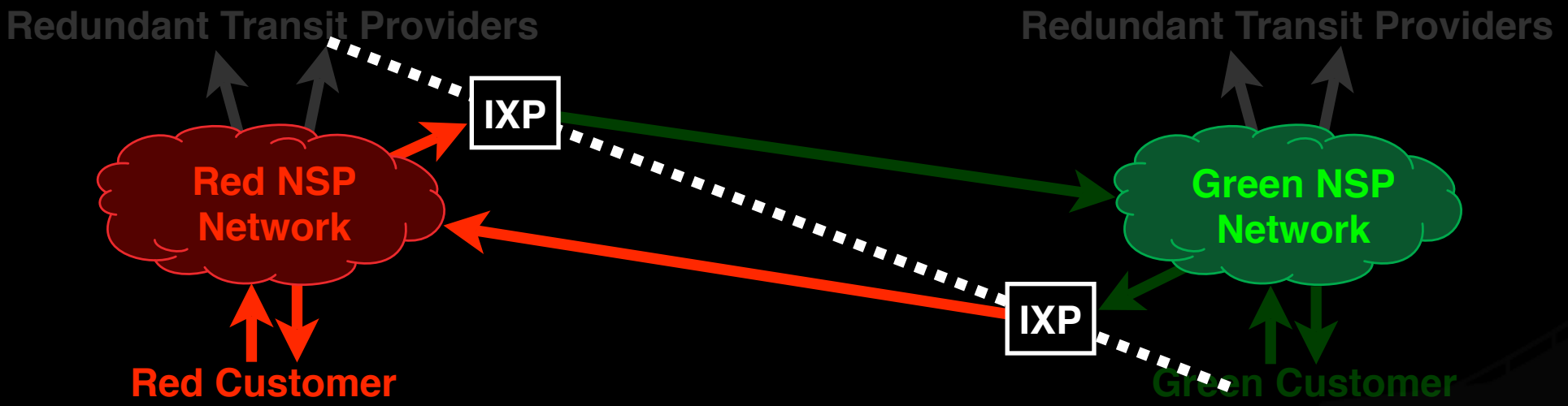
Hot Potato Routing

Red Network is responsible for its own costs



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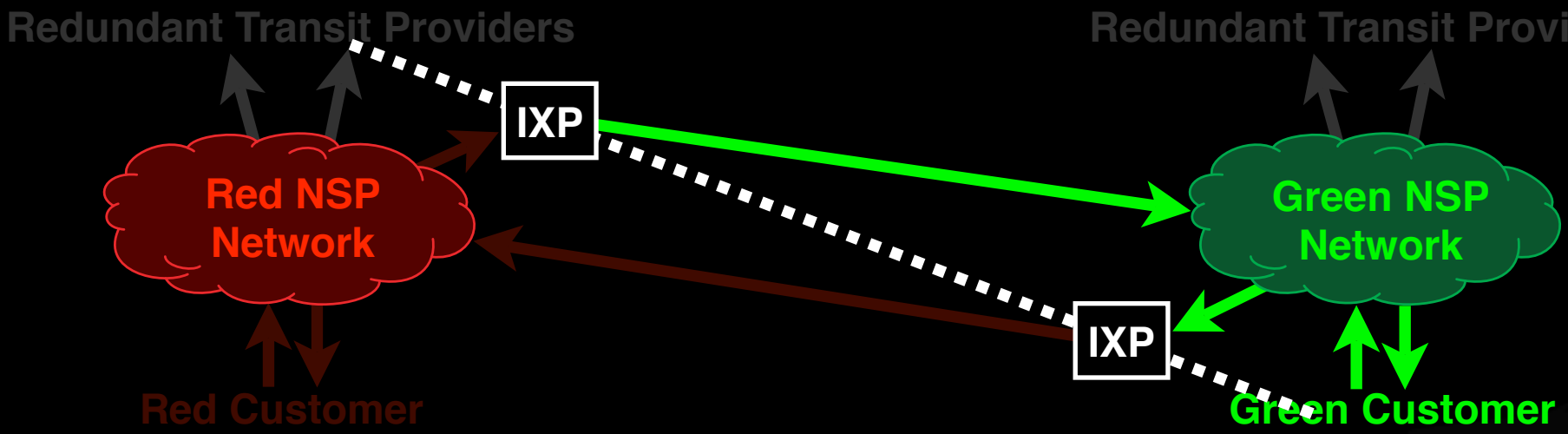
Hot Potato Routing

Green Network is responsible for its own costs



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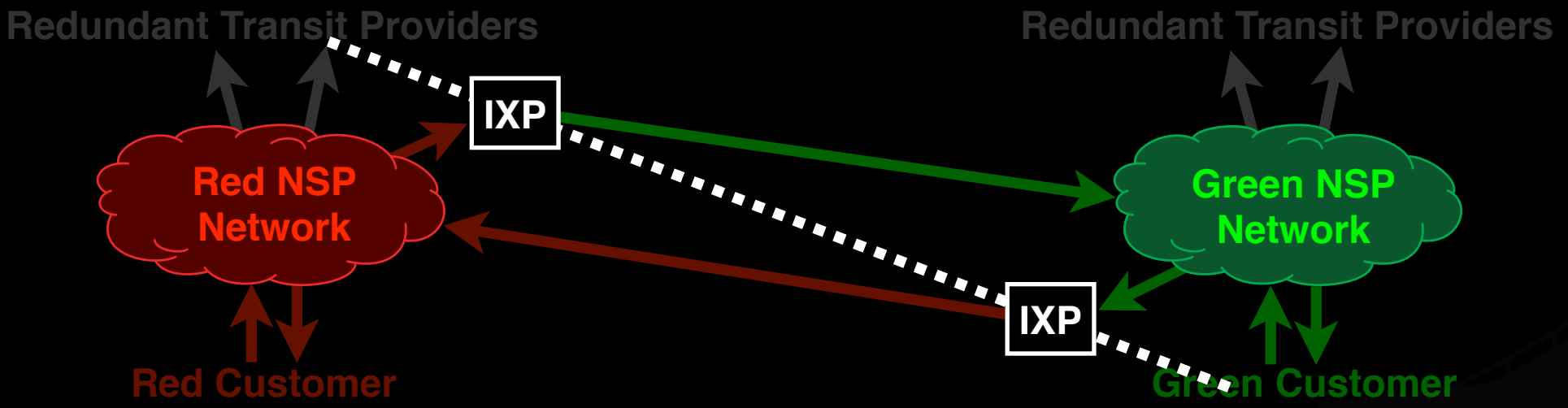
Hot Potato Routing

Symmetry: Fair sharing of costs



The old circuit-switched networks have dubbed our financial model “bill and keep”

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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?

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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.

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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.

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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.

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An analogy

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

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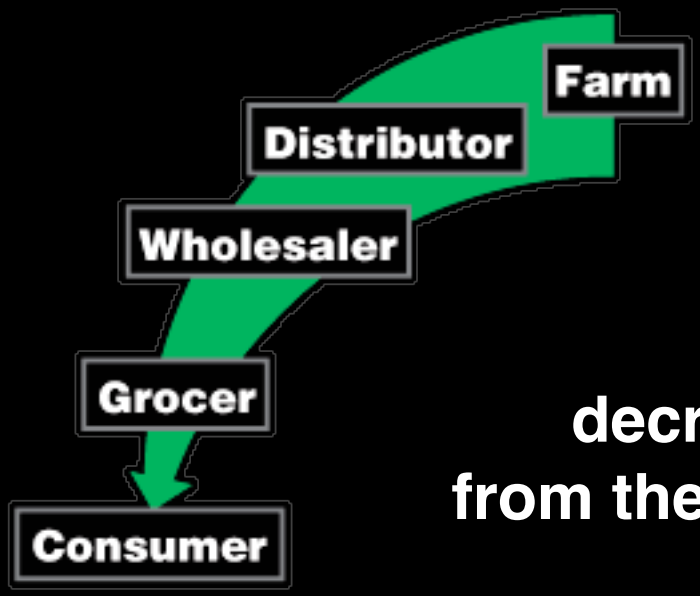
Value decreases with time & distance



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.

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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, diesel fuel, truck amortization, loss and spoilage, insurance, and other factors contribute additively.

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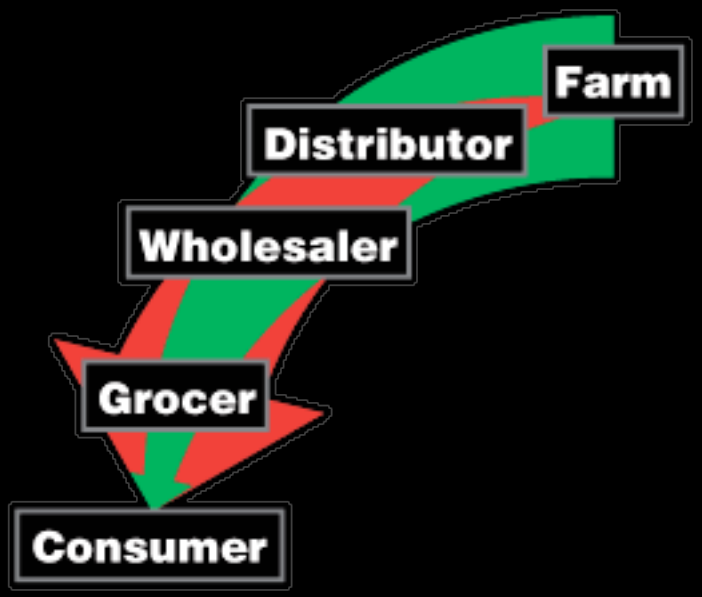

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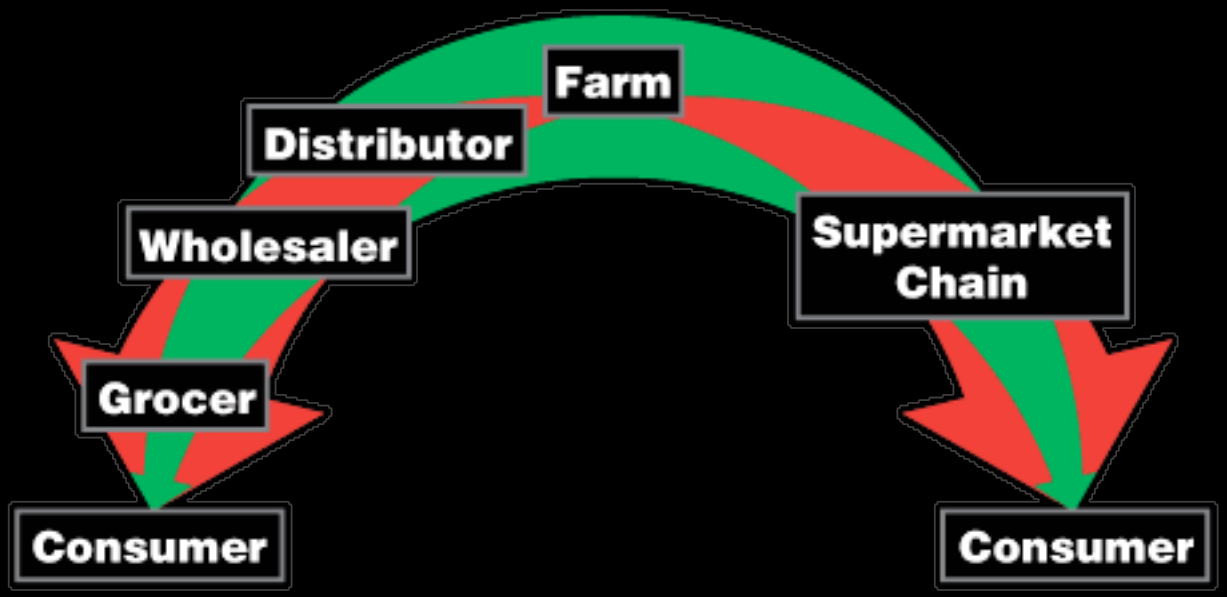

In a competitive environment, retail price is limited by competition, so time and distance influence the price more than the number of middlemen.

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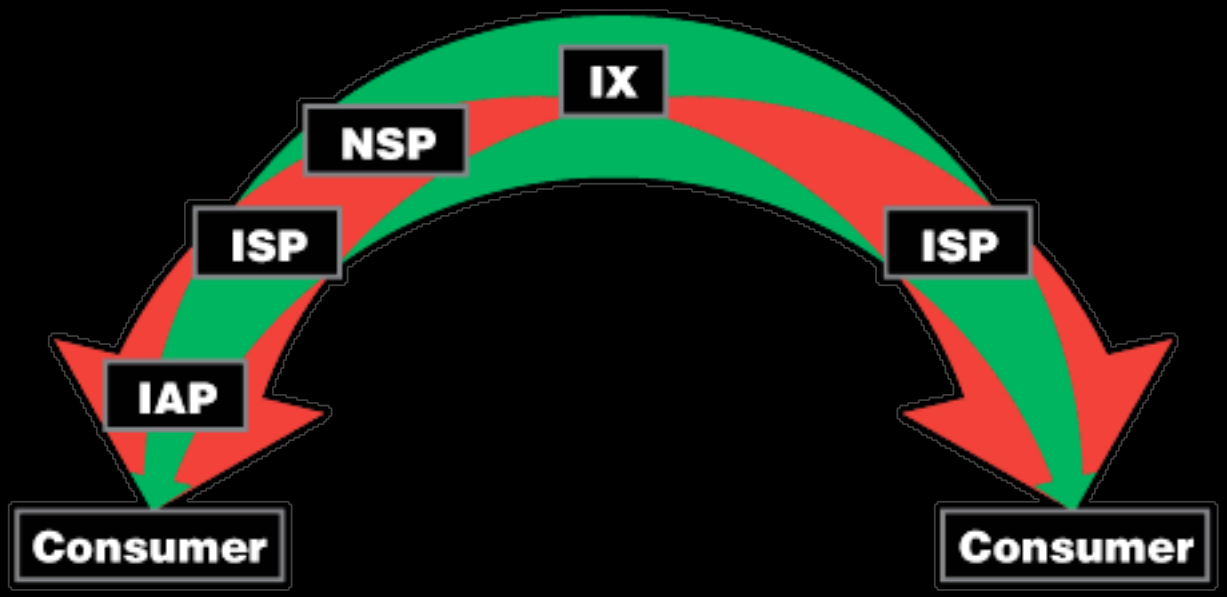
The problem is the same:



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

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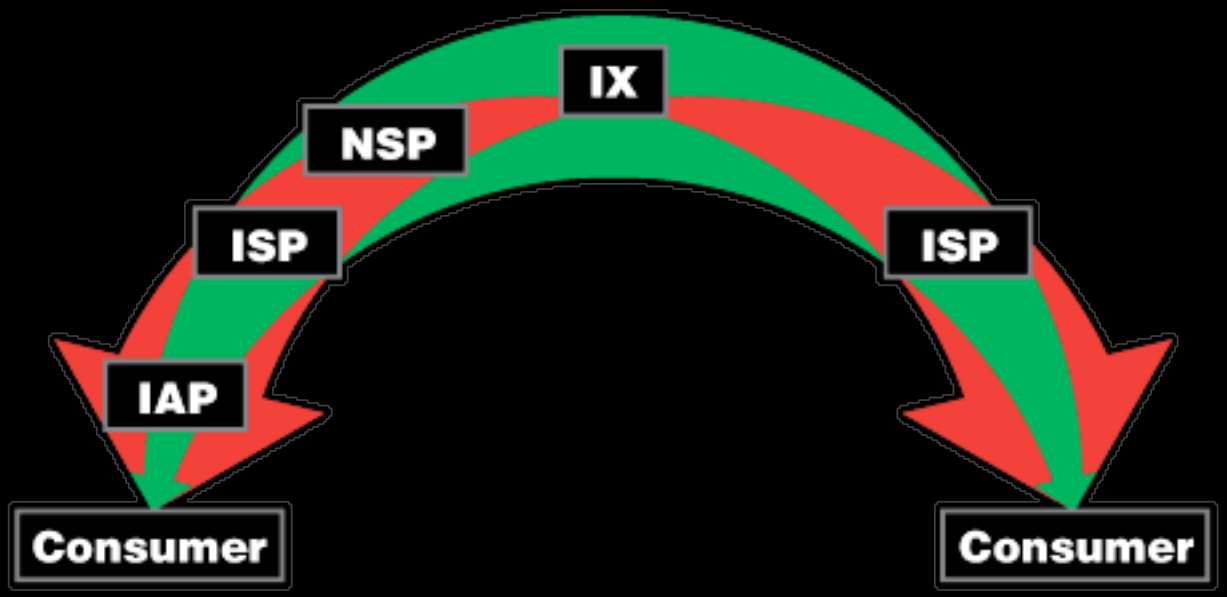
So how do we improve things?



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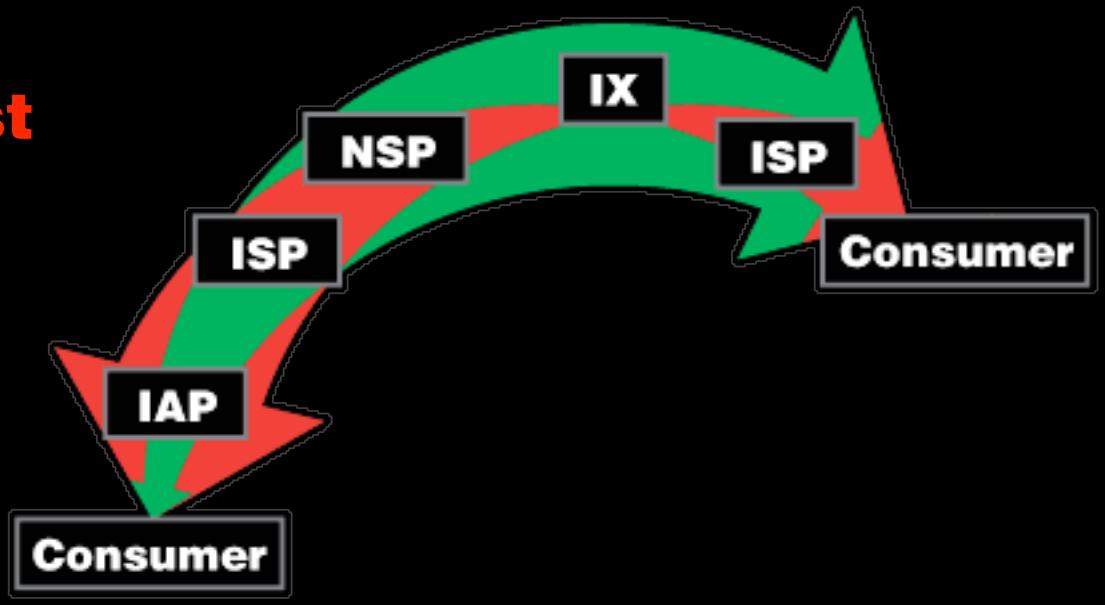
Bring the customer nearer an IX...

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).

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.