

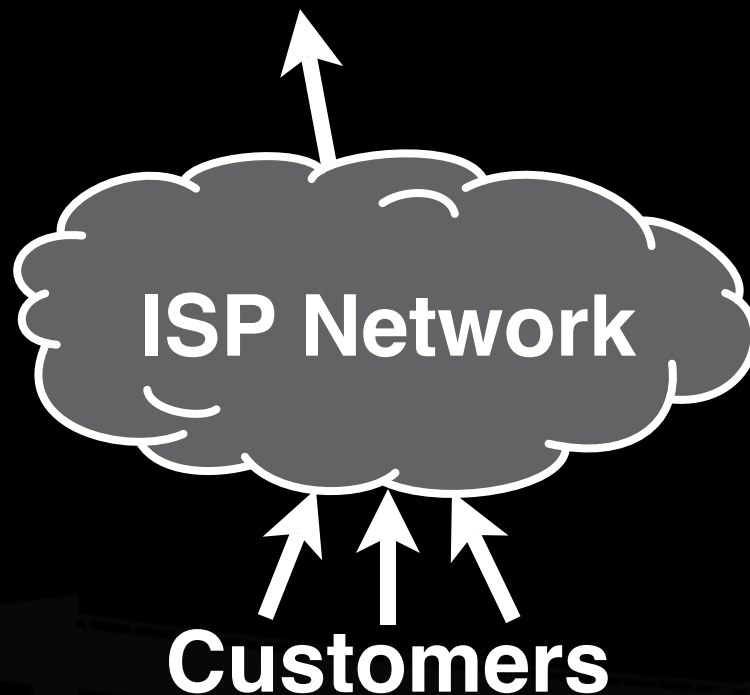
# **Internet Exchange Points & Internet Traffic Exchange**

**IEEE Communications Society  
Technology and Policy Roundtable  
Tuesday, March 18, 2008**

**Bill Woodcock  
Research Director  
Packet Clearing House**

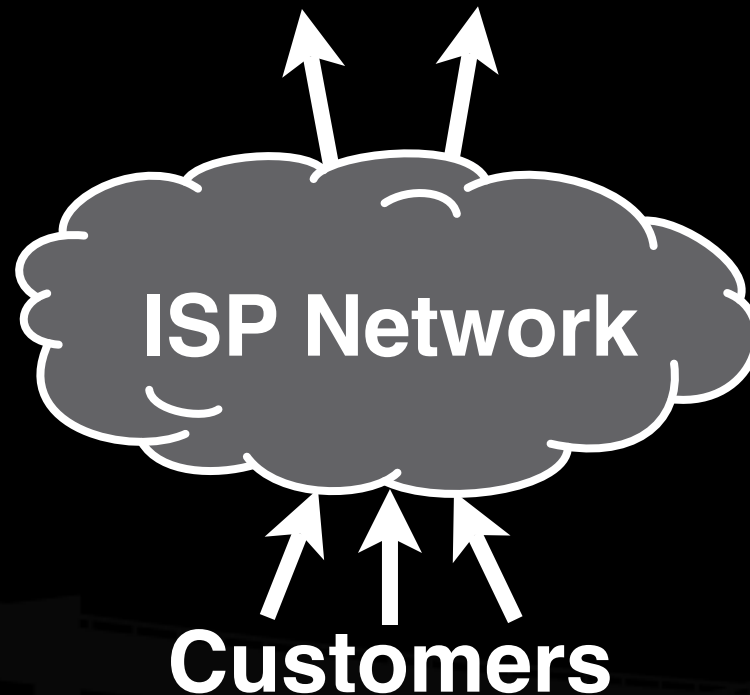
# ISP Lifecycle: Simple Aggregator

Single Transit Provider ——— IXPs



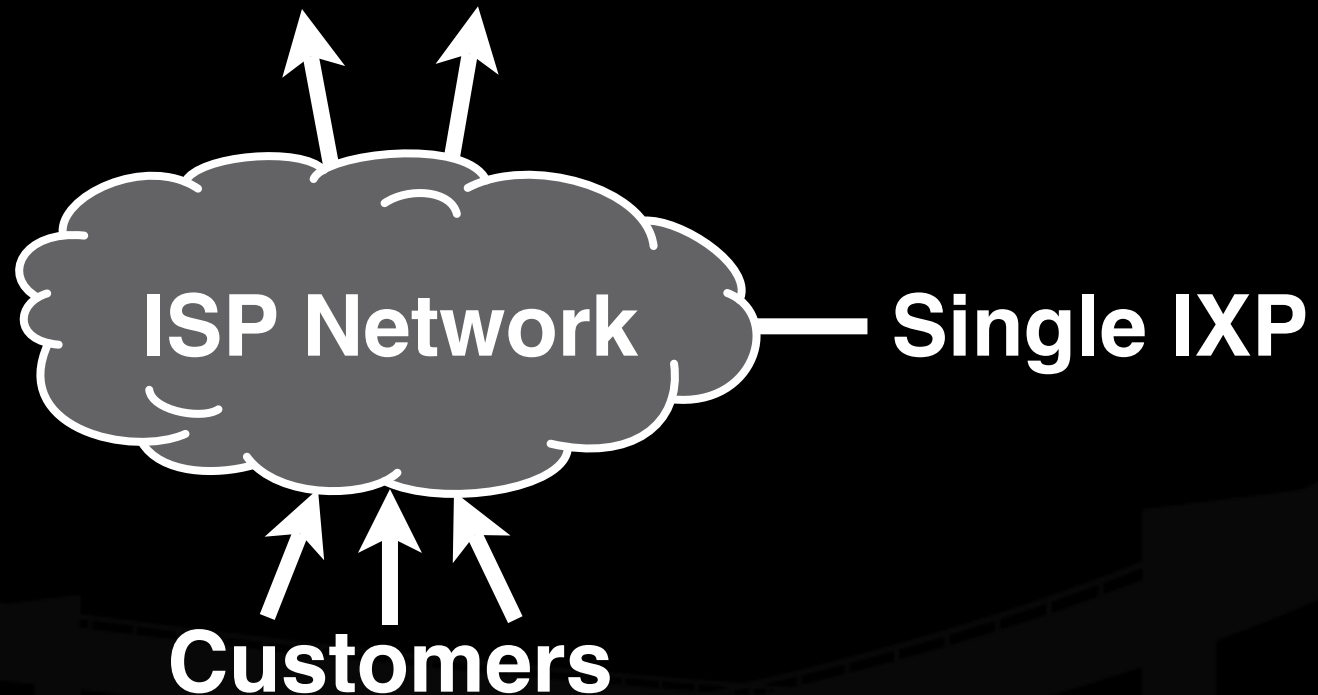
# ISP Lifecycle: Redundancy and LCR

Redundant Transit Providers — IXPs



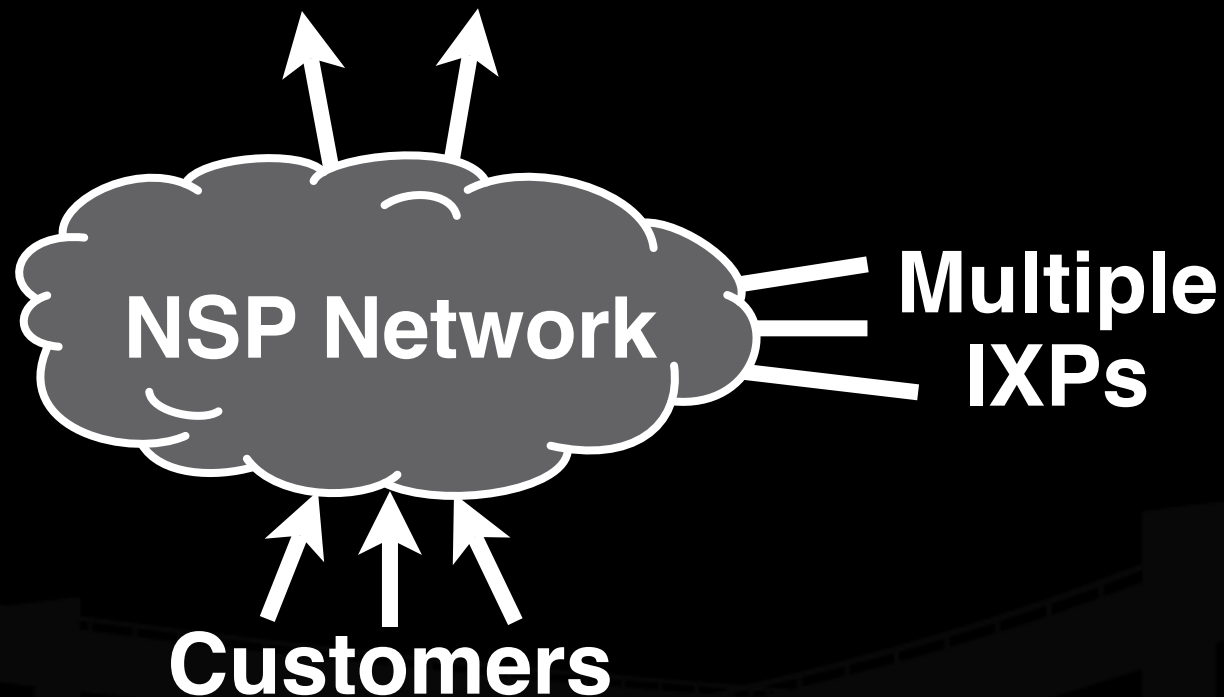
# ISP Lifecycle: Local Peer

Redundant Transit Providers — IXPs

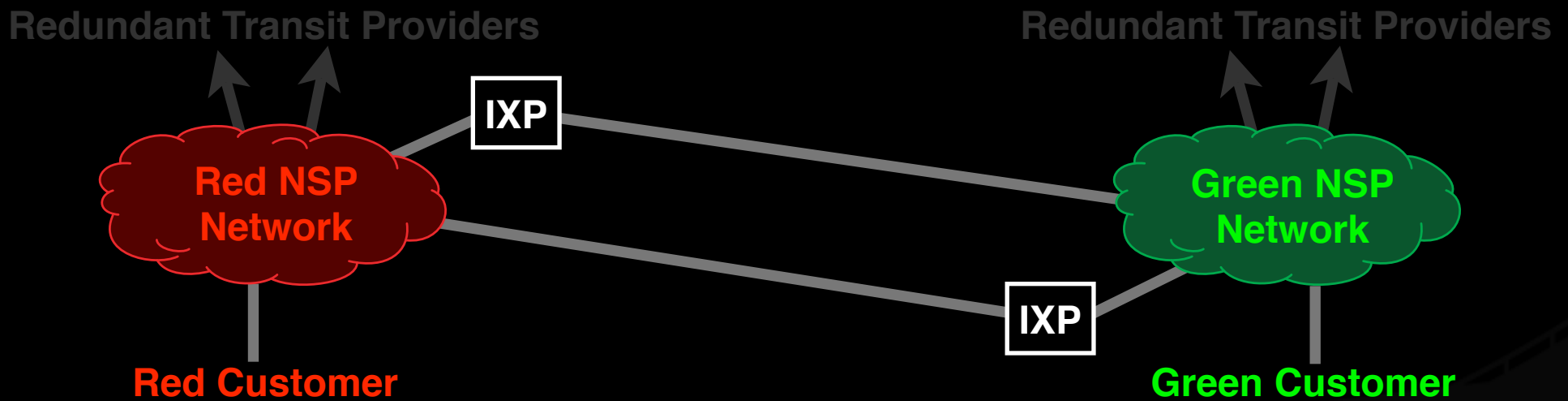


# ISP Lifecycle: Network Service Provider

Redundant Transit Providers — IXP

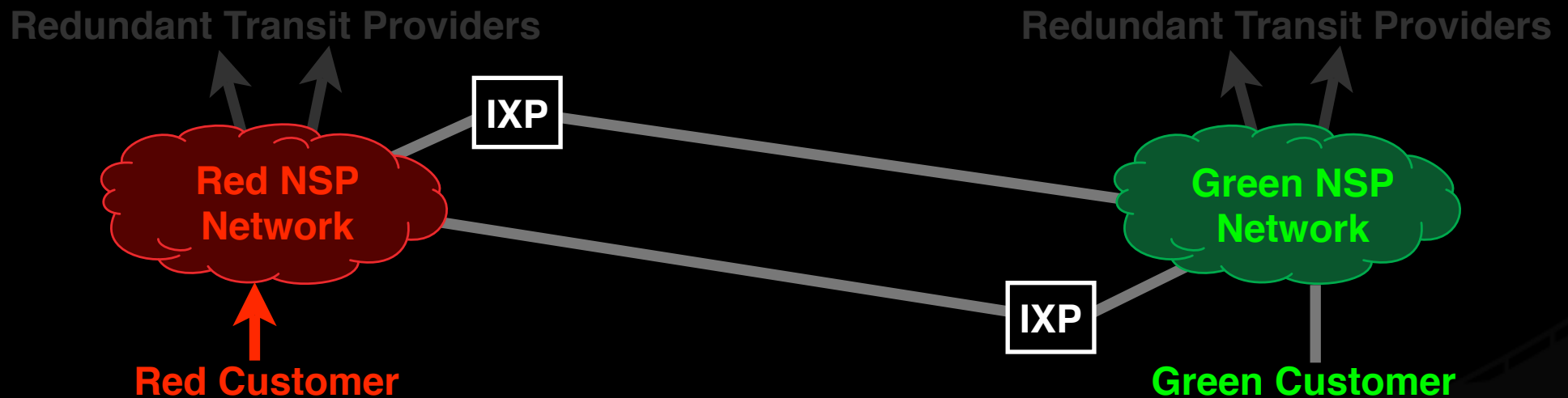


# Hot Potato Routing



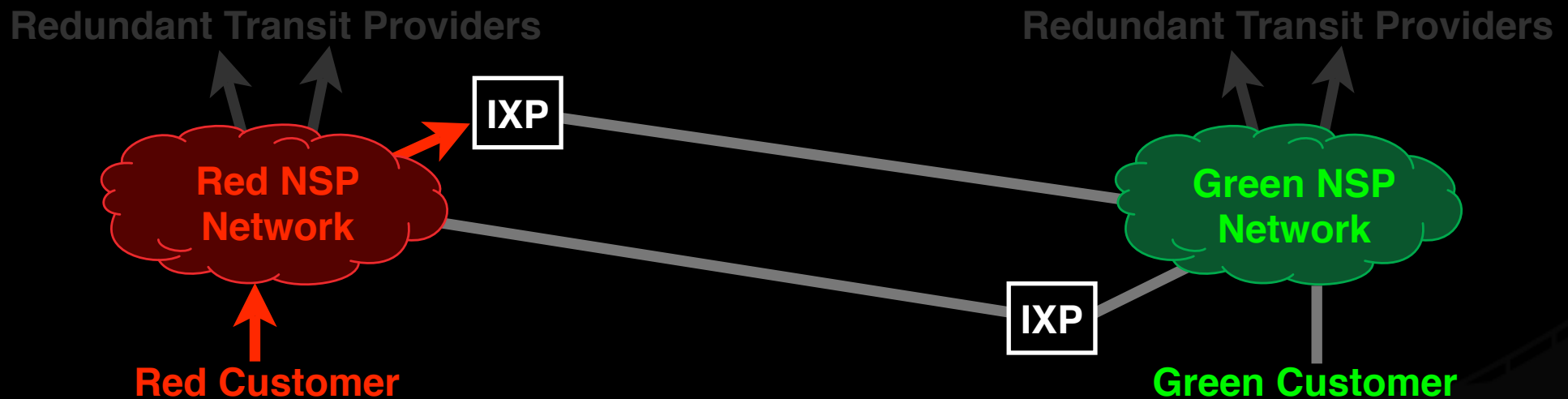
# Hot Potato Routing

**Red Customer sends to Green Customer via Red NSP**



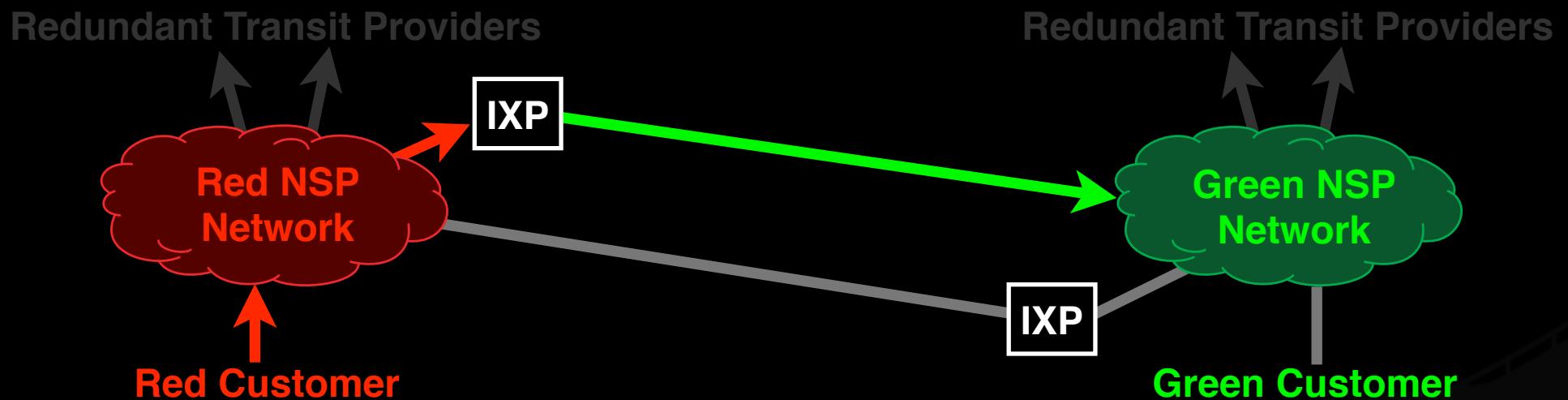
# Hot Potato Routing

Red NSP delivers at *nearest* IXP



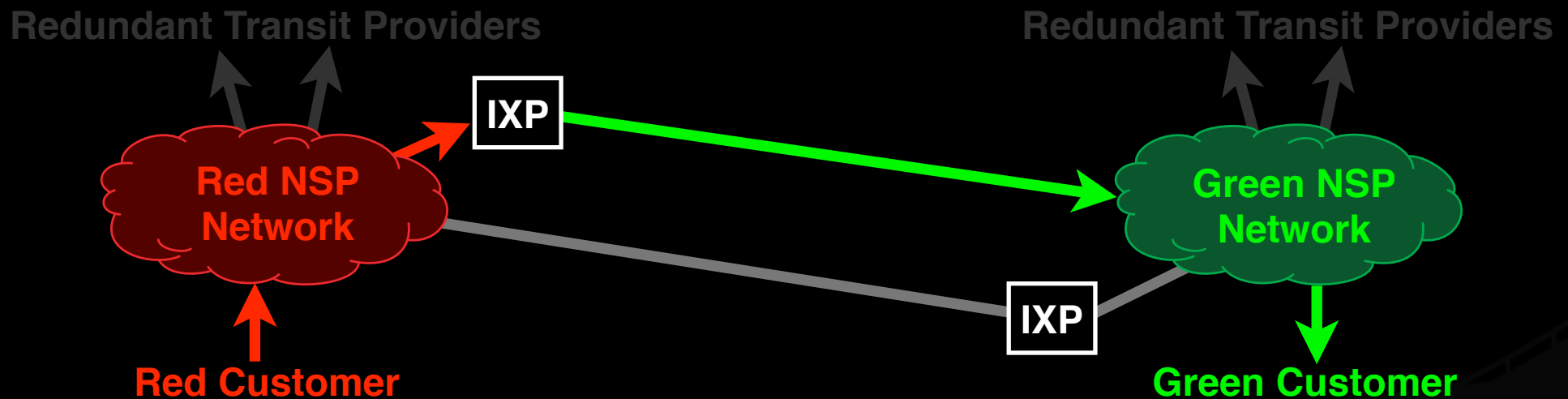
# Hot Potato Routing

## Green NSP backhauls from distant IXP



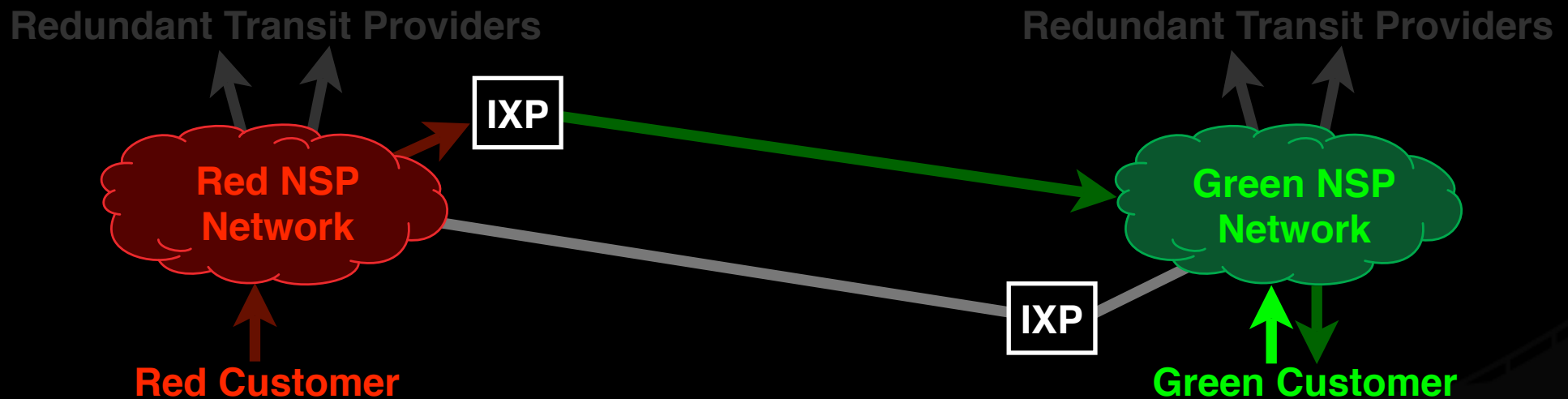
# Hot Potato Routing

## Green ISP delivers to Green Customer



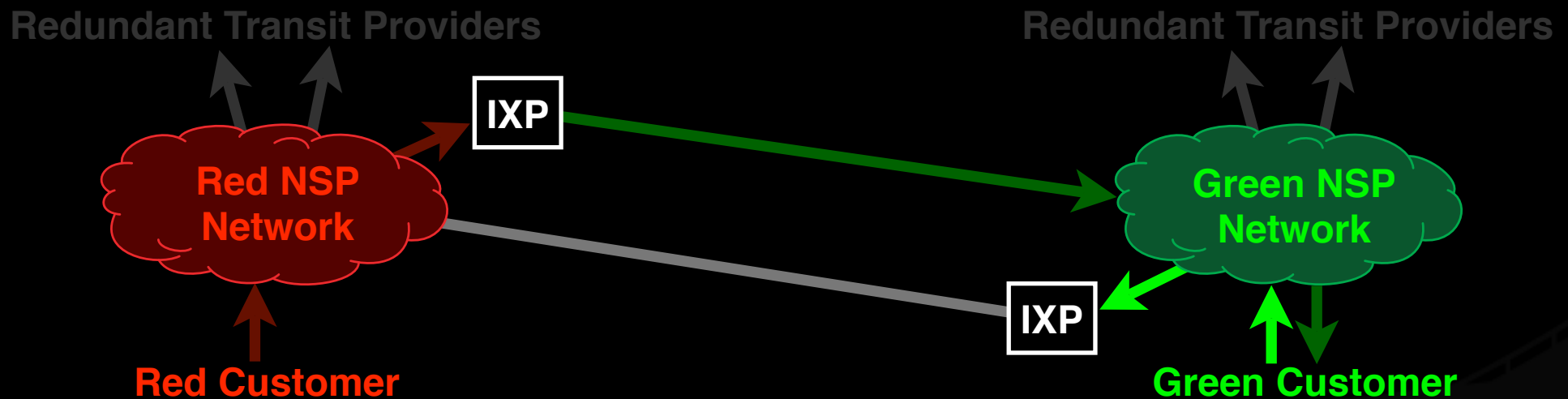
# Hot Potato Routing

## Green Customer replies via Green NSP



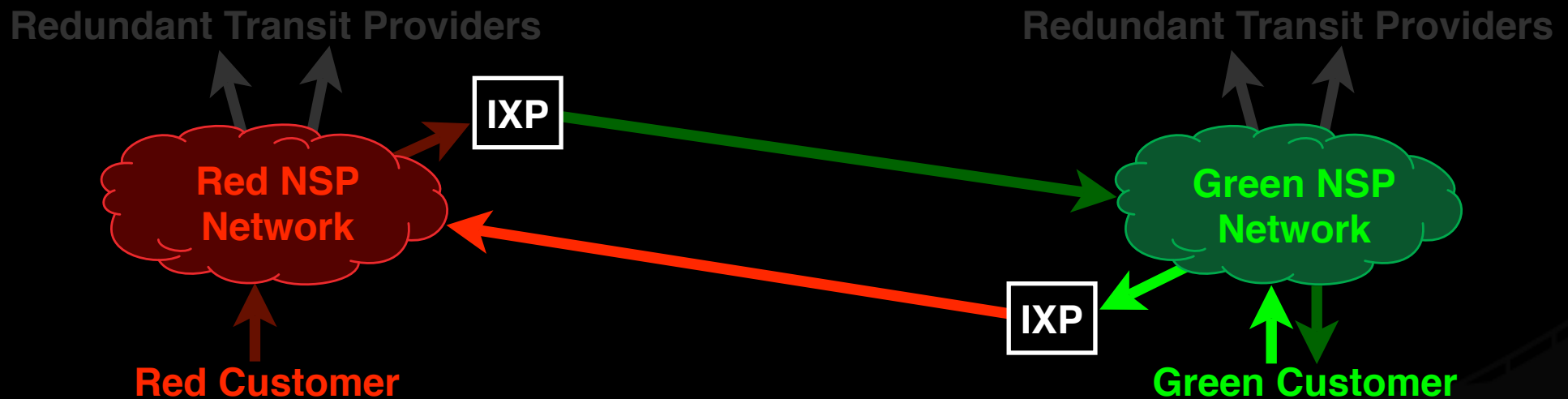
# Hot Potato Routing

**Green NSP delivers at nearest IXP**



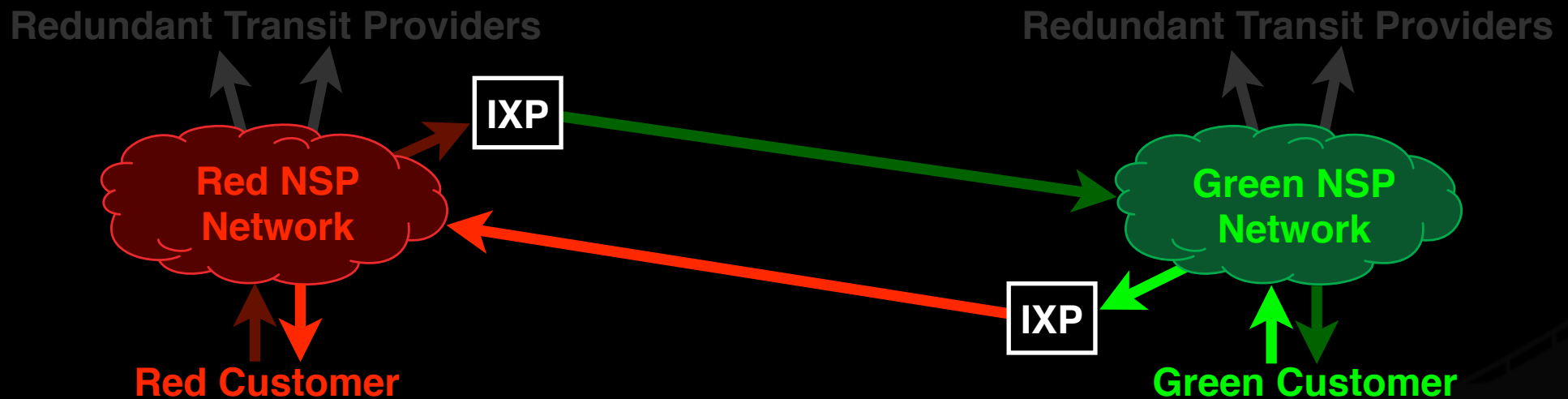
# Hot Potato Routing

## Red NSP backhauls from distant IXP



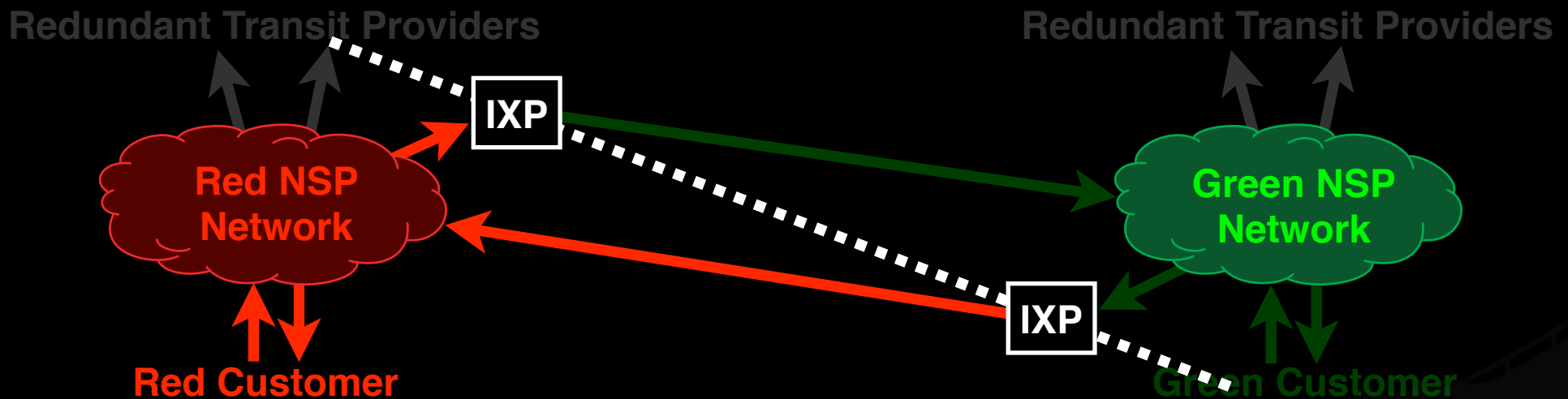
# Hot Potato Routing

Red NSP delivers to Red Customer



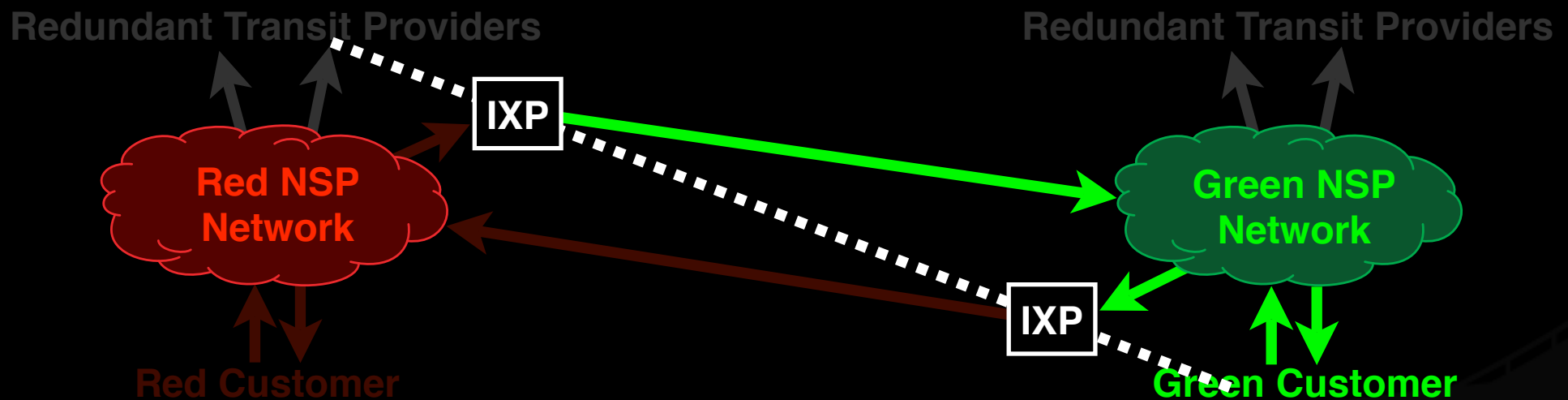
# Hot Potato Routing

**Red Network** is responsible for its own costs



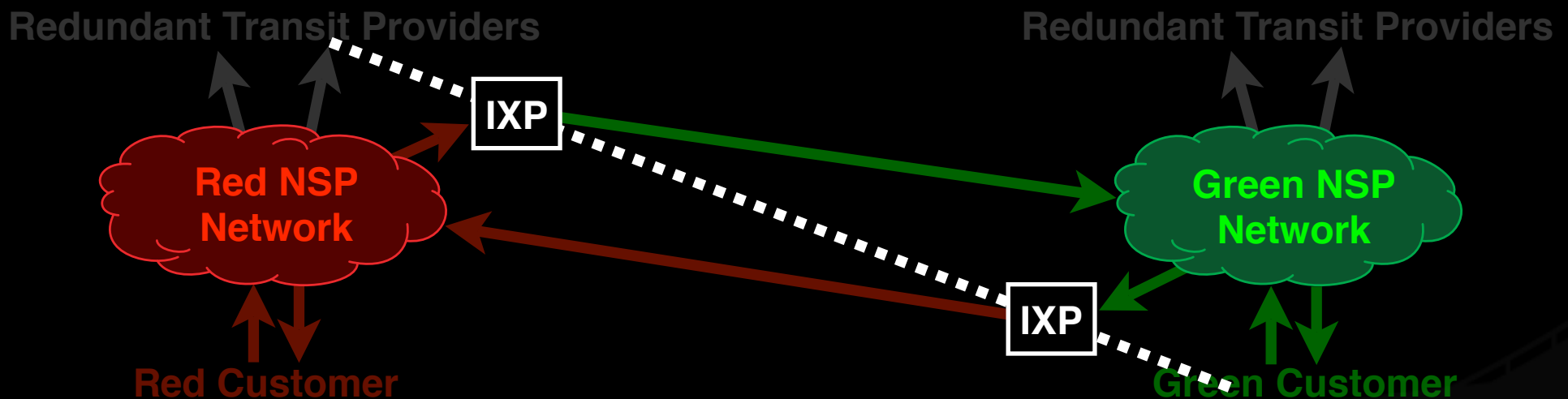
# Hot Potato Routing

**Green Network** is responsible for its own costs



# Hot Potato Routing

**Symmetry: Fair sharing of costs**



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

# 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.

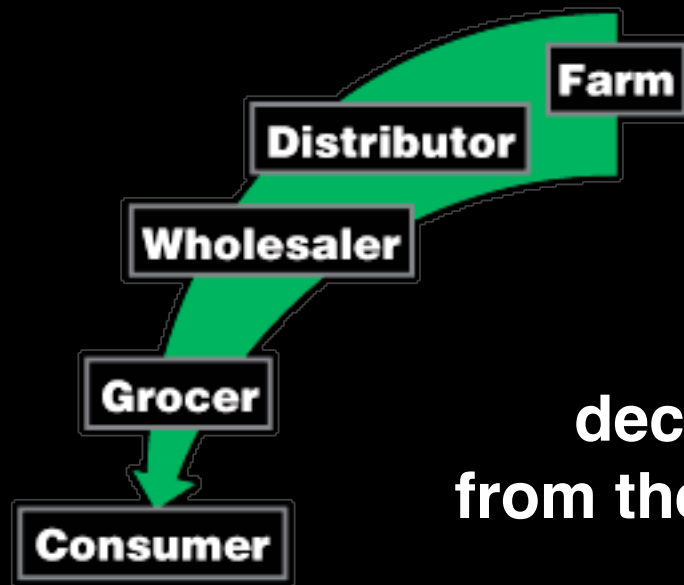
The value is produced at the point at which communication occurs between two ISPs, and it is transported to the customers who utilize it.

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.**

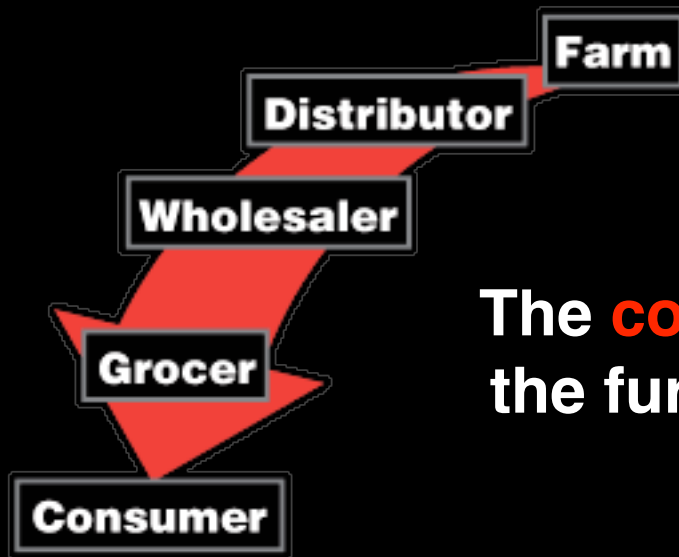
# Value decreases with time & distance



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

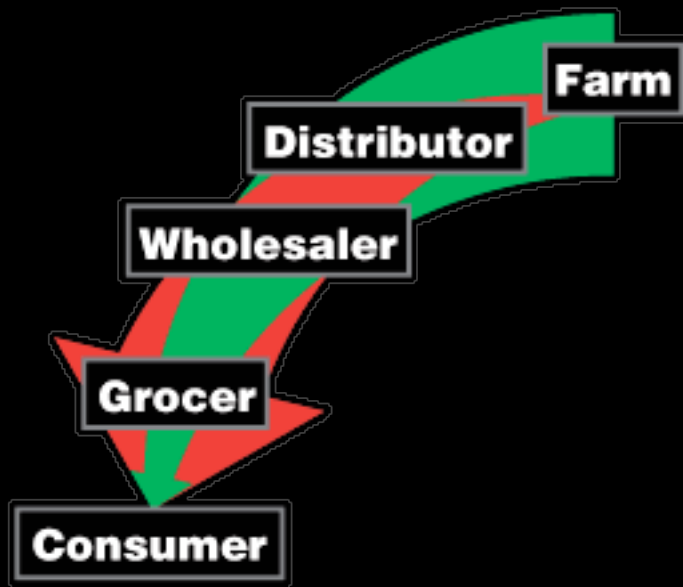
The shelf-life which the consumer can expect decreases, and eventually it becomes overripe, then rotten.

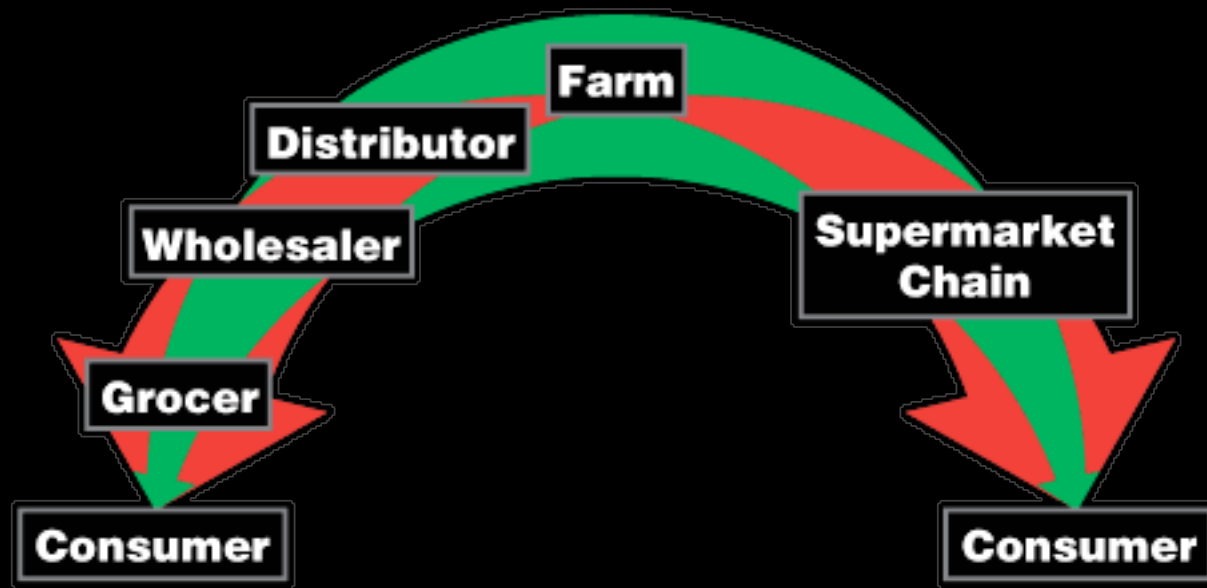
# Cost increases with time & distance



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

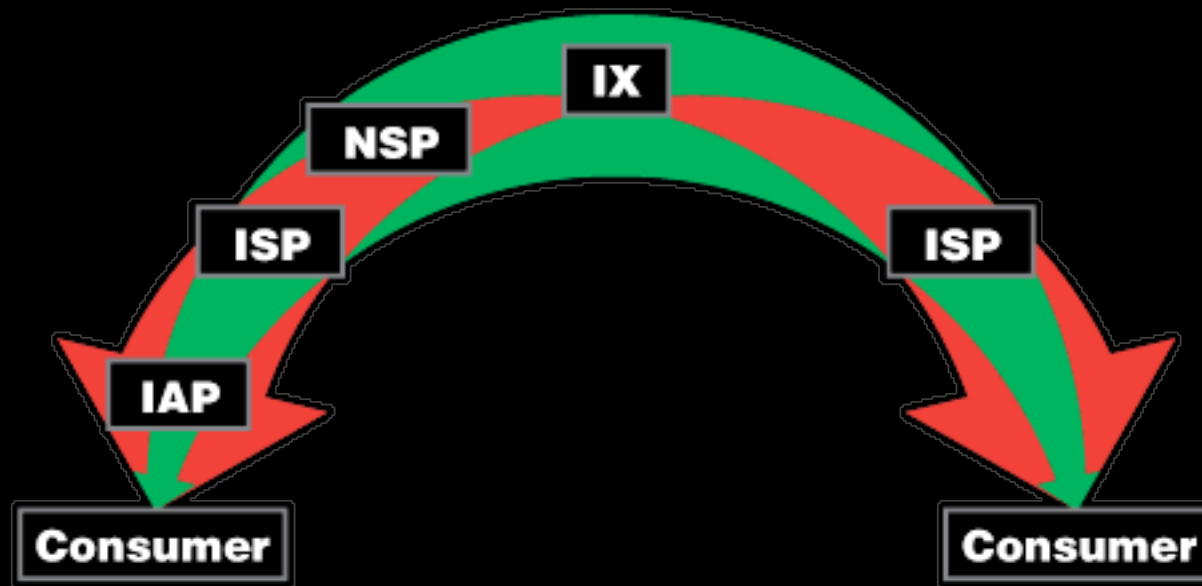
Salaries and hourly labor, warehouse leasing, diesel fuel, truck amortization, loss and spoilage, insurance, and other factors contribute additively.





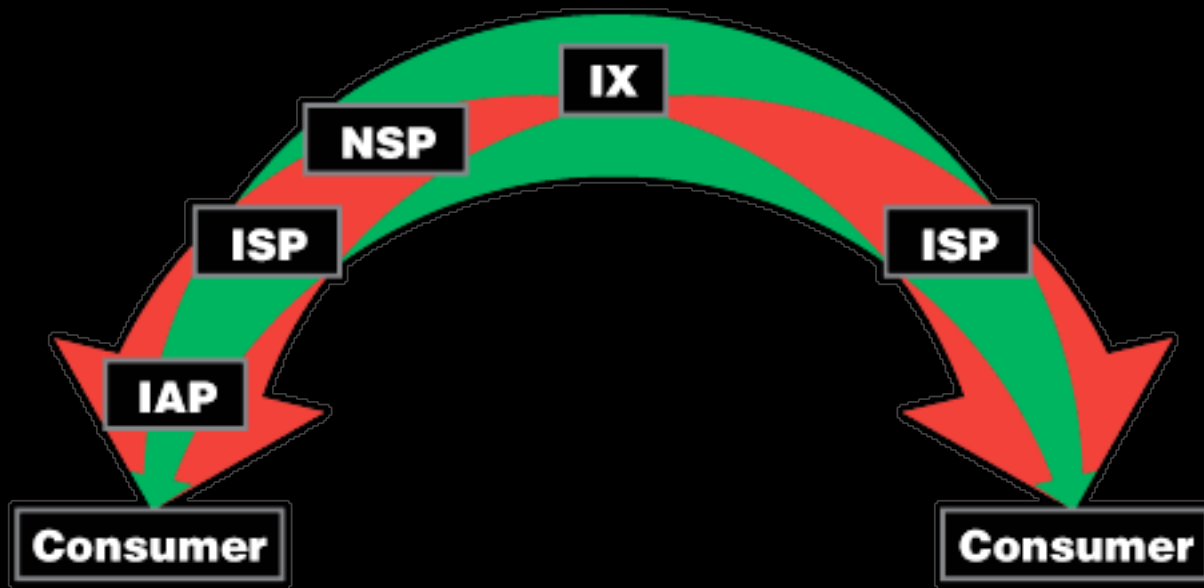
In a competitive environment, retail price is limited by competition, so time and distance influence the price more than the number of middlemen.

# The problem is the same:

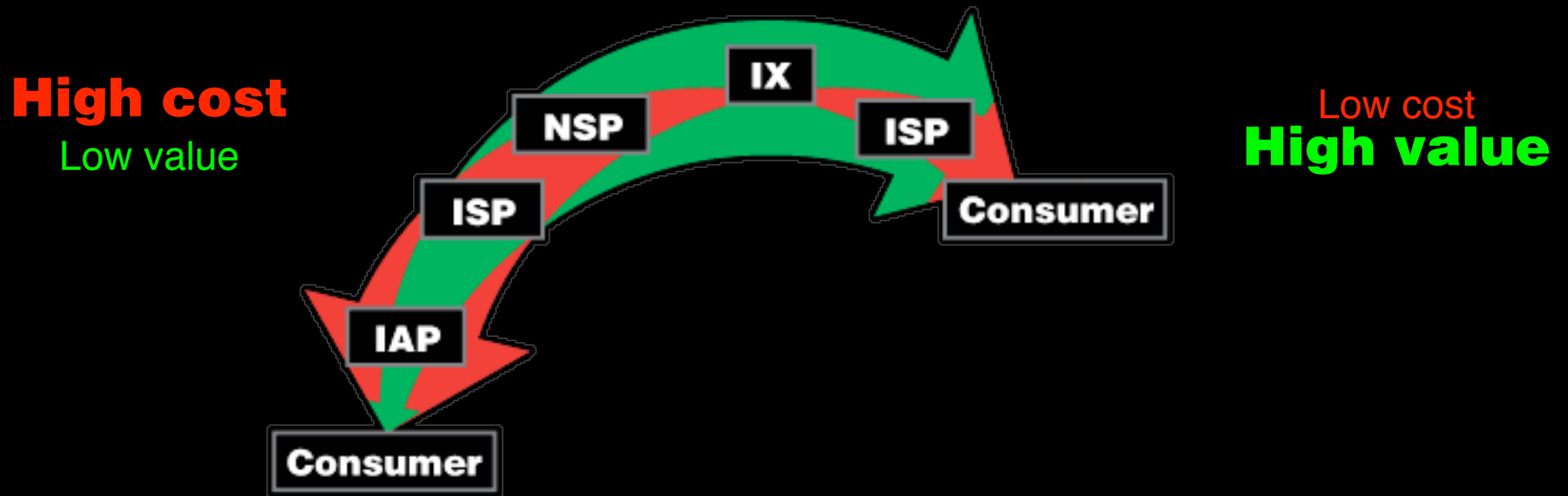


ISPs form a delivery chain, bringing perishable bits to the consumers who purchase them.

# So how do we improve things?



# Bring the customer nearer an IX...



...or bring an IX nearer the customer.

## 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.

# Thanks, and Questions?

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

**[http:// www.pch.net / resources / tutorials / ix-construction](http://www.pch.net/resources/tutorials/ix-construction)**

Bill Woodcock  
Research Director  
Packet Clearing House  
**woody@pch.net**