6.1800 Spring 2025

Lecture #10: Routing at scale, and with policy

Katrina's favorite protocol to teach

Katrina LaCurts | lacurts@mit.edu | 6.1800 2025

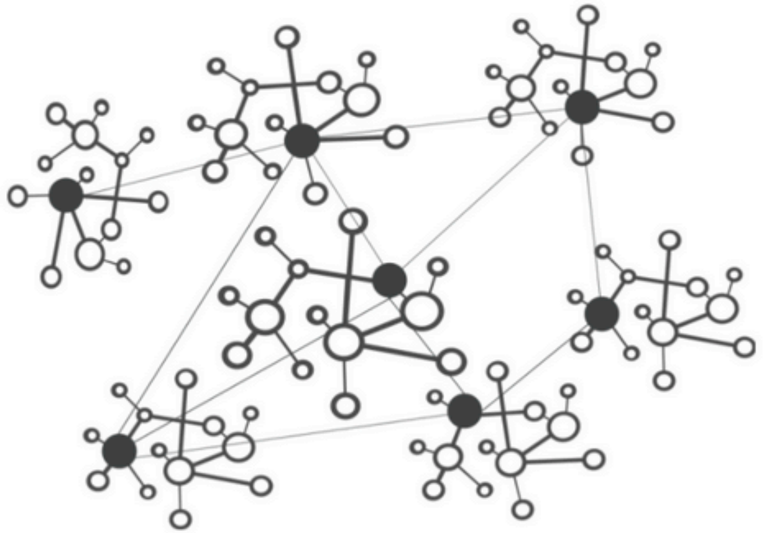
6.1800 in the news

Understanding How Facebook Disappeared from the Internet

10/04/2021

 Celso Martinho  Tom Strickx

This post is also available in 简体中文, 繁體中文, 日本語, 한국어, Deutsch, Français, Español, Português, Русский, and Italiano.



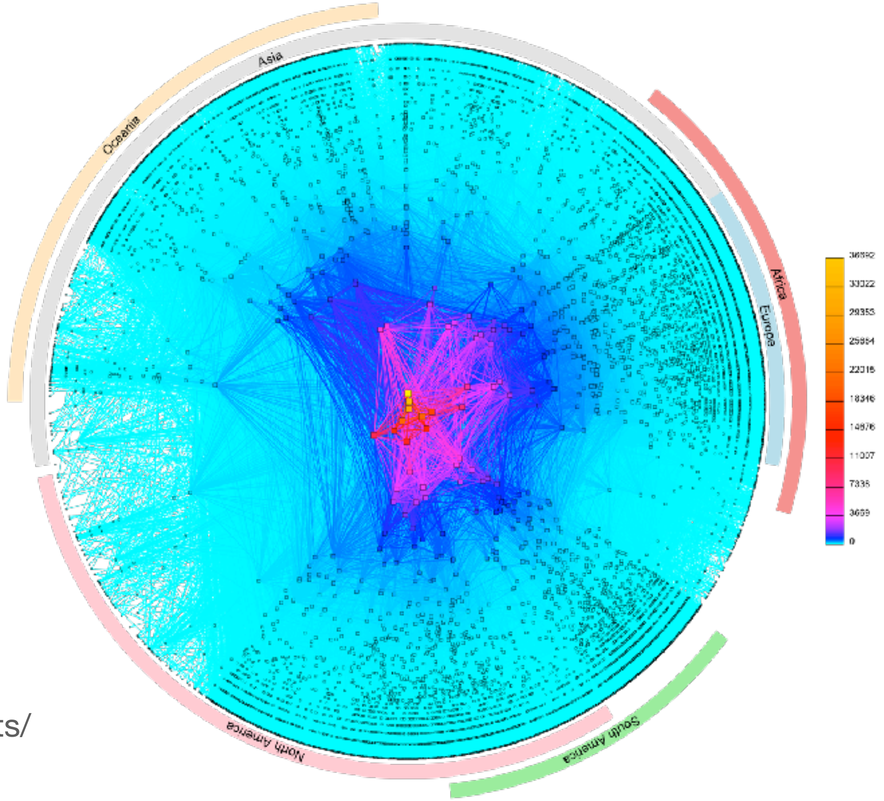
The Internet - A Network of Networks

"Facebook can't be down, can it?", we thought, for a second.

https://blog.cloudflare.com/october-2021-facebook-outage/

1970s: ARPAnet | 1978: flexibility and layering | early 80s: growth → change | late 80s: growth → problems | 1993: commercialization

hosts.txt | **distance-vector routing** | TCP, UDP | **OSPF**, EGP, DNS (a link-state routing protocol) | congestion collapse | policy routing | CIDR



CAIDA's IPv4 AS Core, January 2020 (https://www.caida.org/projects/cartography/as-core/2020/)

last time: neither distance-vector nor link-state routing will scale to the size of the Internet, nor do either let us address policy routing

application	the things that actually generate traffic
transport	sharing the network, reliability (or not) *examples: TCP, UDP*
network	naming, addressing, routing *examples: IP*
link	communication between two directly-connected nodes *examples: ethernet, bluetooth, 802.11 (wifi)*

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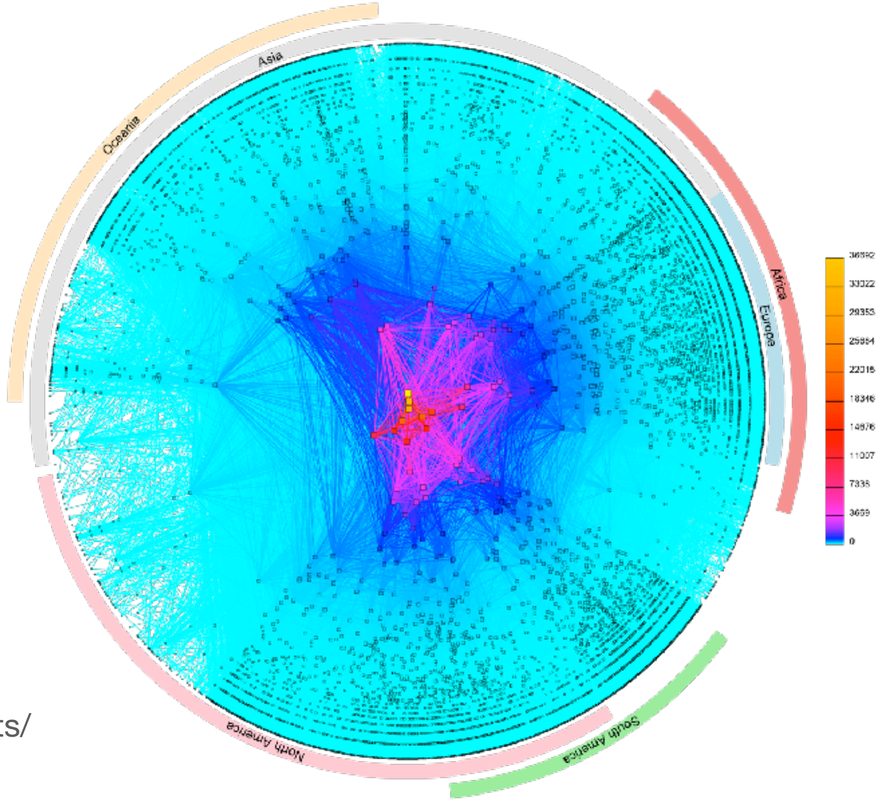

CAIDA's IPv4 AS Core, January 2020 (https://www.caida.org/projects/cartography/as-core/2020/)

this time: scale and policy!

(so we're thinking about the Internet specifically today, not just any network)

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transport	sharing the network, reliability (or not) *examples: TCP, UDP*
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neither one of these algorithms will scale to the size of the internet, nor do either of them allow for *policy routing*

	link state	**distance vector**
what's in an advertisement	its **link costs** to each of its **neighbors**	its **current costs** to **every node it's aware of**
who gets a node's advertisement	effectively, **every other node** (via flooding)	only its **neighbors**
what happens when things fail?	flooding makes link-state routing very resilient to failure	failures can be complicated because of timing
what limits scale?	the **overhead** of flooding	failure handling

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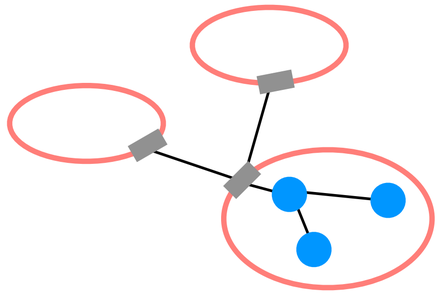

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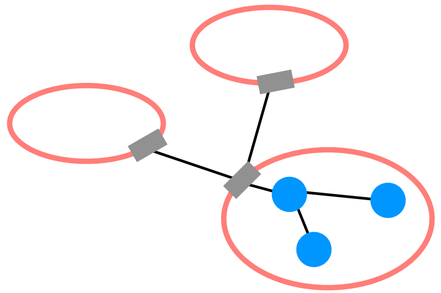

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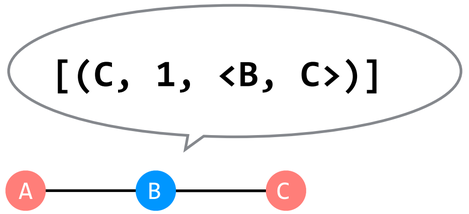

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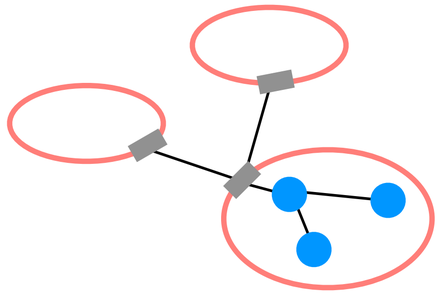

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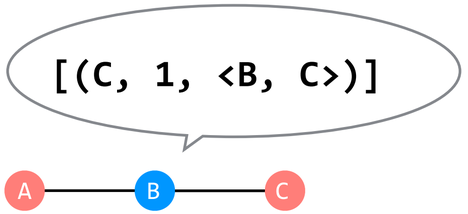

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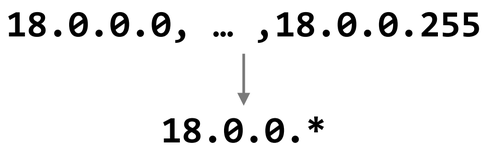

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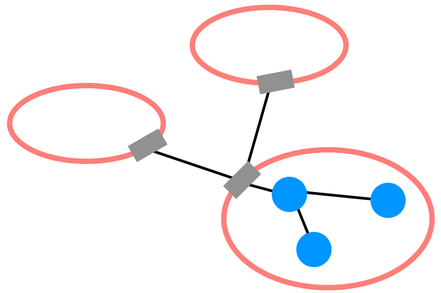

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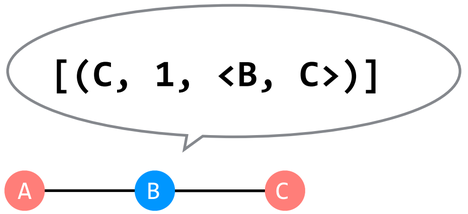

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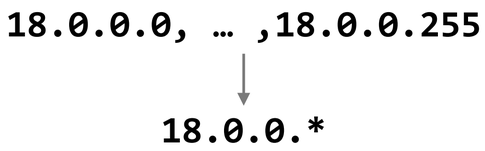

now that we have **scale**, we want a means to implement **policy**

common AS relationships

arrows describe the flow of money; traffic may flow in both directions

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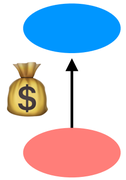

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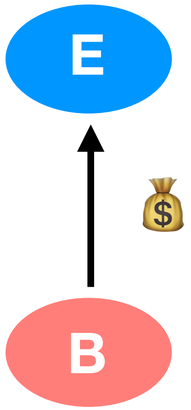

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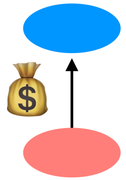

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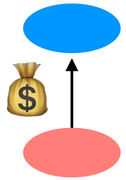

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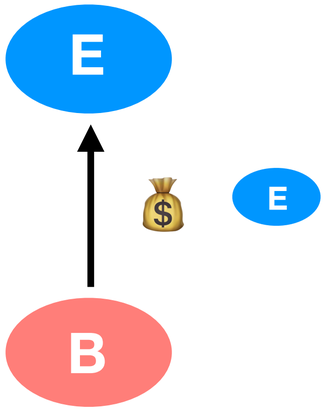

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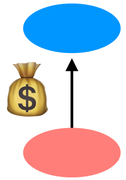

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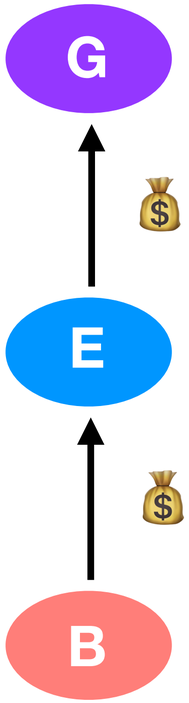

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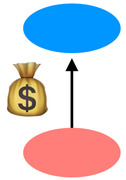

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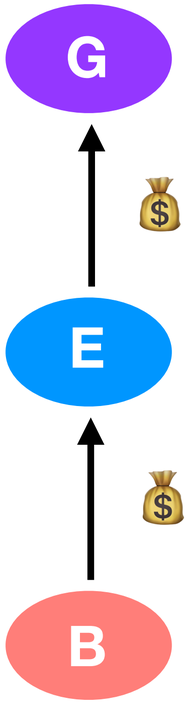
typically a provider will charge more money to its customers than it pays its own provider, so E makes a profit when traffic flows between B and G



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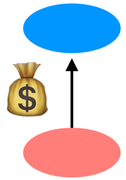

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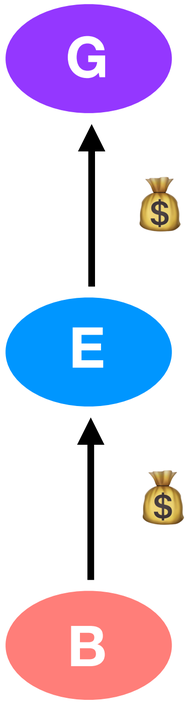

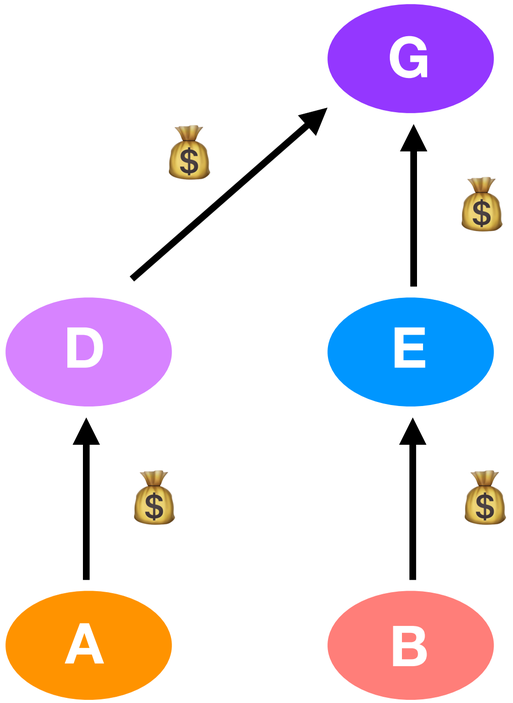

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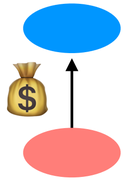

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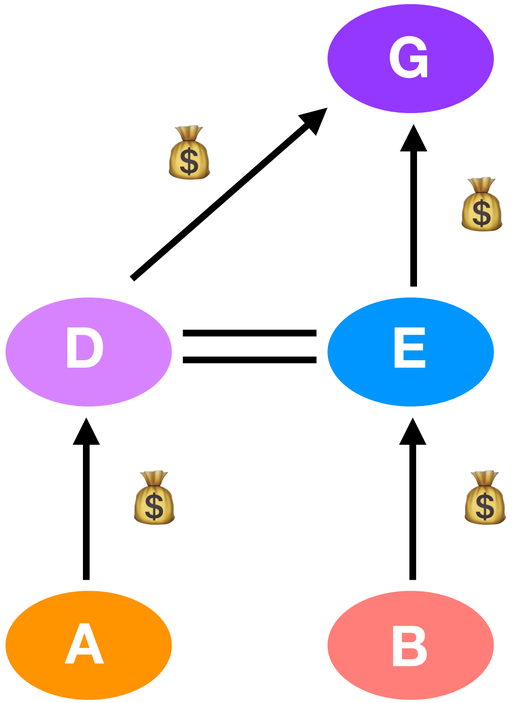

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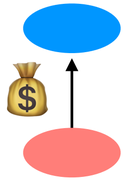

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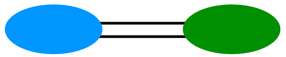
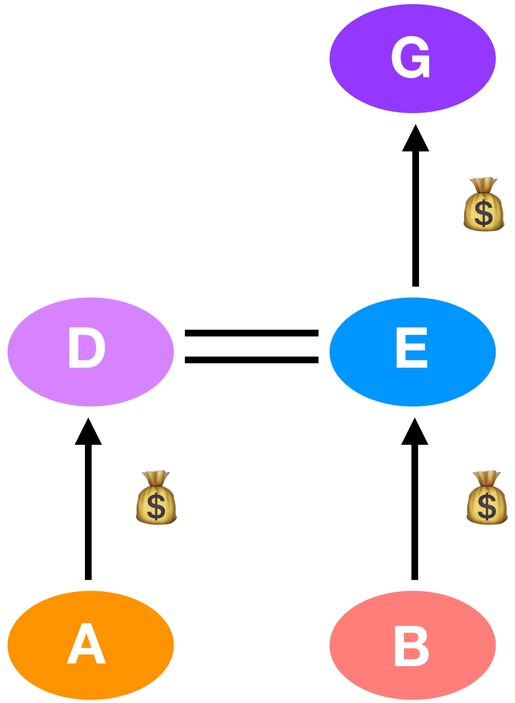


peers allow (free*) mutual access to each other's customers

*as long as the amount of traffic in each direction is roughly equal



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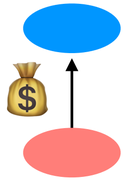

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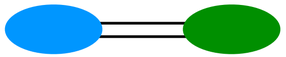

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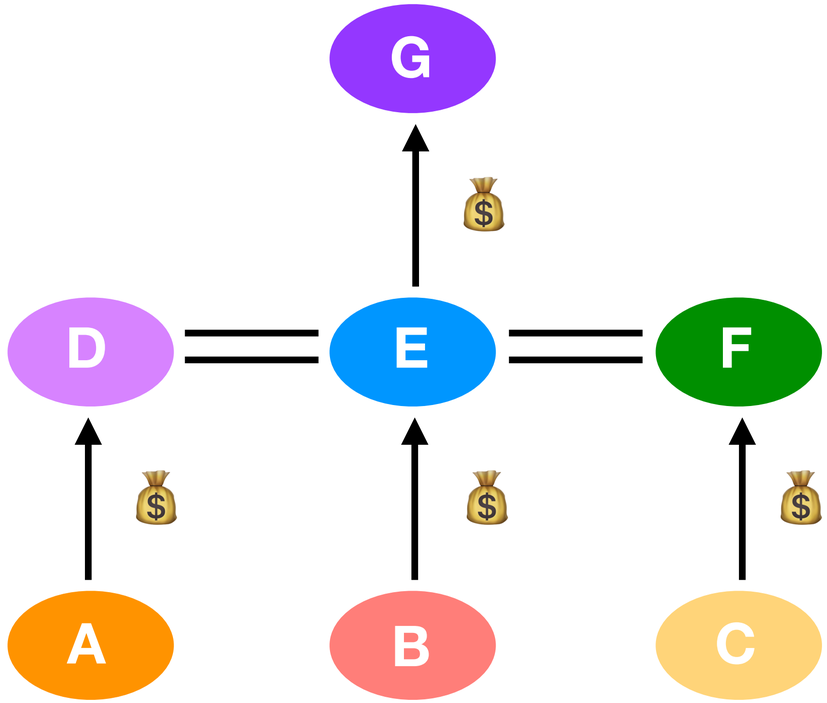

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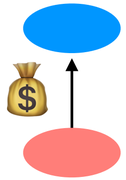

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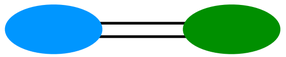

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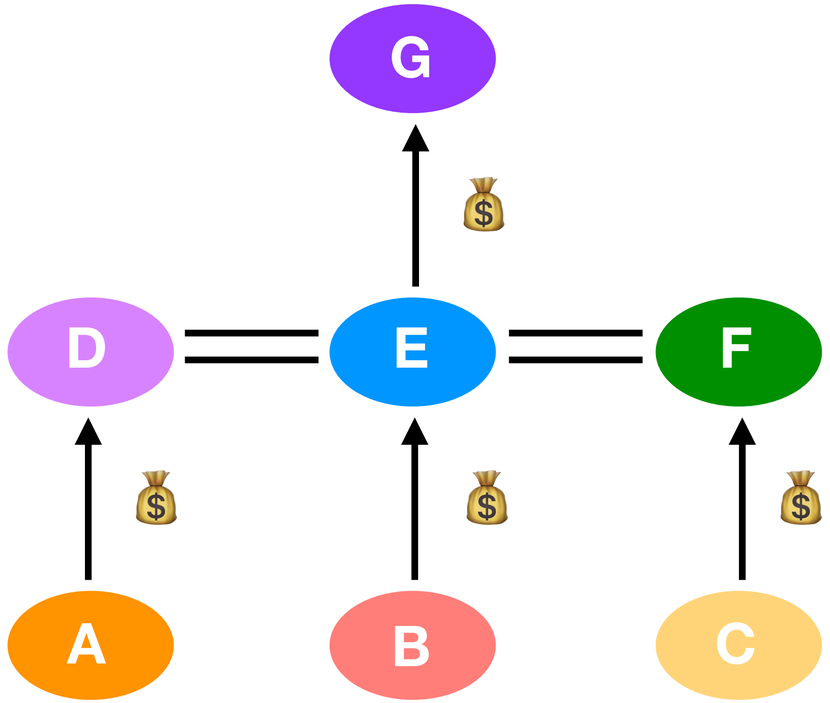

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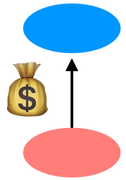

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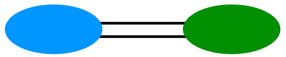

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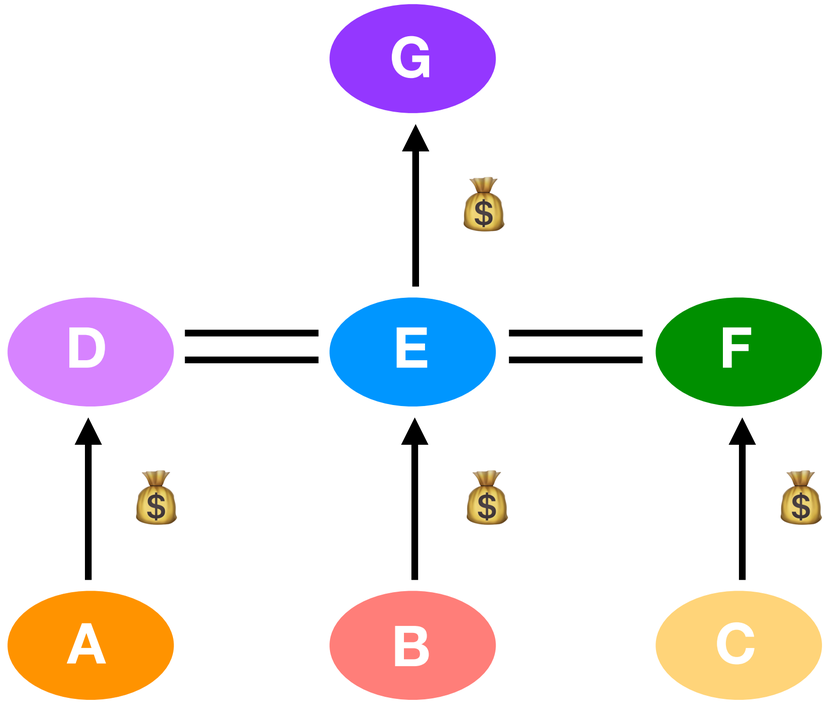

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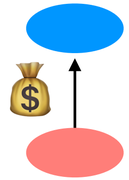

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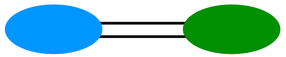

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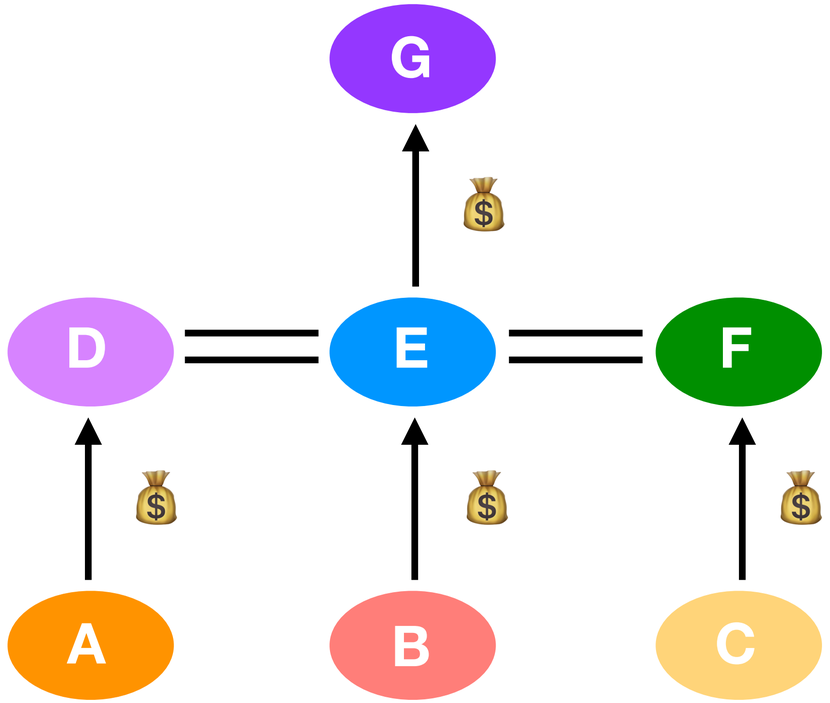

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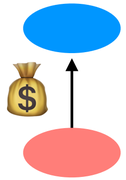

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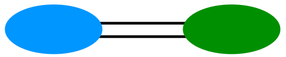

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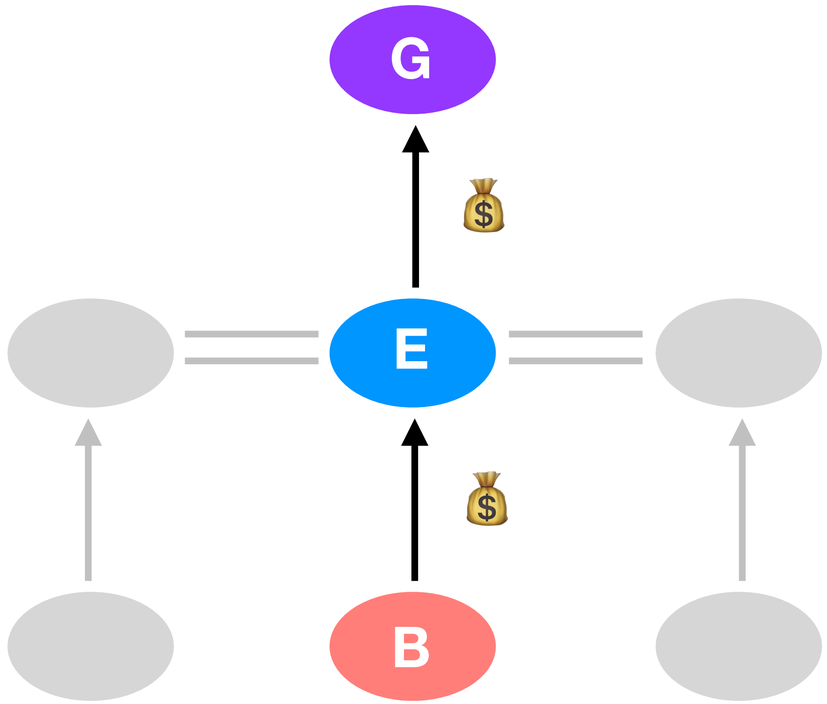
these relationships are reflected in **export policies**

which routes to advertise, and to whom



we're focusing on the middle node (E) right now; ignore the gray nodes

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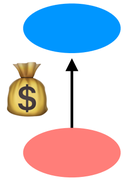

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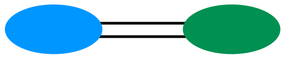

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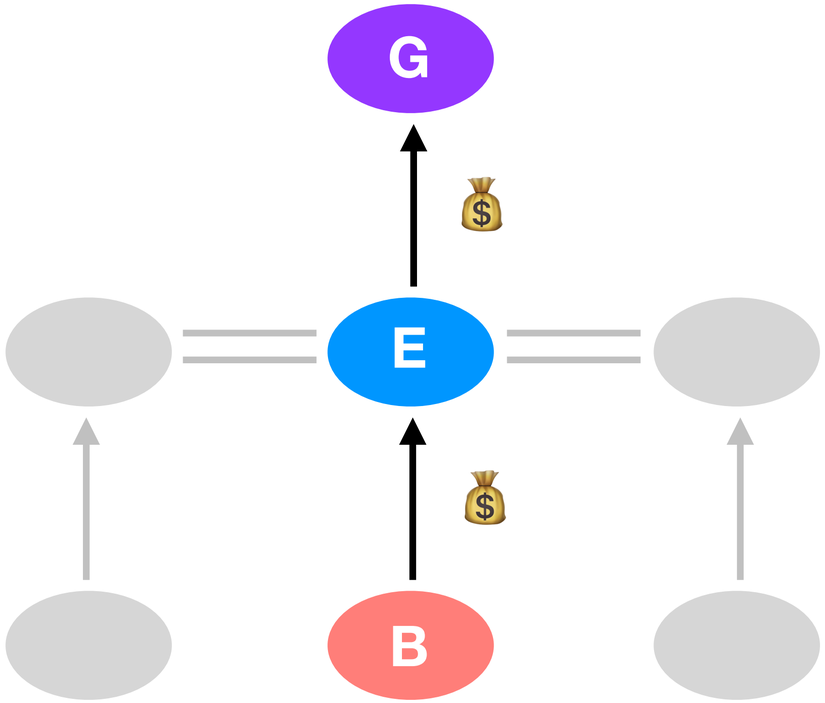
a provider wants its customers to send and receive *as much traffic through the provider as possible*



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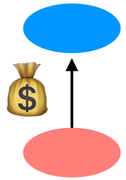

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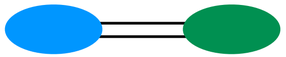

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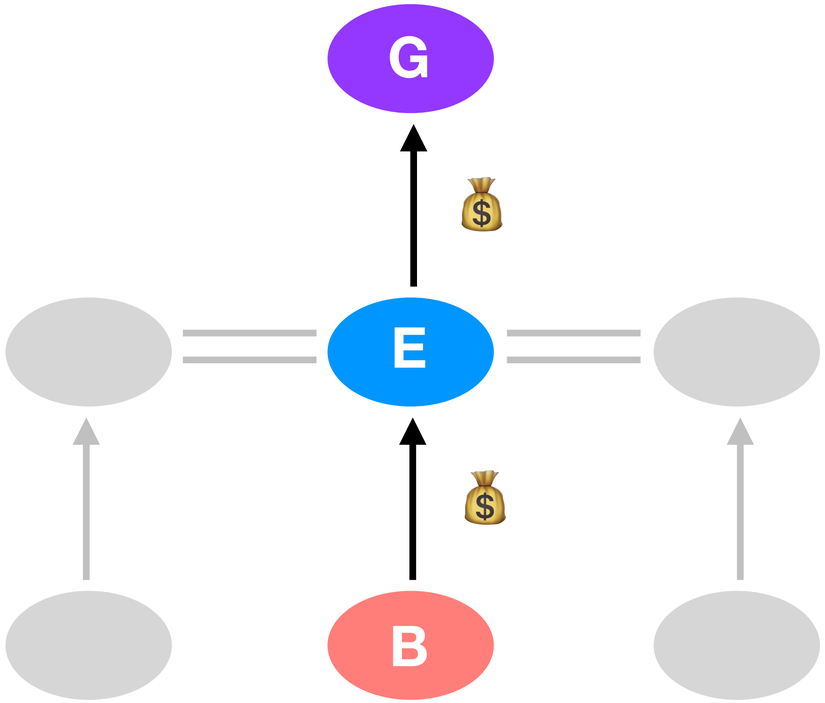

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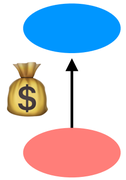

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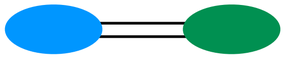

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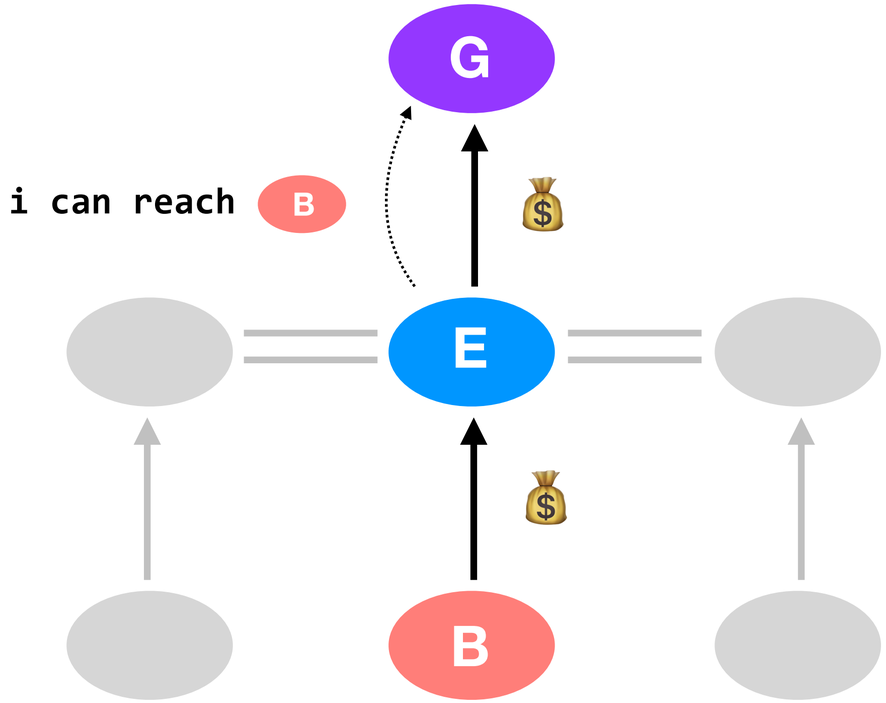

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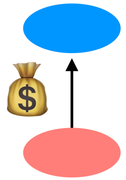

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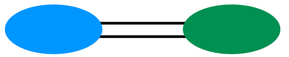

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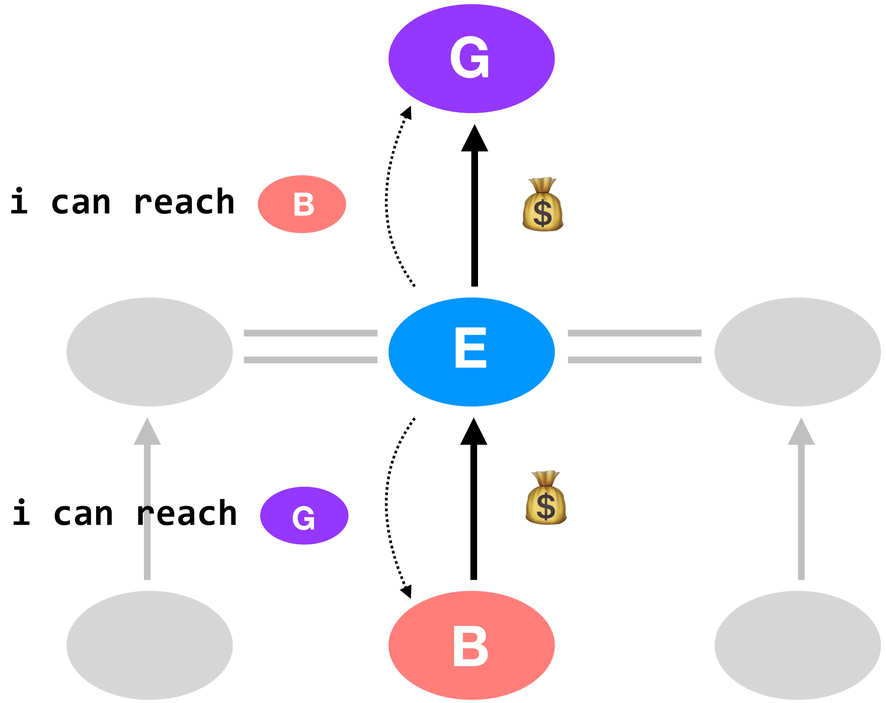

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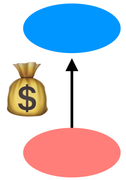

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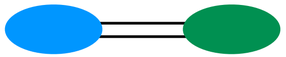

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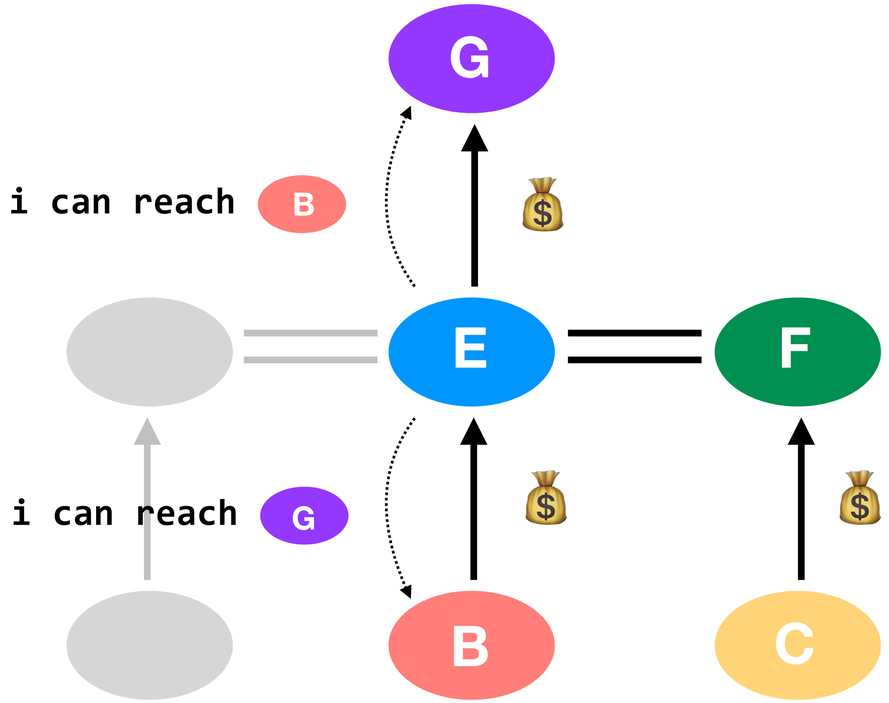

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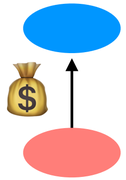

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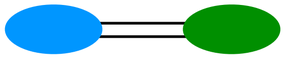

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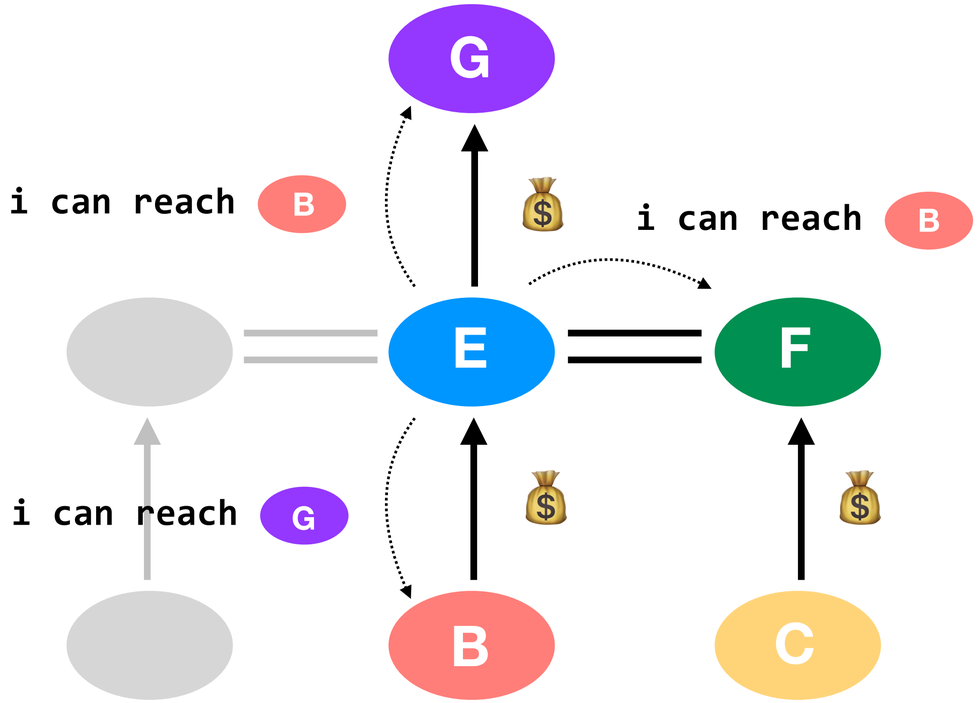

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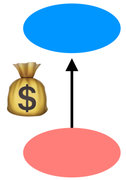

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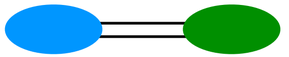

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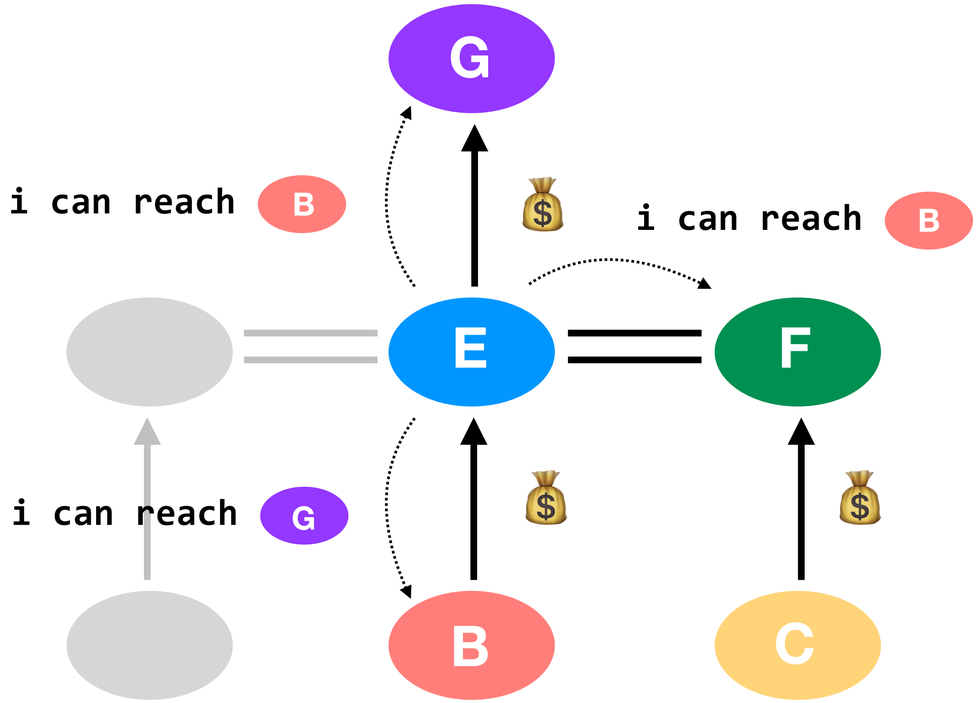

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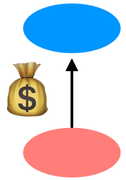

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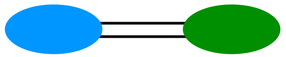

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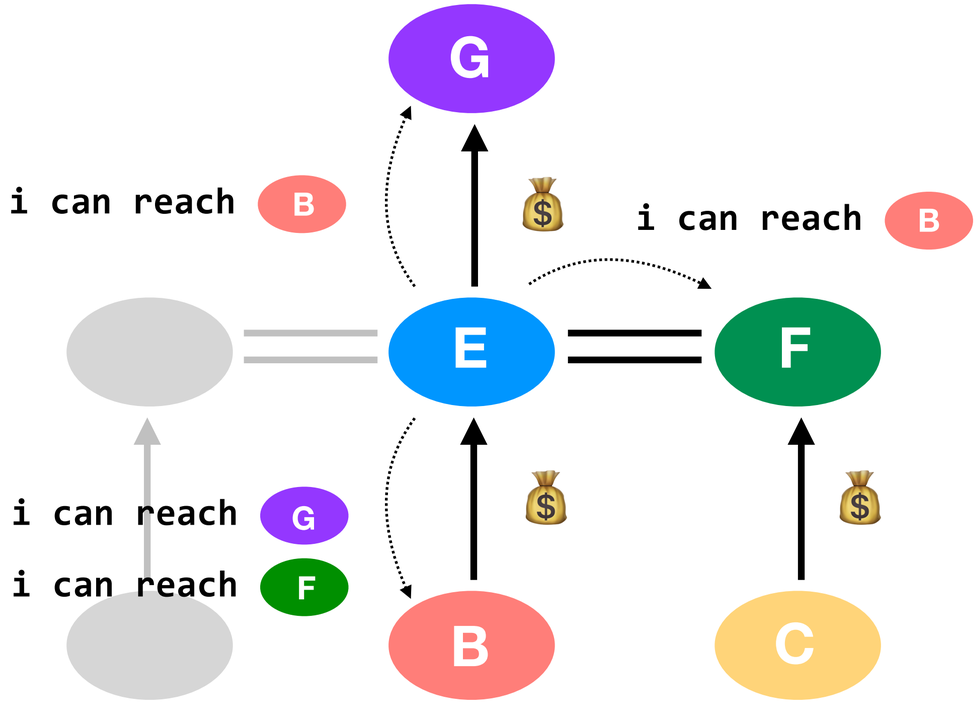

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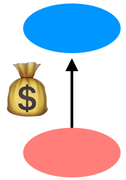

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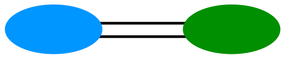

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question: after all advertisements have been sent, does C know about a route to G?

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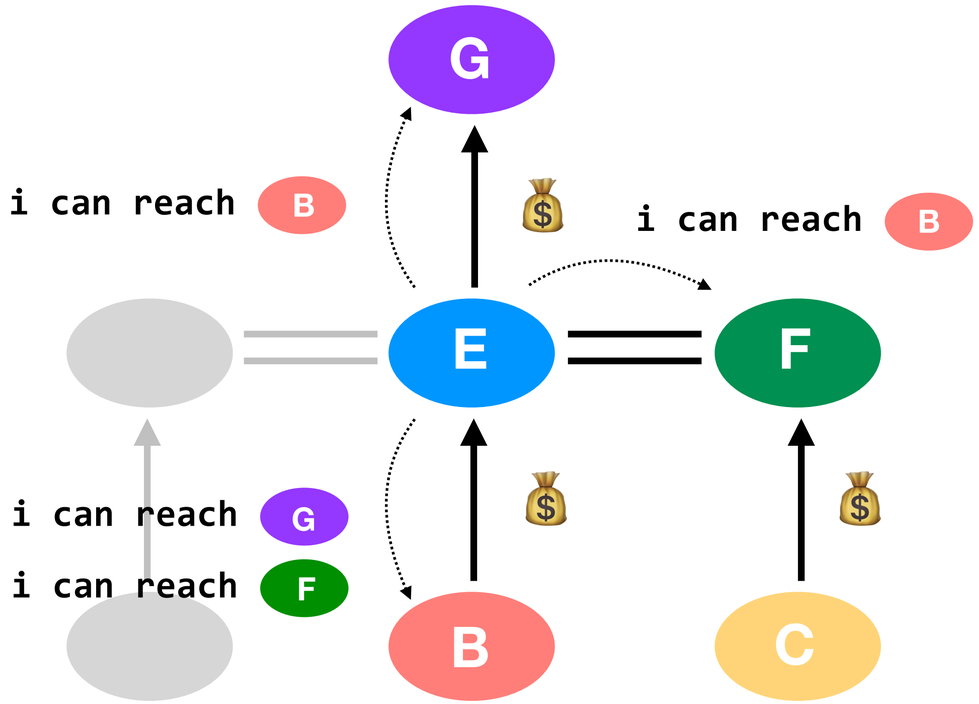

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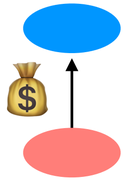

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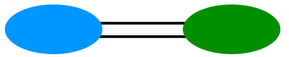

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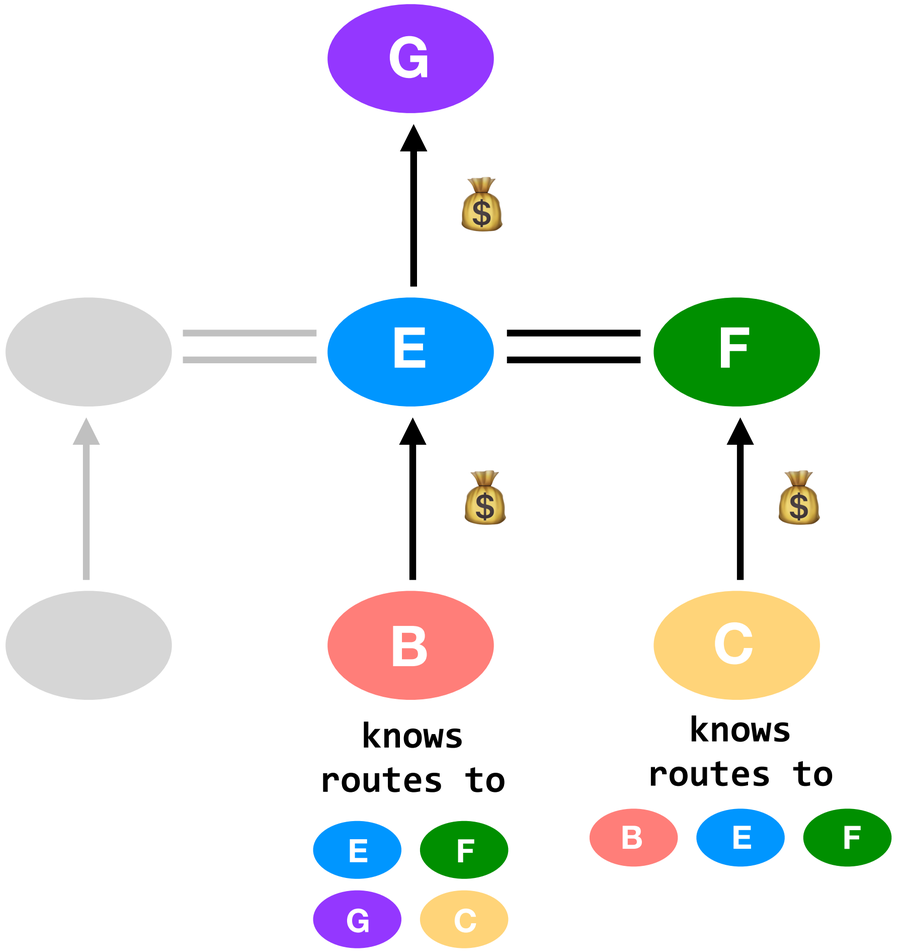

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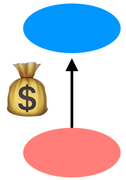

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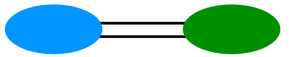

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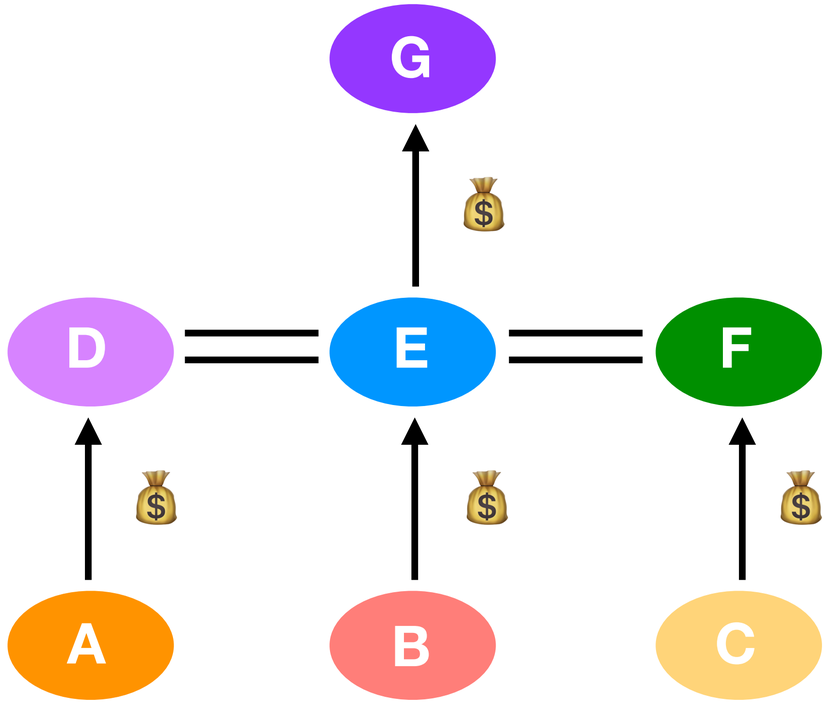

in fact, there are quite a few ASes here that are disconnected from one another

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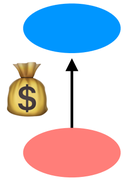

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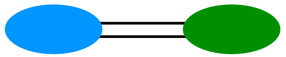

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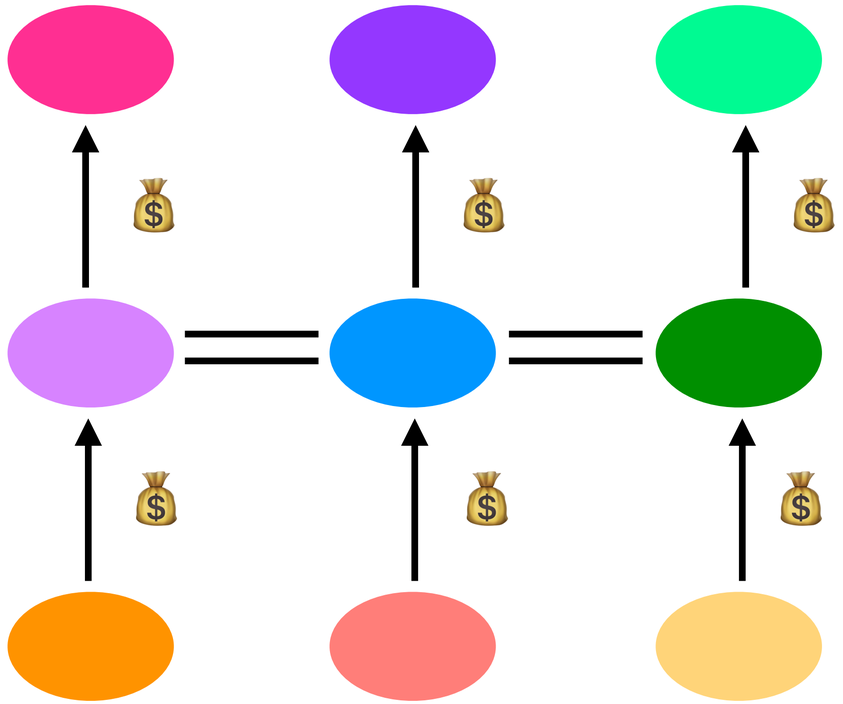

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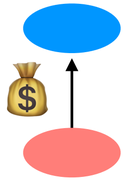

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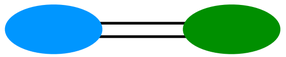

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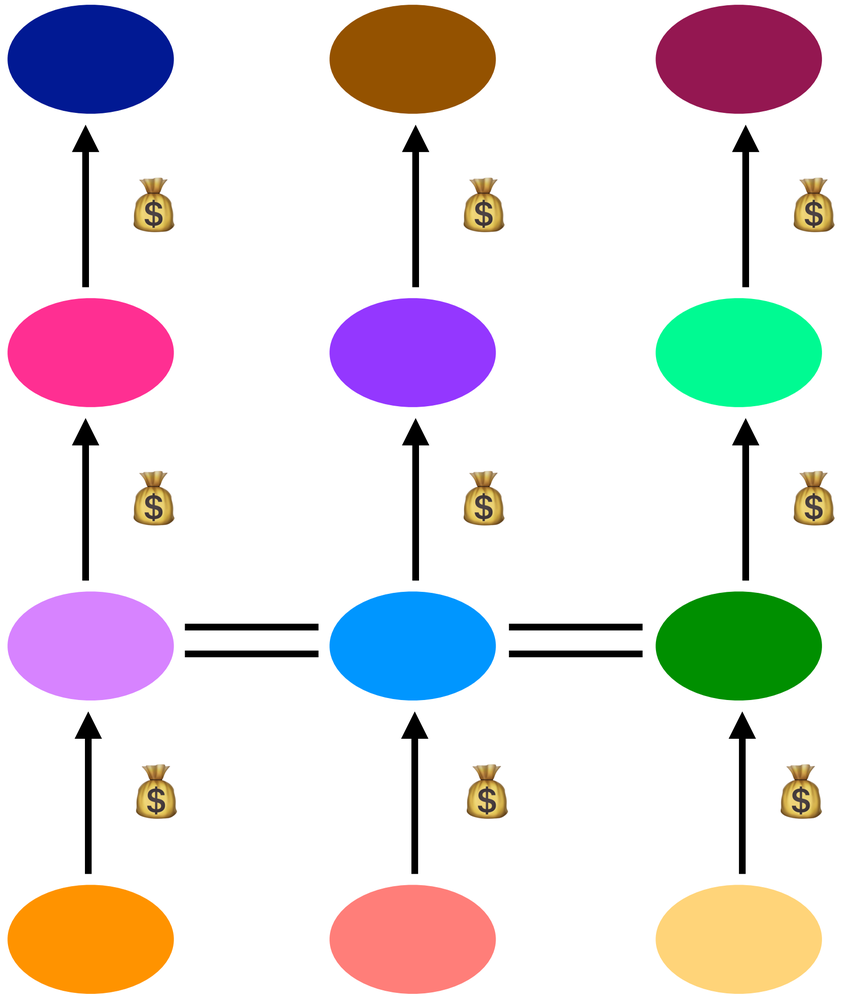

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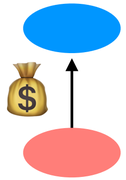

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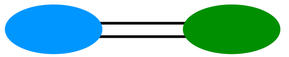

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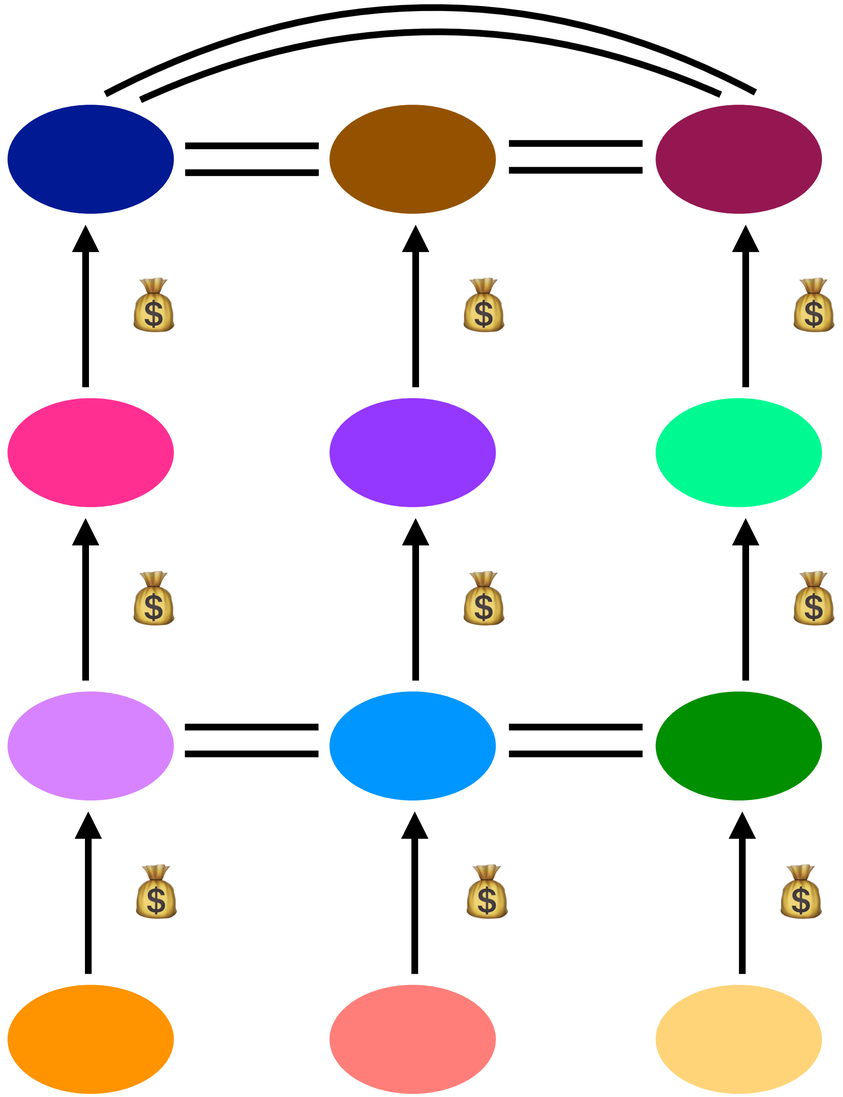

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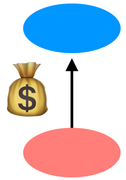

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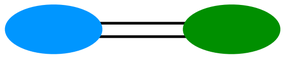

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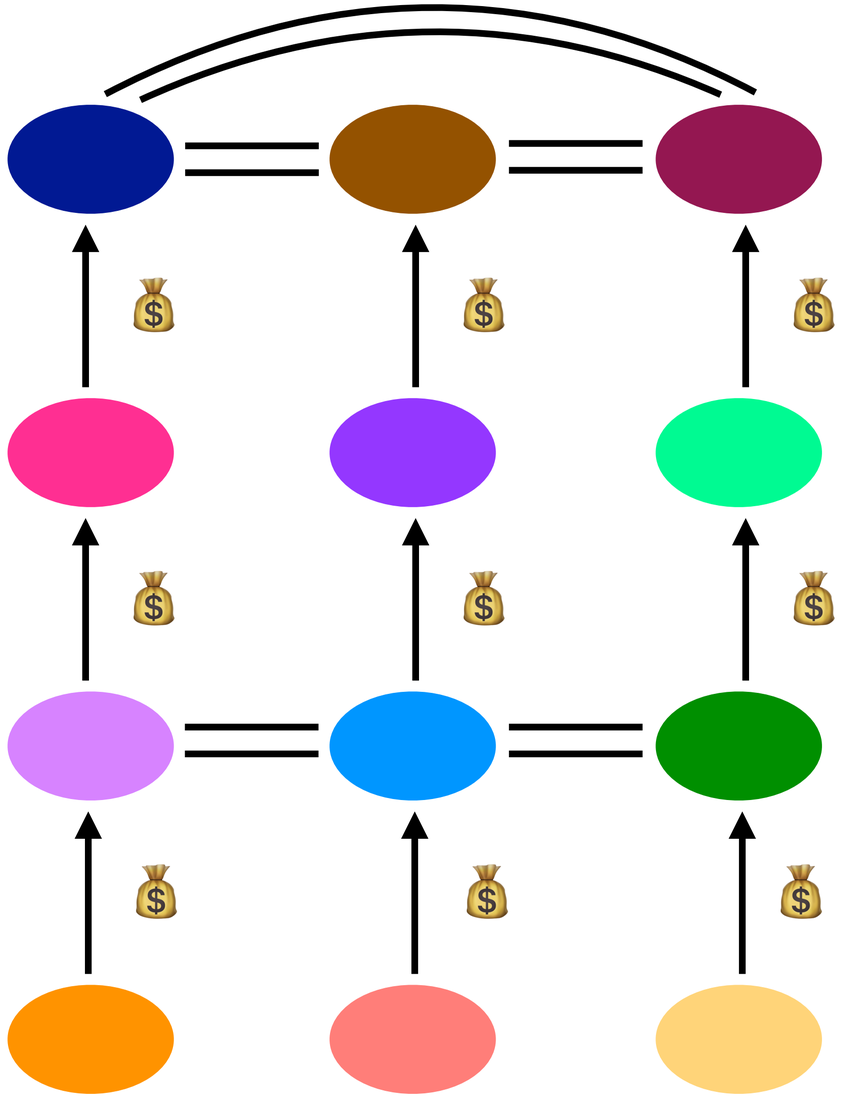

on the Internet, all of the top tier (“tier-1”) ISPs peer, to provide global connectivity

this is an extremely simplified diagram. you’d expect to see other sorts of peering agreements in this graph, and in fact other sorts of AS relationships

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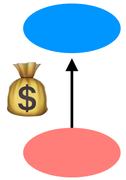

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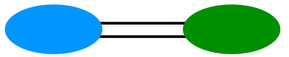

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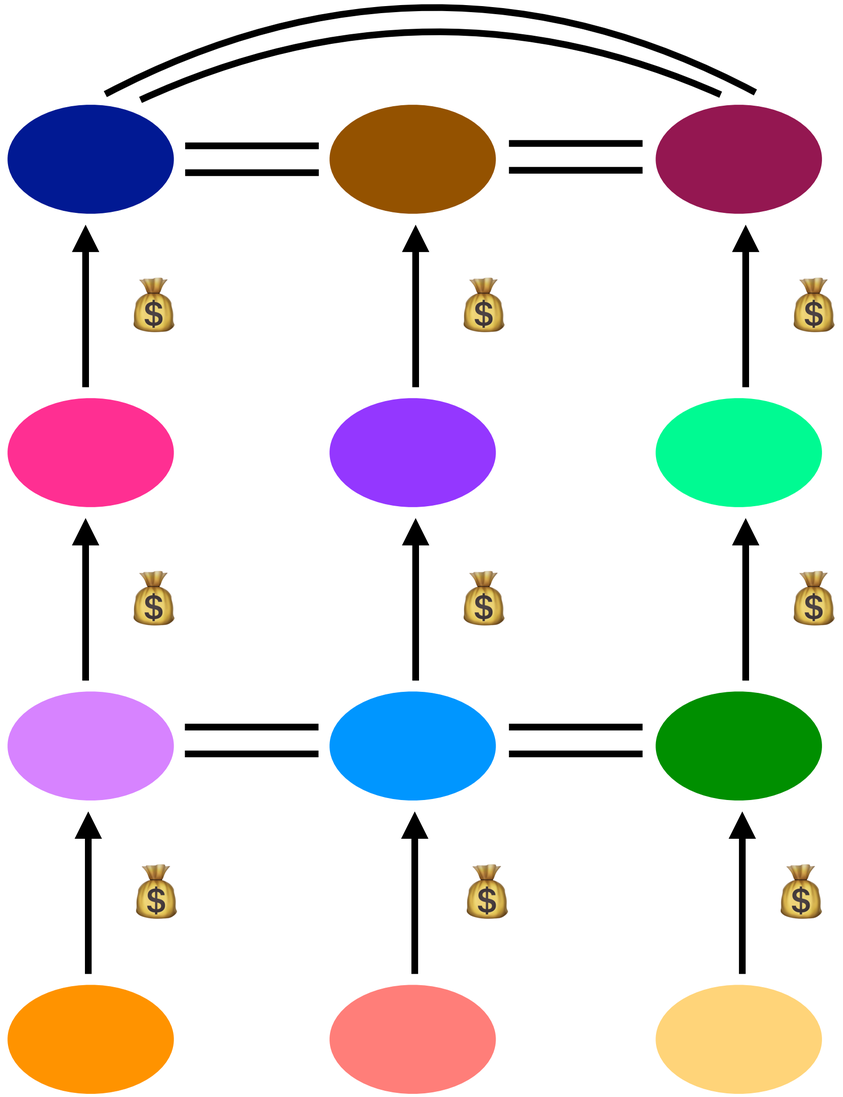
Katrina LaCurts | lacurts@mit.edu | 6.1800 2025



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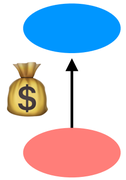
common AS relationships

arrows describe the flow of money; traffic may flow in both directions



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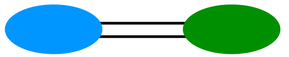

peers allow (free*) mutual access to each other’s customers

*as long as the amount of traffic in each direction is roughly equal

these relationships are also reflected in **import policies**

which routes to *use*

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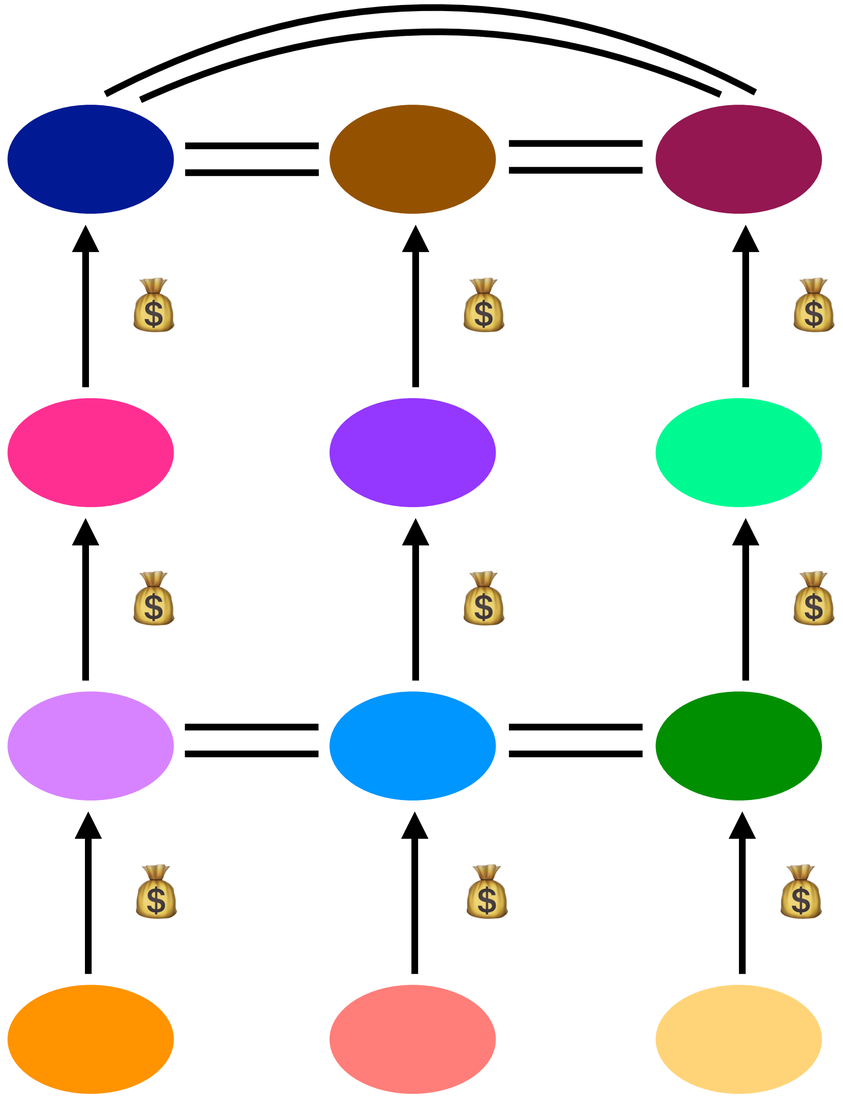

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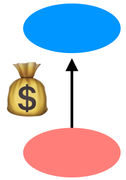

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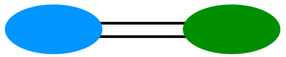

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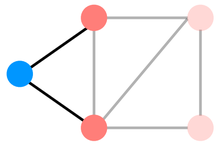
ASes set their own *import policies*. typically, if an AS hears about multiple routes to a destination, it will prefer to use its customers first, then peers, then providers

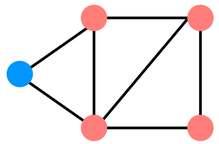
if that’s not enough, a variety of other attributes are provided

BGP as a distributed routing protocol

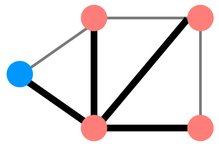
1. nodes learn about their neighbors via the `HELLO` protocol



2. nodes learn about other reachable nodes via advertisements



3. nodes determine the minimum-cost routes (of the routes they know about)



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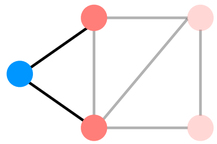

nodes send “KEEPALIVE” messages to their neighbors once every ~sixty seconds

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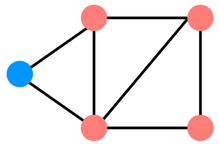

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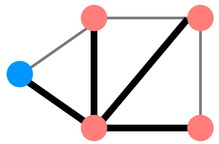

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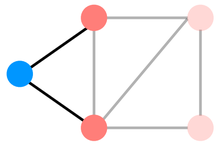

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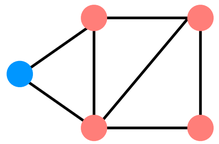

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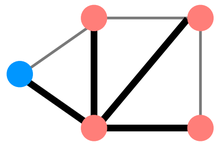

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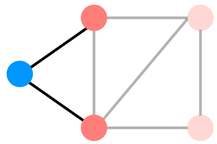

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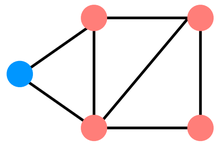

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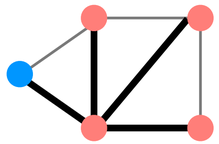

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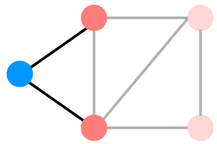

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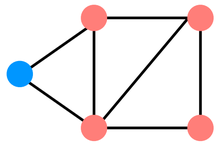

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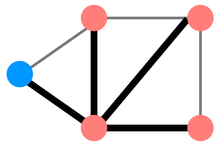

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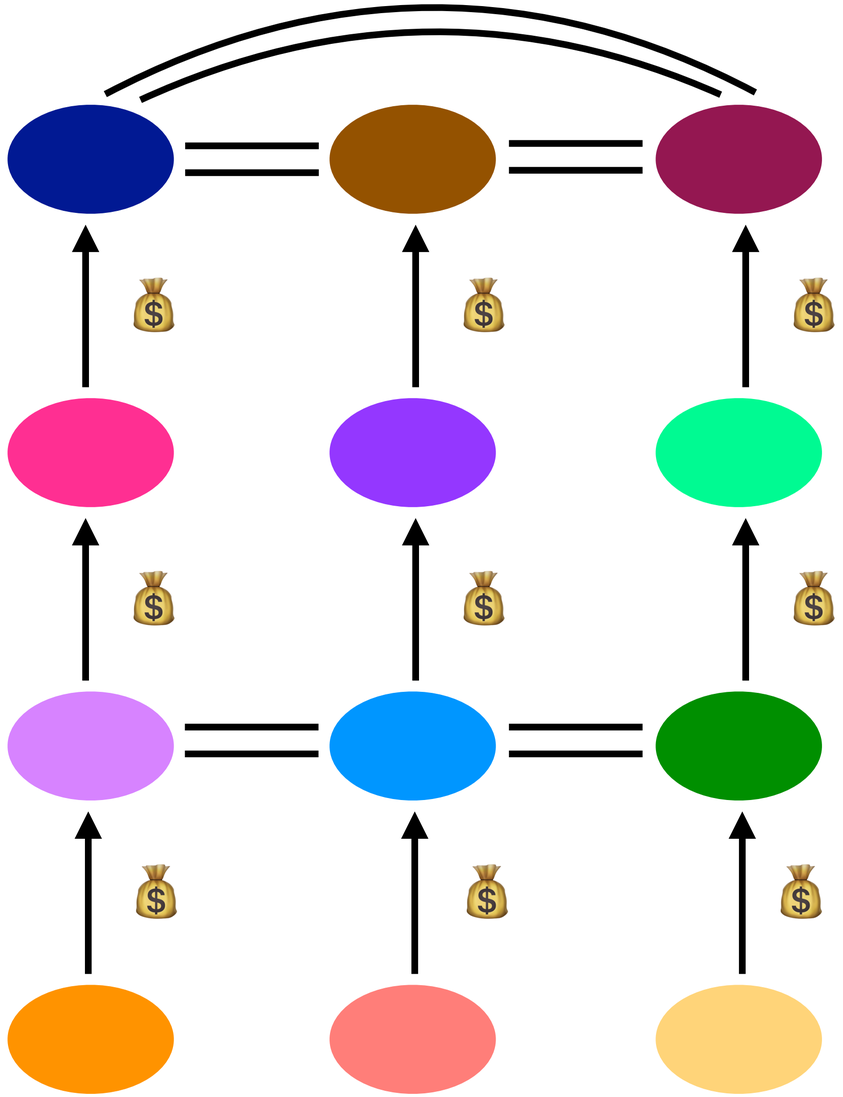

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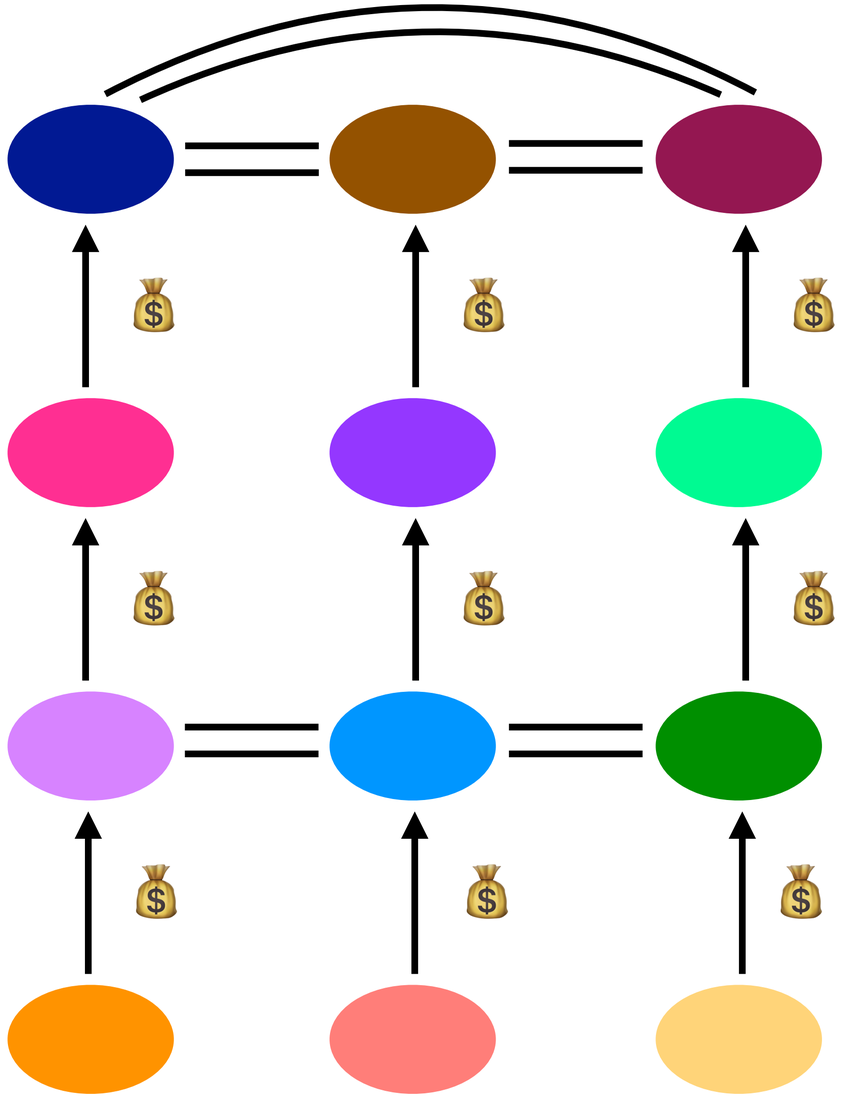

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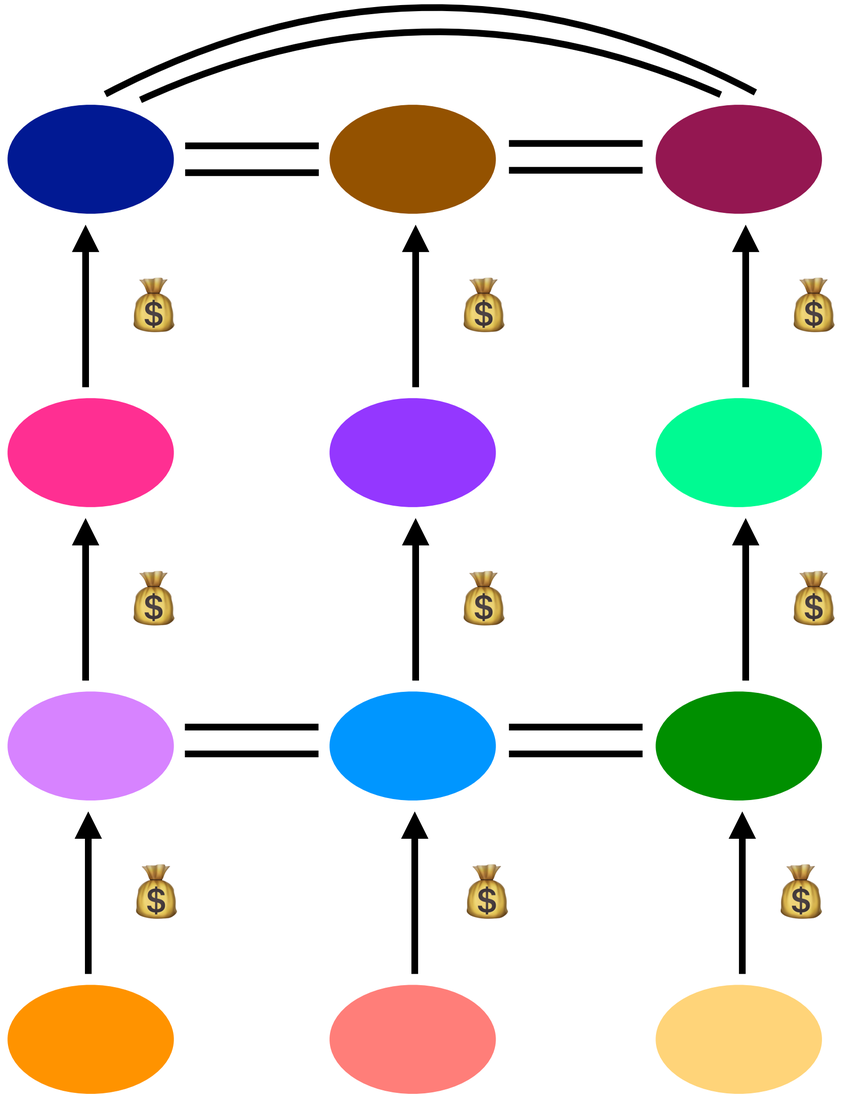

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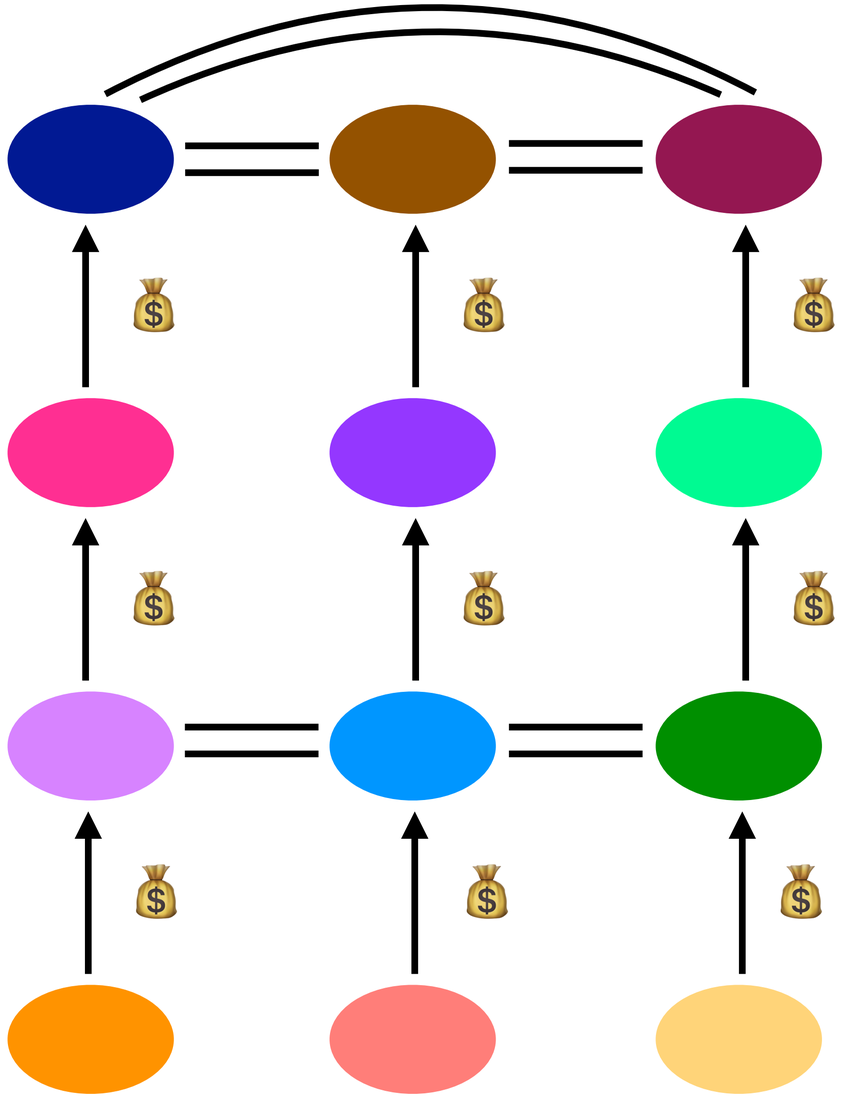

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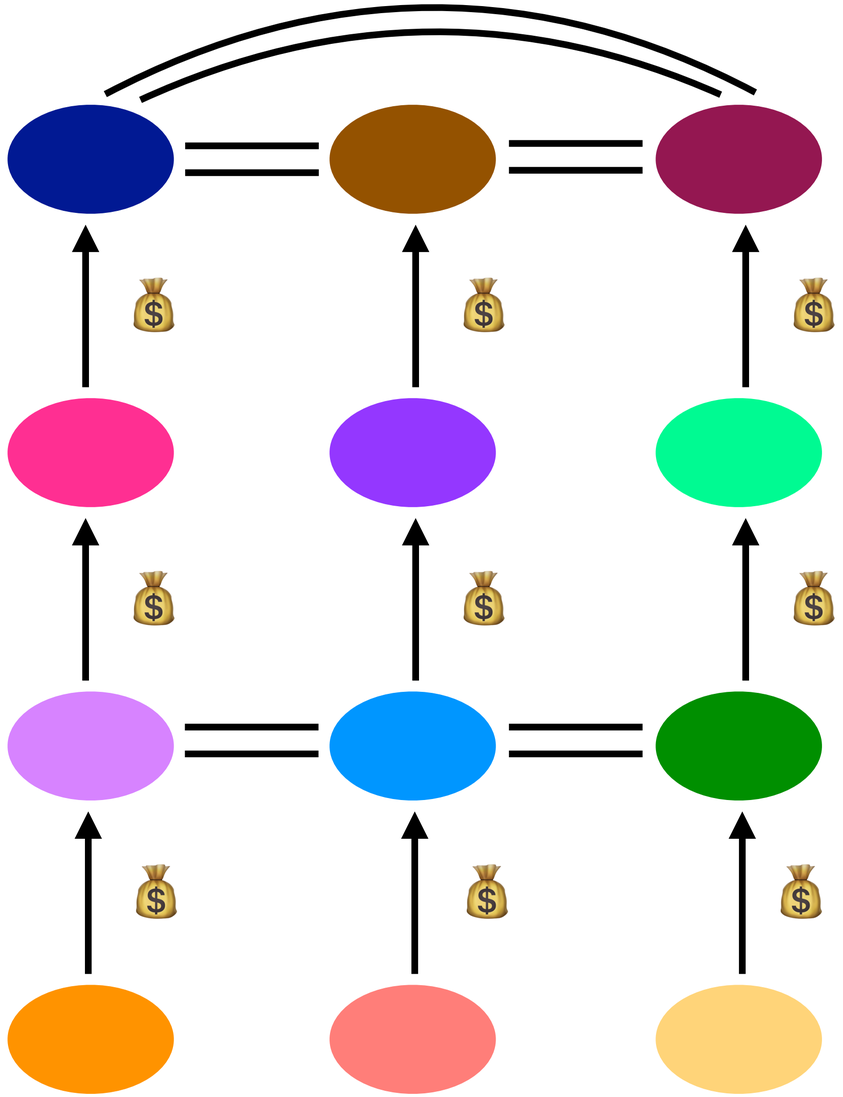

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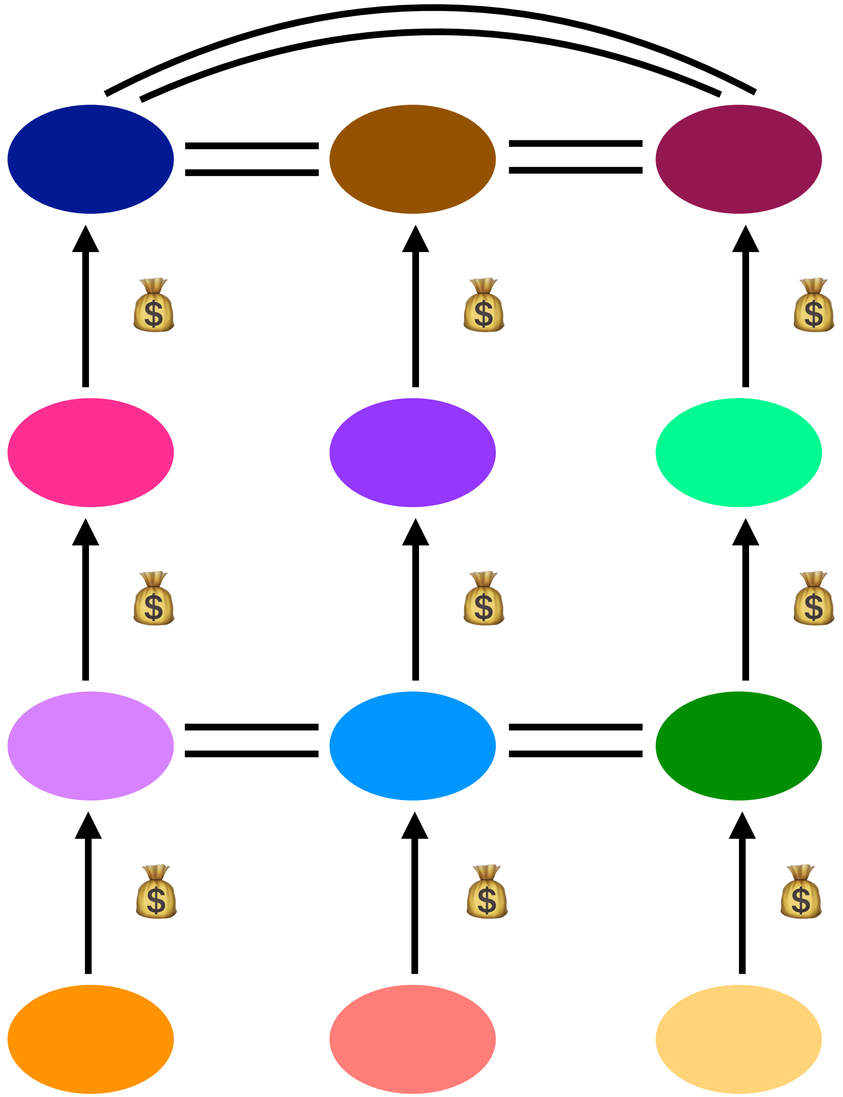
absolutely — it is a huge part of the Internet’s infrastructure



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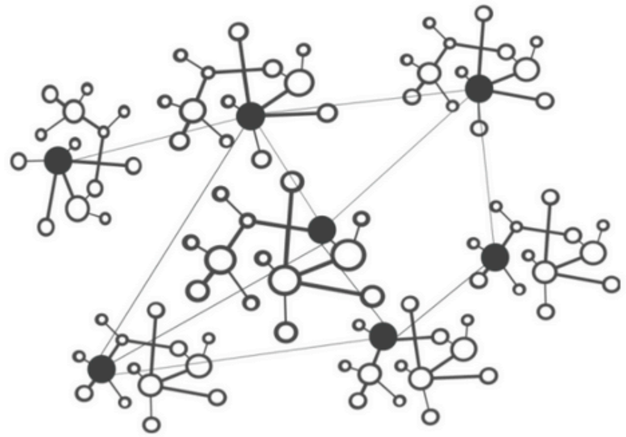
Understanding How Facebook Disappeared from the Internet

10/04/2021

Celso Martinho Tom Strickx

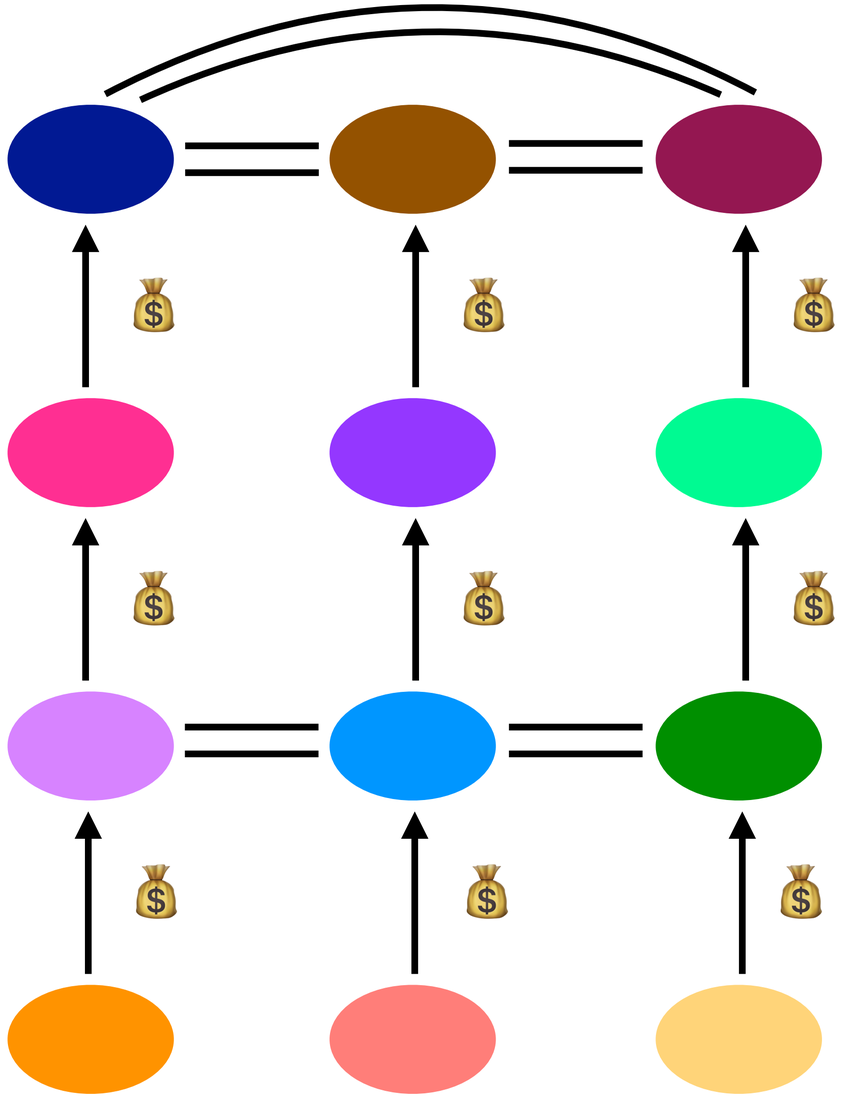
This post is also available in 简体中文, 繁體中文, 日本語, 한국어, Deutsch, Français, Español, Português, Русский, and Italiano.



The Internet - A Network of Networks

“Facebook can't be down, can it?”, we thought, for a second.

https://blog.cloudflare.com/october-2021-facebook-outage/



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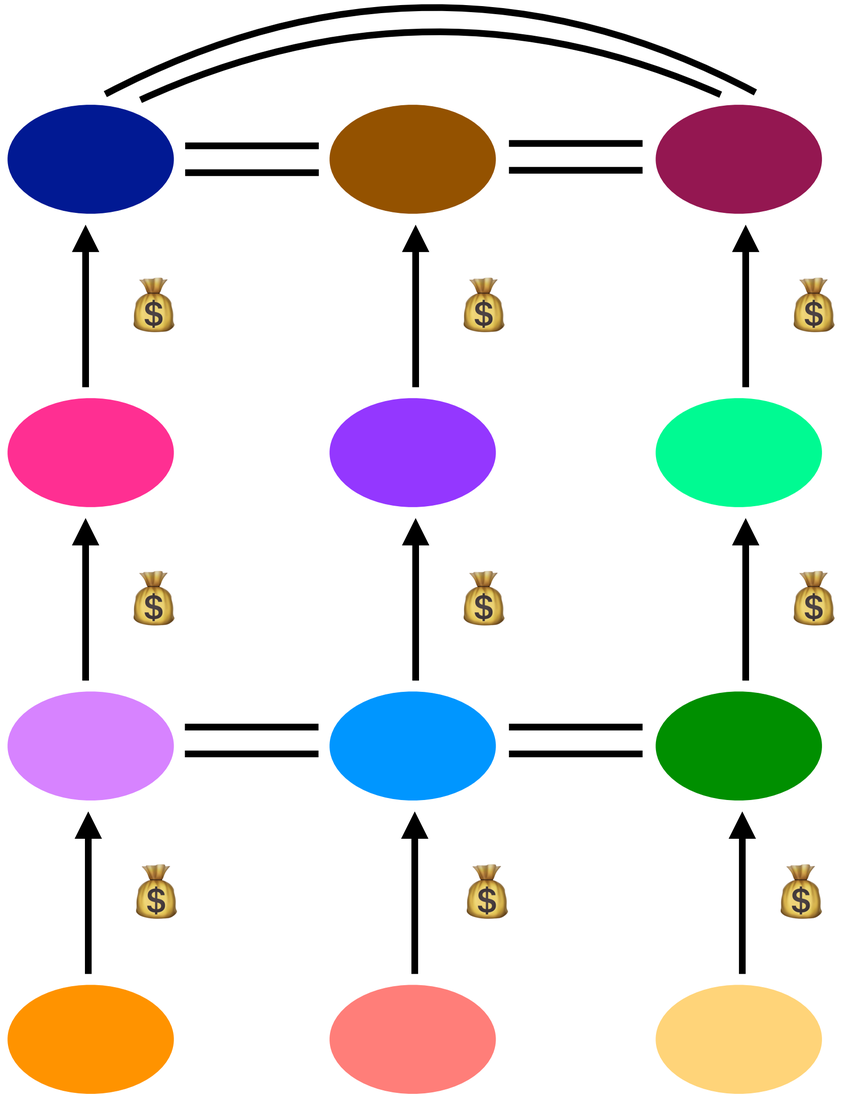
https://engineering.fb.com/2021/10/05/networking-traffic/outage-details/



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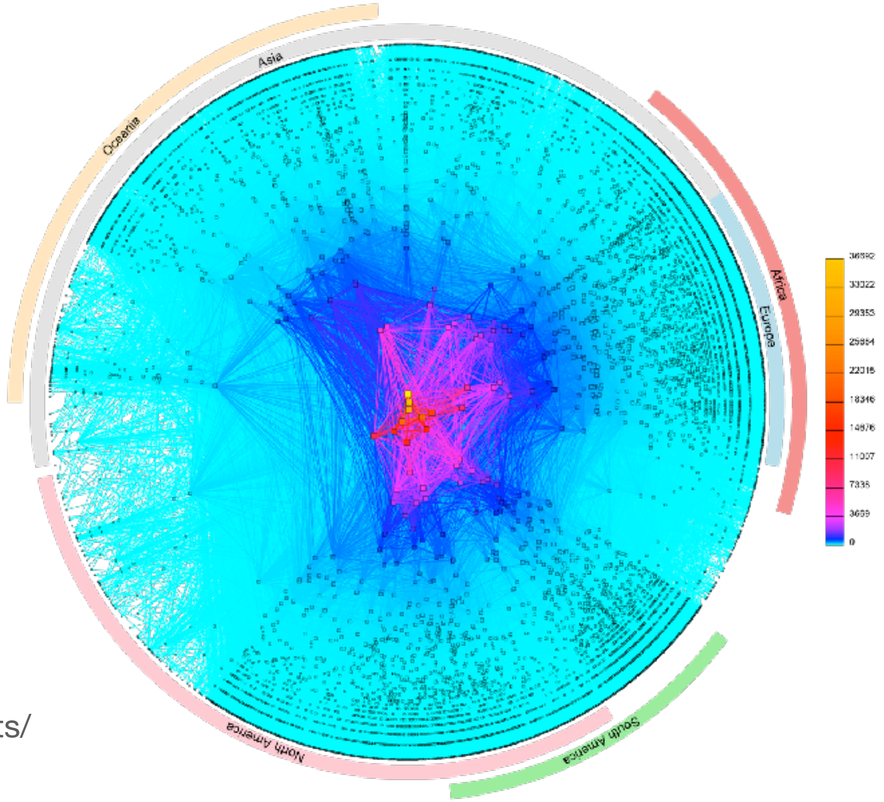
All of this happened very fast. And as our engineers worked to figure out what was happening and why, they faced two large obstacles: first, it was not possible to access our data centers through our normal means because their networks were down, and second, the total loss of DNS broke many of the internal tools we'd normally use to investigate and resolve outages like this.

https://engineering.fb.com/2021/10/05/networking-traffic/outage-details/

1970s: ARPAnet | 1978: flexibility and layering | early 80s: growth → change | late 80s: growth → problems | 1993: commercialization

hosts.txt | **distance-vector routing** | TCP, UDP | **OSPF**, EGP, DNS (a link-state routing protocol) | congestion collapse | policy routing | CIDR



CAIDA's IPv4 AS Core, January 2020 (https://www.caida.org/projects/cartography/as-core/2020/)

on the Internet, we have to solve all of the "normal" networking problems (addressing, routing, transport) **at massive scale, while supporting a diverse group of applications and competing economic interests**

application	the things that actually generate traffic
transport	sharing the network, reliability (or not) *examples: TCP, UDP*
network	naming, addressing, routing *examples: IP*
link	communication between two directly-connected nodes *examples: ethernet, bluetooth, 802.11 (wifi)*