Routing Attacks in Cryptocurrencies

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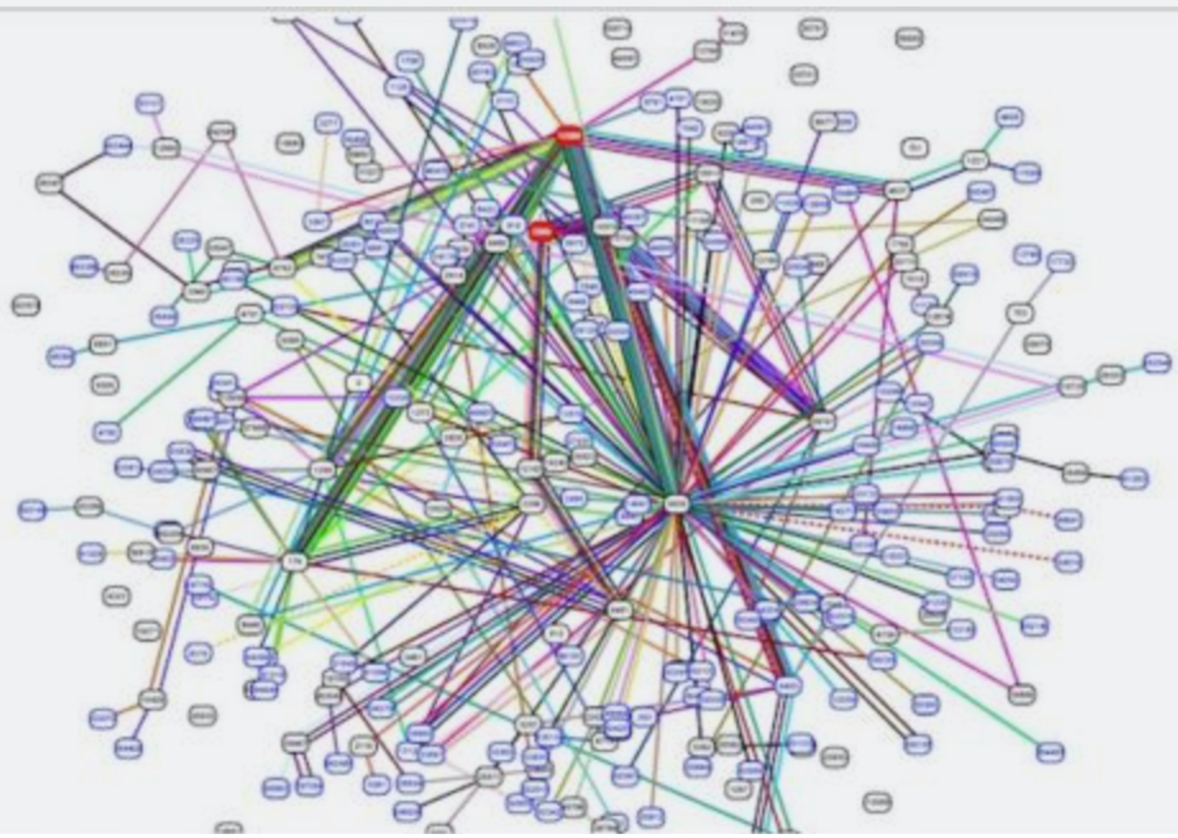
Joint work with Aviv Zohar, Gian Marti, Jan Müller, Laurent Vanbever

Routing attacks quite often make the news

Russian-controlled telecom hijacks financial services’ Internet traffic

Visa, MasterCard, and Symantec among dozens affected by "suspicious" BGP mishap.

DAN GOODIN - 4/27/2017, 10:20 PM



source: arstechnica.com

THREAT LEVEL

Hacker Redirects Traffic From 19 Internet Providers to Steal Bitcoins

BY ANDY GREENBERG 08.07.14 | 1:00 PM | PERMALINK

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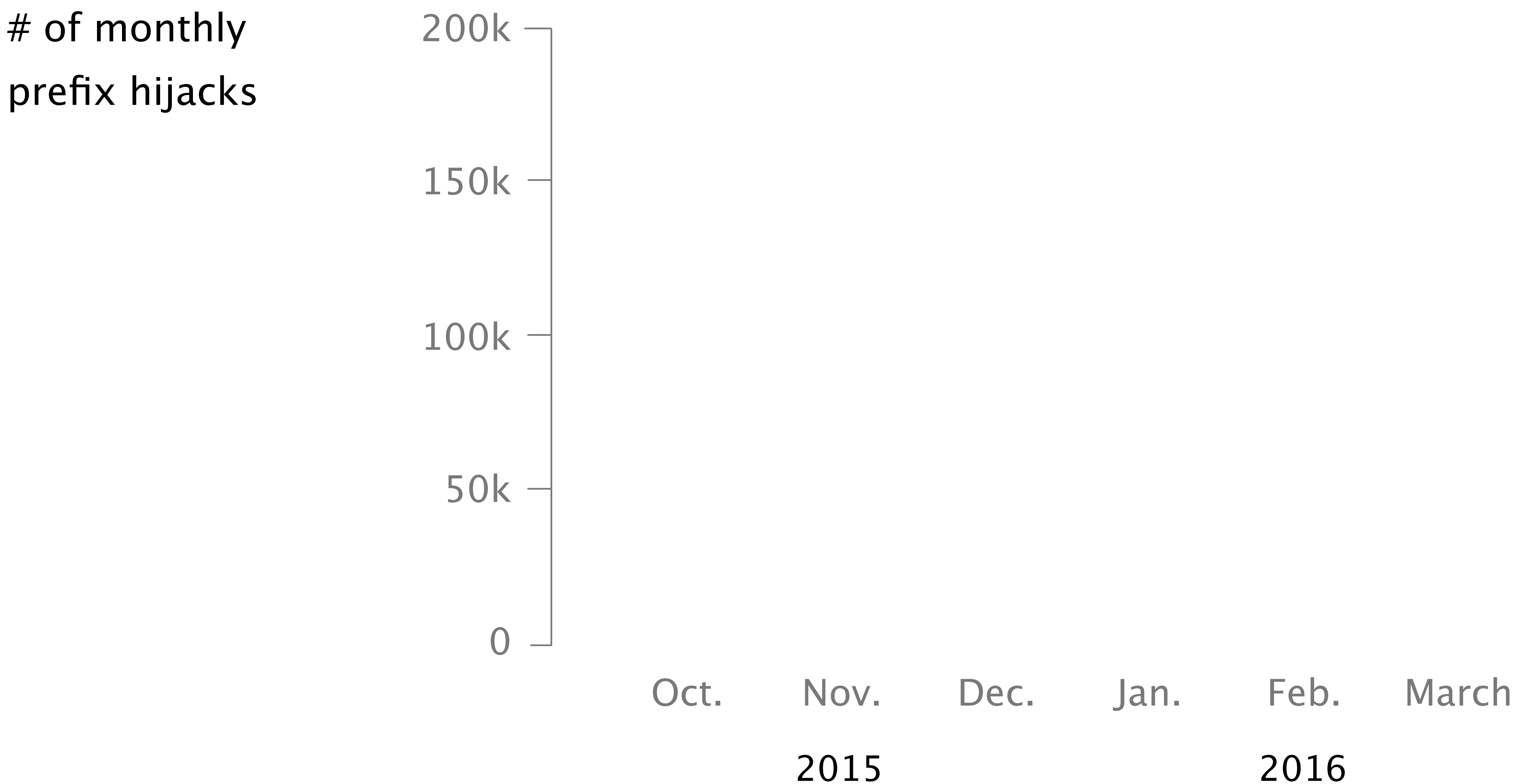
source: wired.com

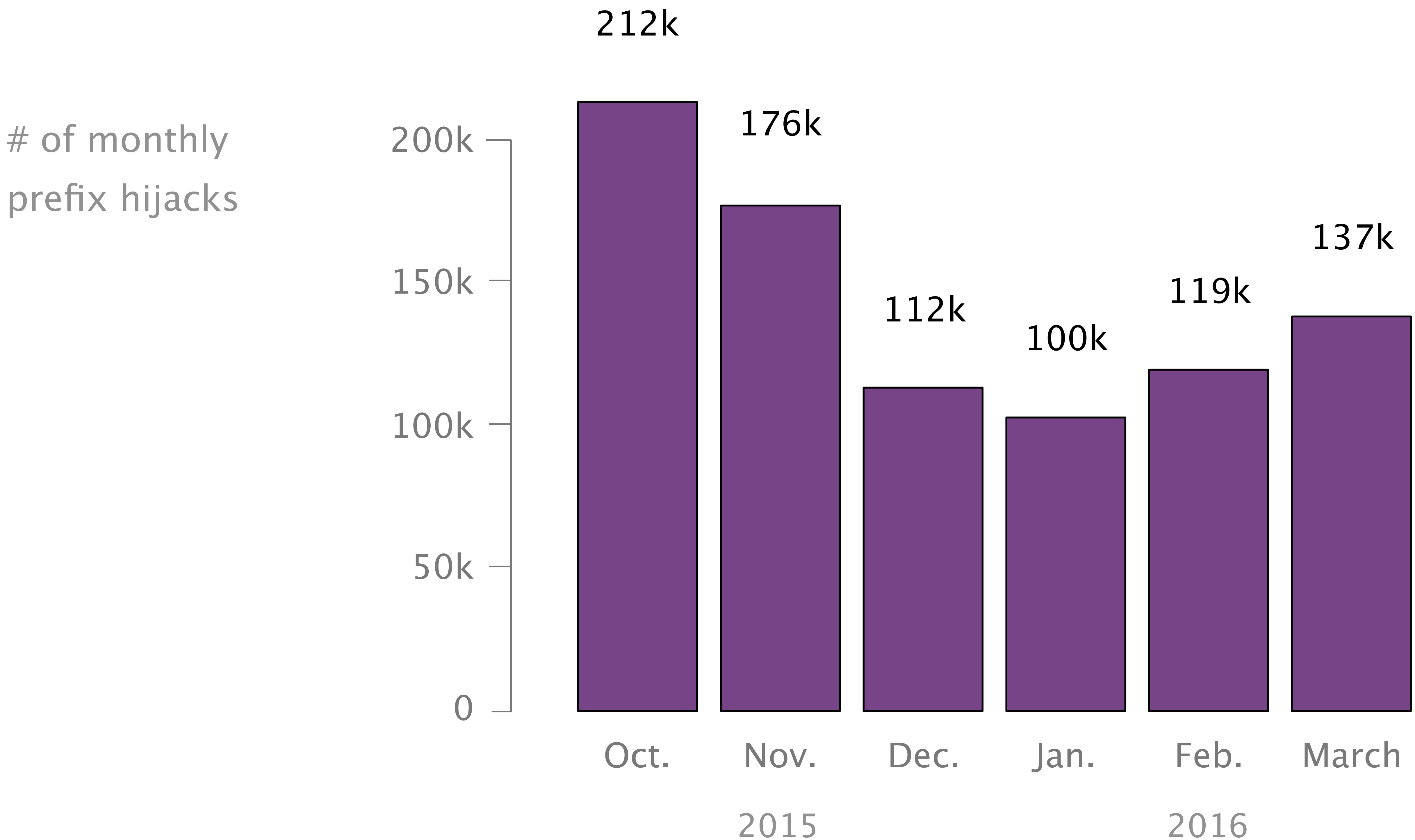
Security Blogwatch

Apr 26, 2018

BGP hijack steals AWS IP range; cryptocurrency theft ensues

That is only the tip of the iceberg of routing manipulations


# of monthly
prefix hijacks
200k
150k
100k
50k
0
Oct.
Nov.
Dec.
Jan.
Feb.
March
2015
2016



# of monthly
prefix hijacks
200k
150k
100k
50k
0
212k
176k
112k
100k
119k
137k
Oct.
Nov.
Dec.
Jan.
Feb.
March
2015
2016

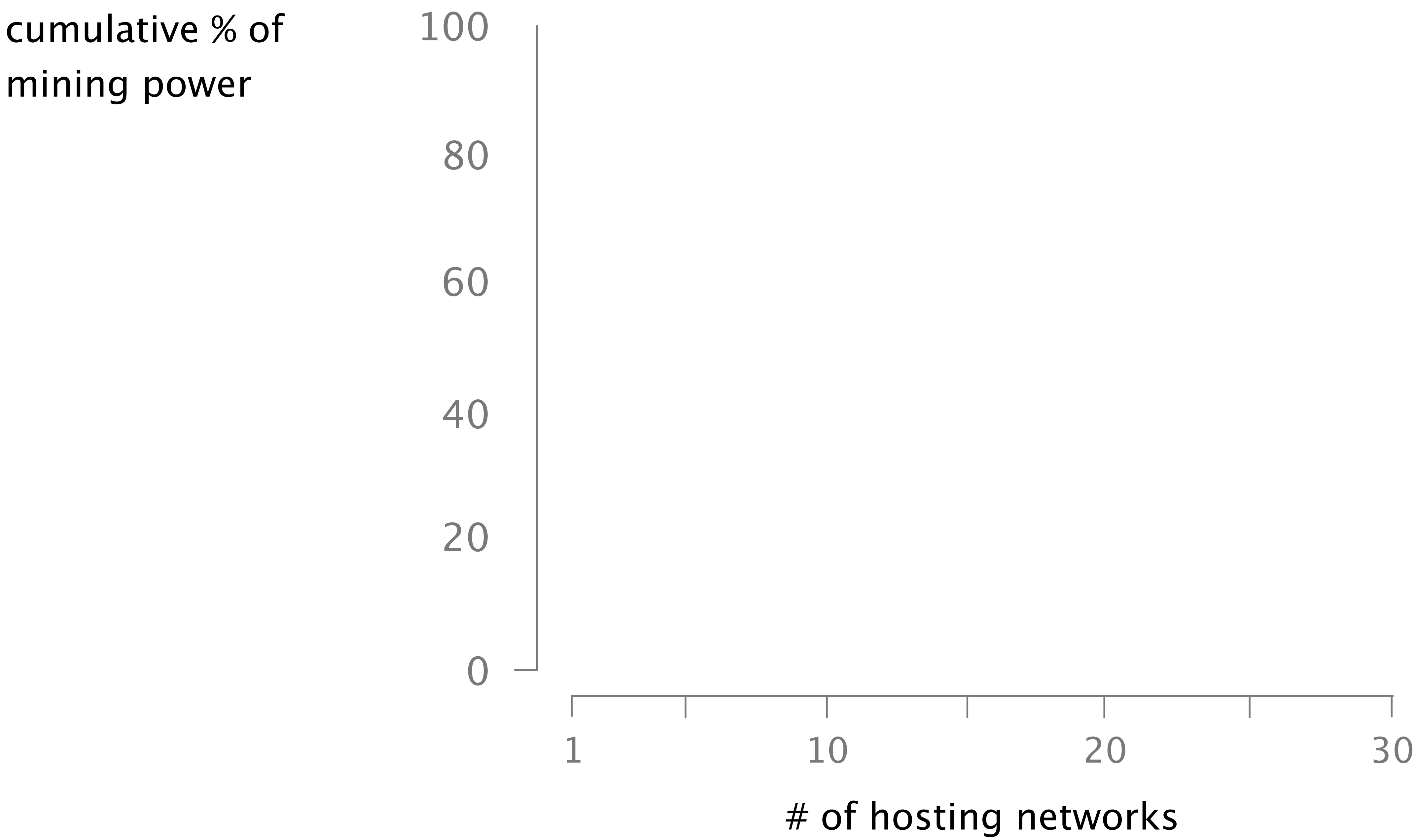
Can routing attacks impact Bitcoin?

Bitcoin is highly decentralized
making it robust to routing attacks, in theory…

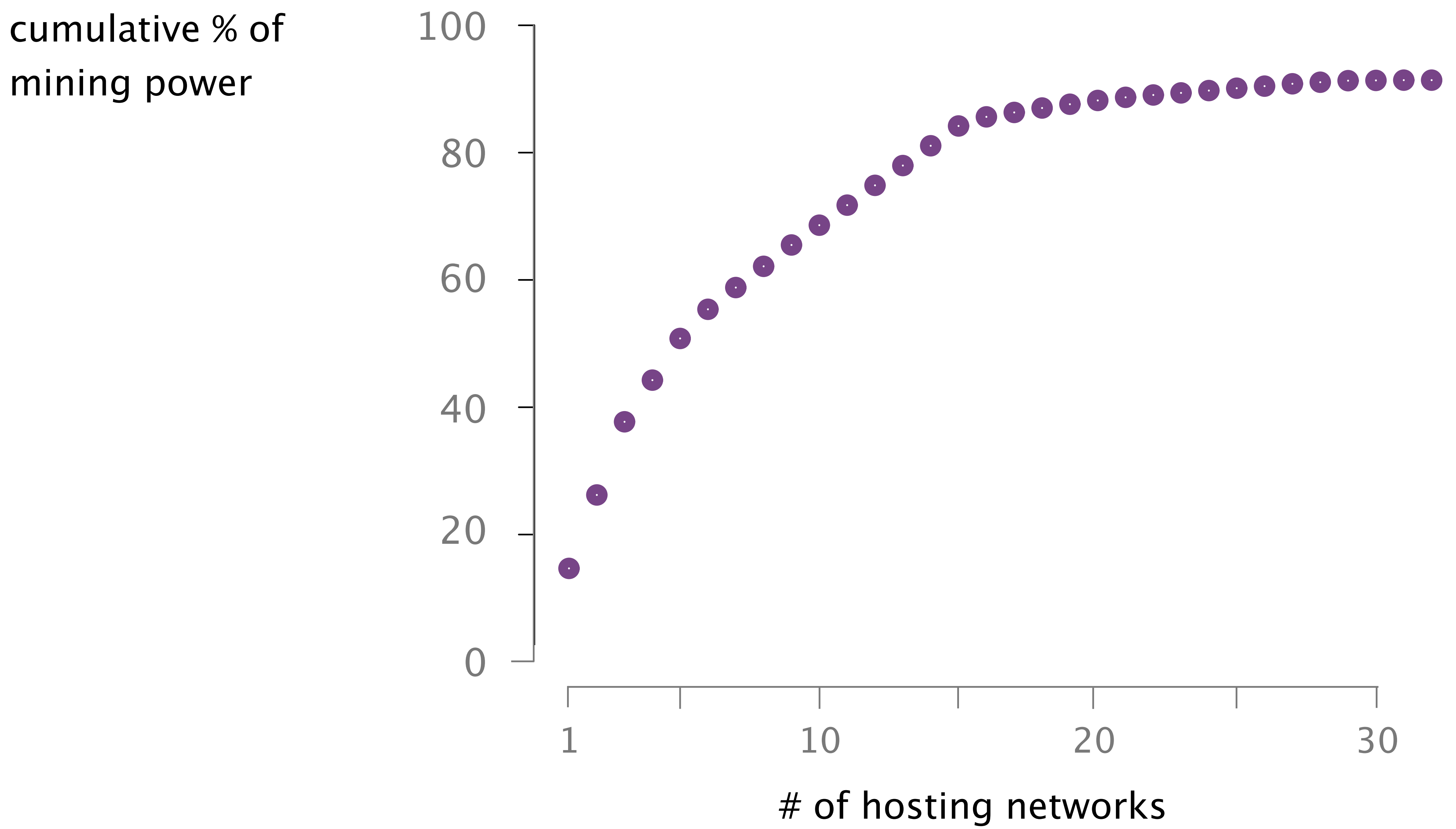
Bitcoin nodes …

- are scattered all around the globe
- establish random connections
- use multihoming and extra relay networks

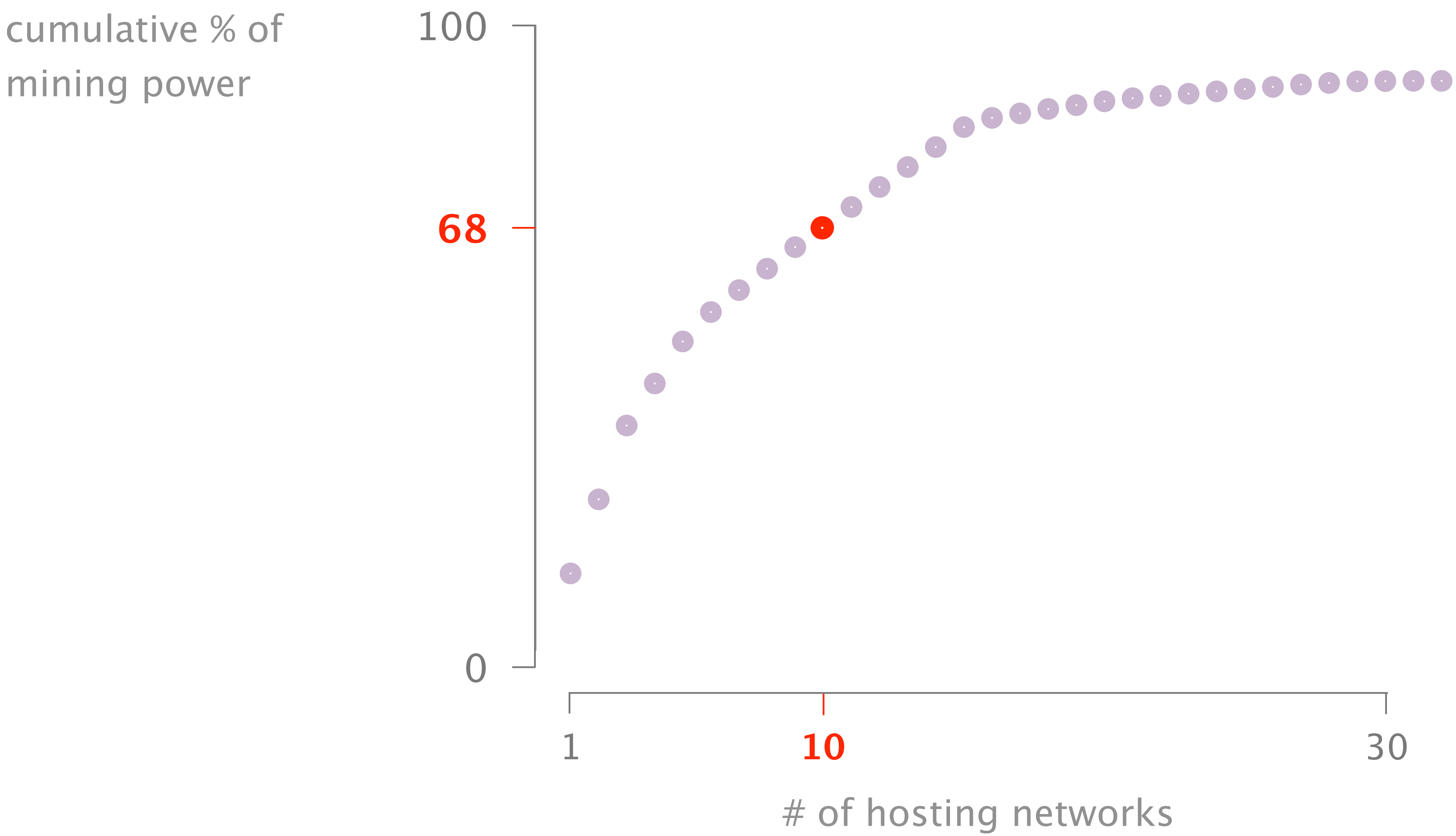
In practice, Bitcoin is highly centralized,
both from a routing and mining viewpoint


cumulative % of
mining power
100
80
60
40
20
0
1
10
20
30
# of hosting networks

Mining power is centralized to few hosting networks



68% of the mining power is hosted in 10 networks only



Each attack differs in terms of its
visibility, impact, and targets

Attack 1

Partitioning

Attack 2

Delay

Each attack differs in terms of its
visibility, **impact**, and **targets**

Attack 1

Partitioning

Attack 2

Delay

This talk…

Attack 1

Partitioning

visible

network-wide attack

generalizable to all Blockchains

Hijacking Bitcoin

Routing Attacks on Cryptocurrencies

1 **Background**

BGP & Bitcoin

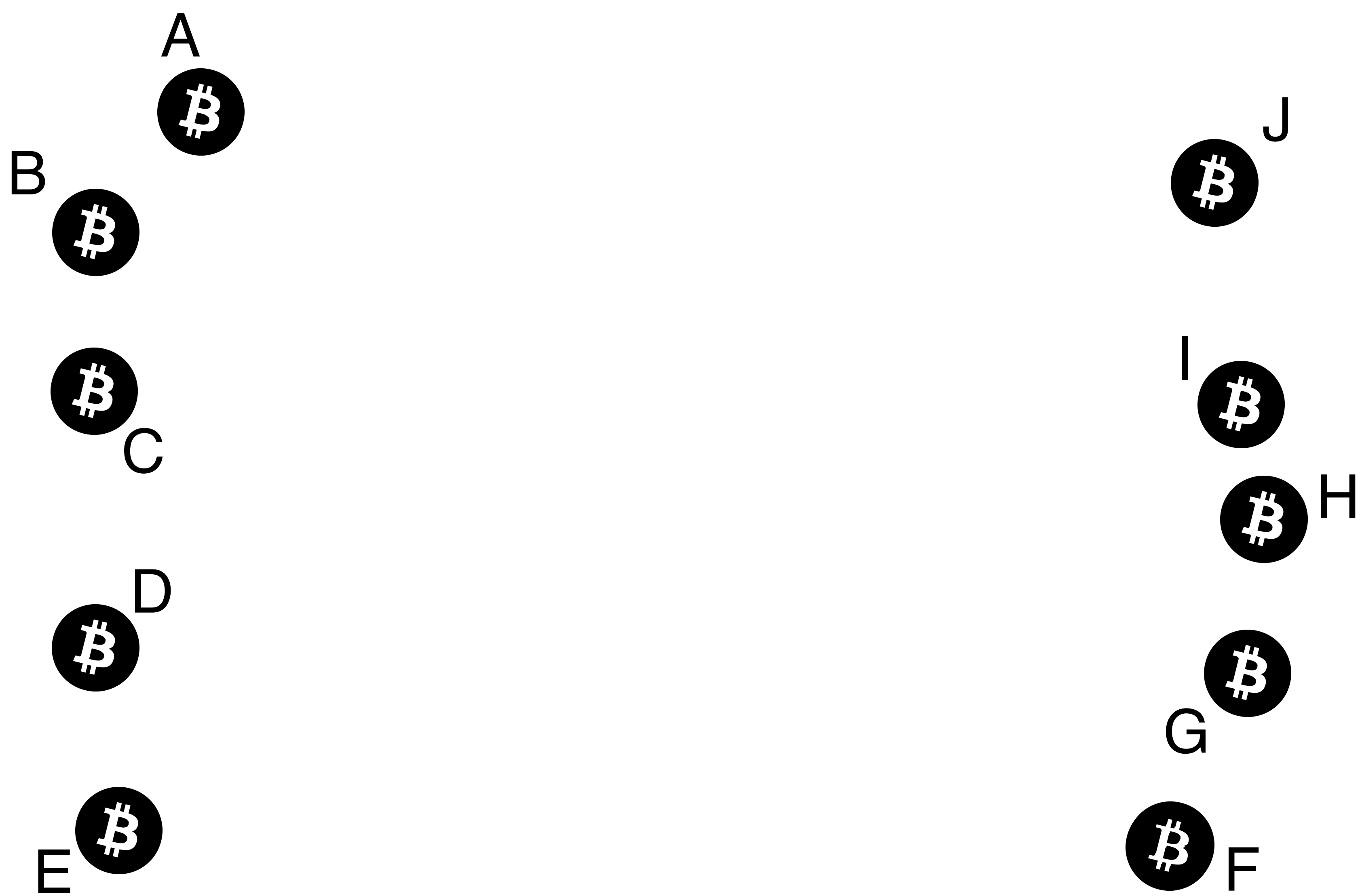
2 **Partitioning attack**

splitting the network

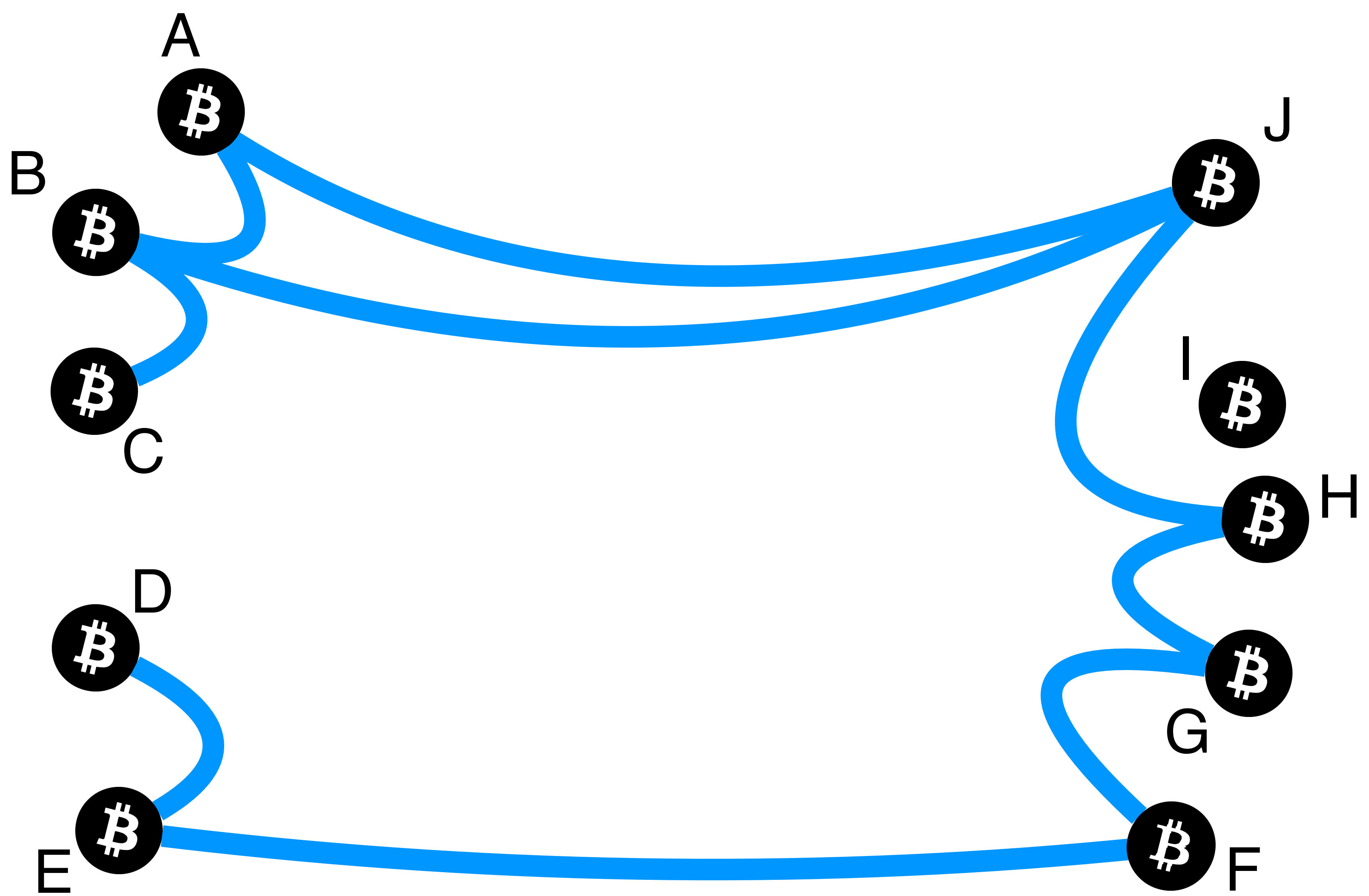
4 **Countermeasures**

short-term & long-term

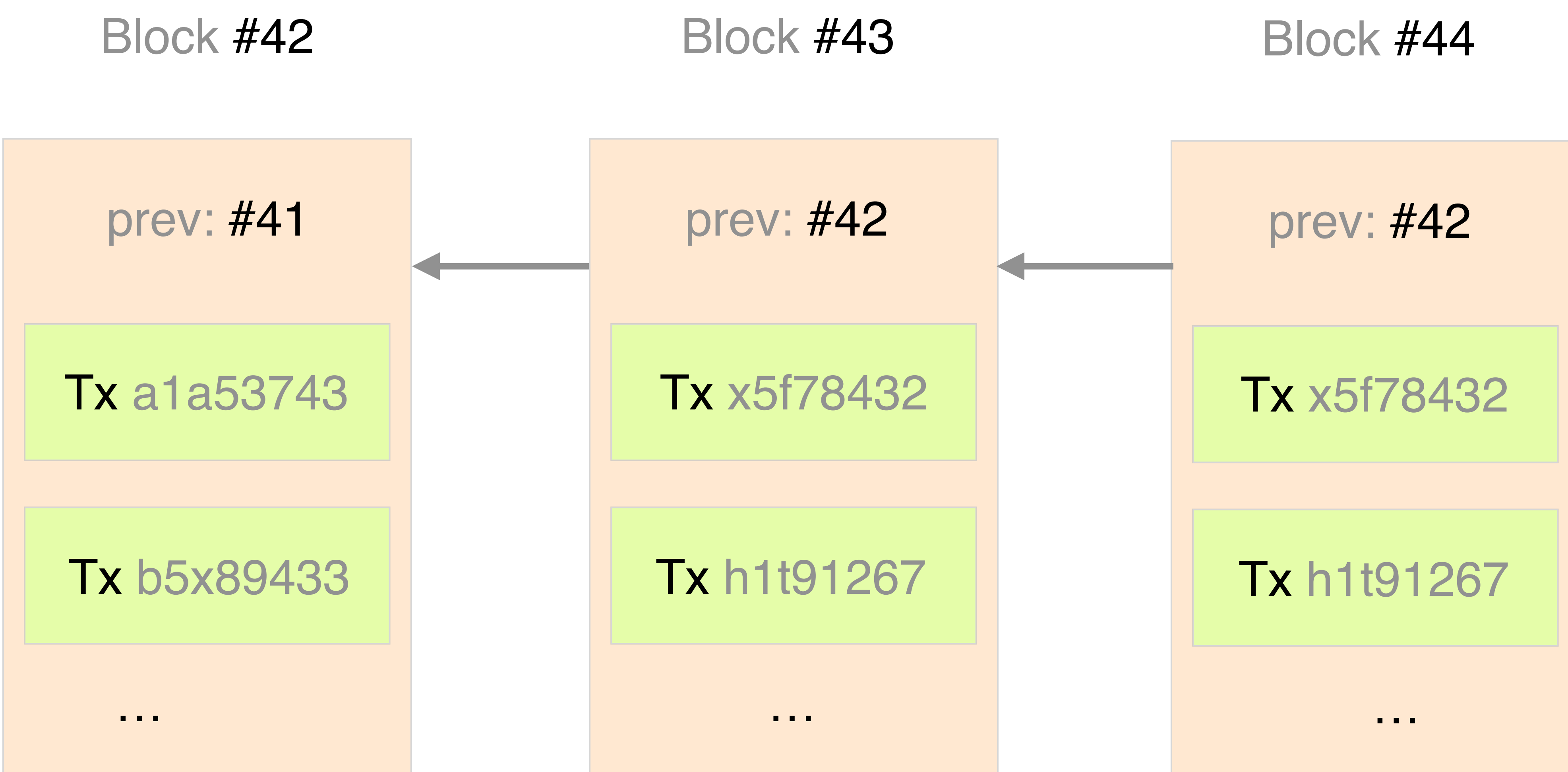
Bitcoin is a distributed network of nodes



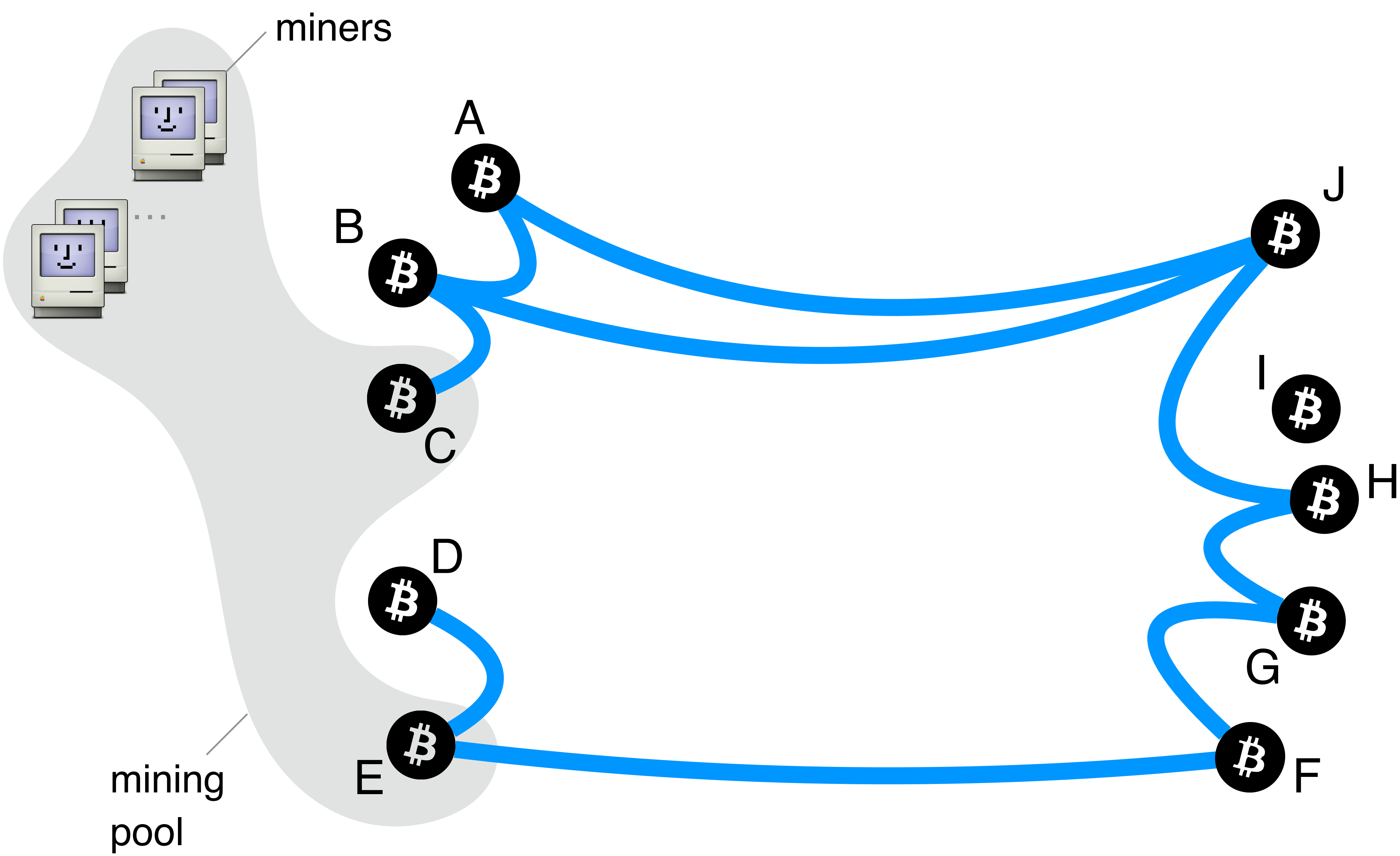
Bitcoin nodes establish random connections between each other



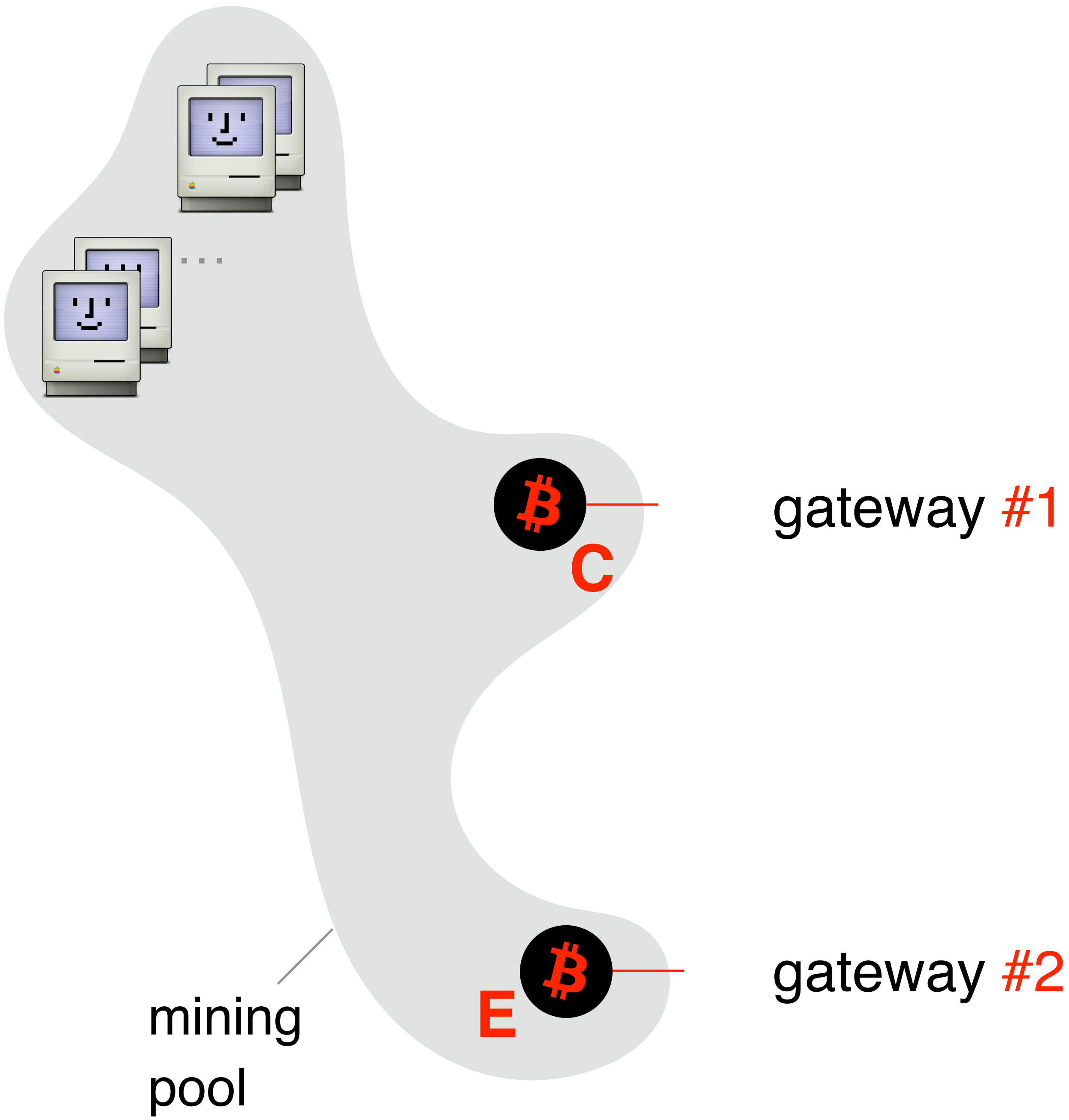
The Blockchain is a chain of Blocks



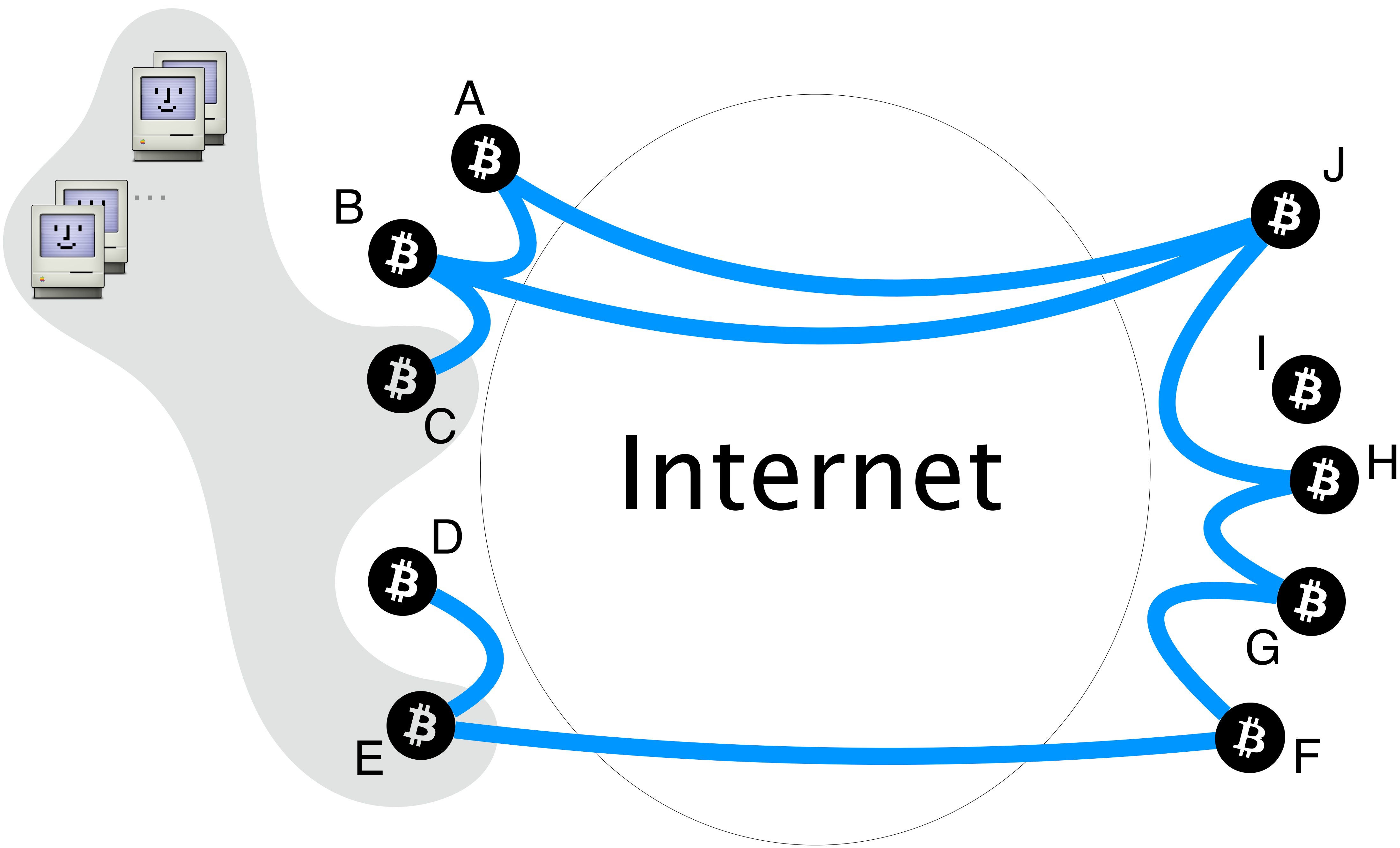
Miners are grouped in mining pools



Mining pools connect to the Bitcoin network through multiple gateways

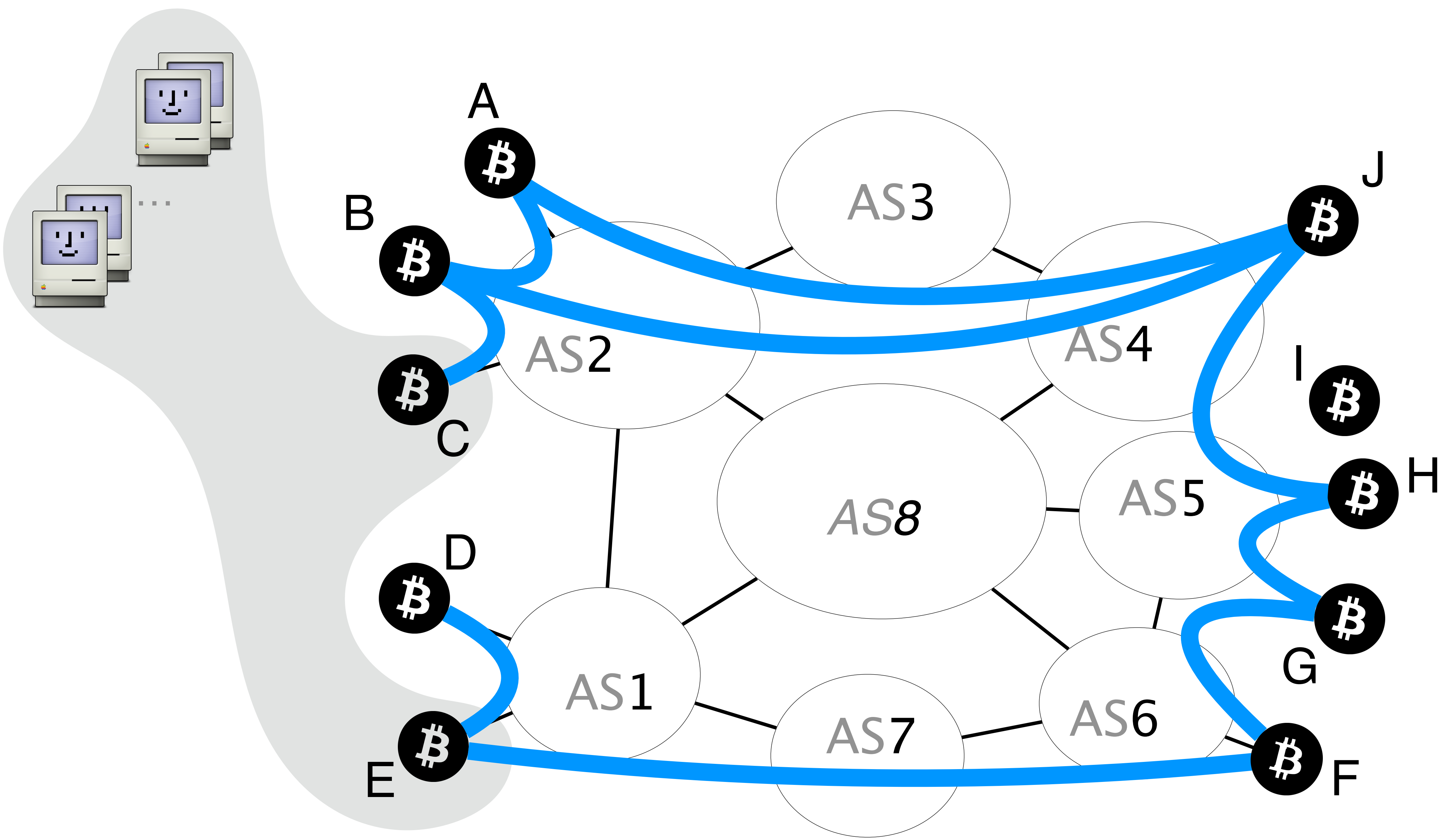


Bitcoin connections are routed over the Internet

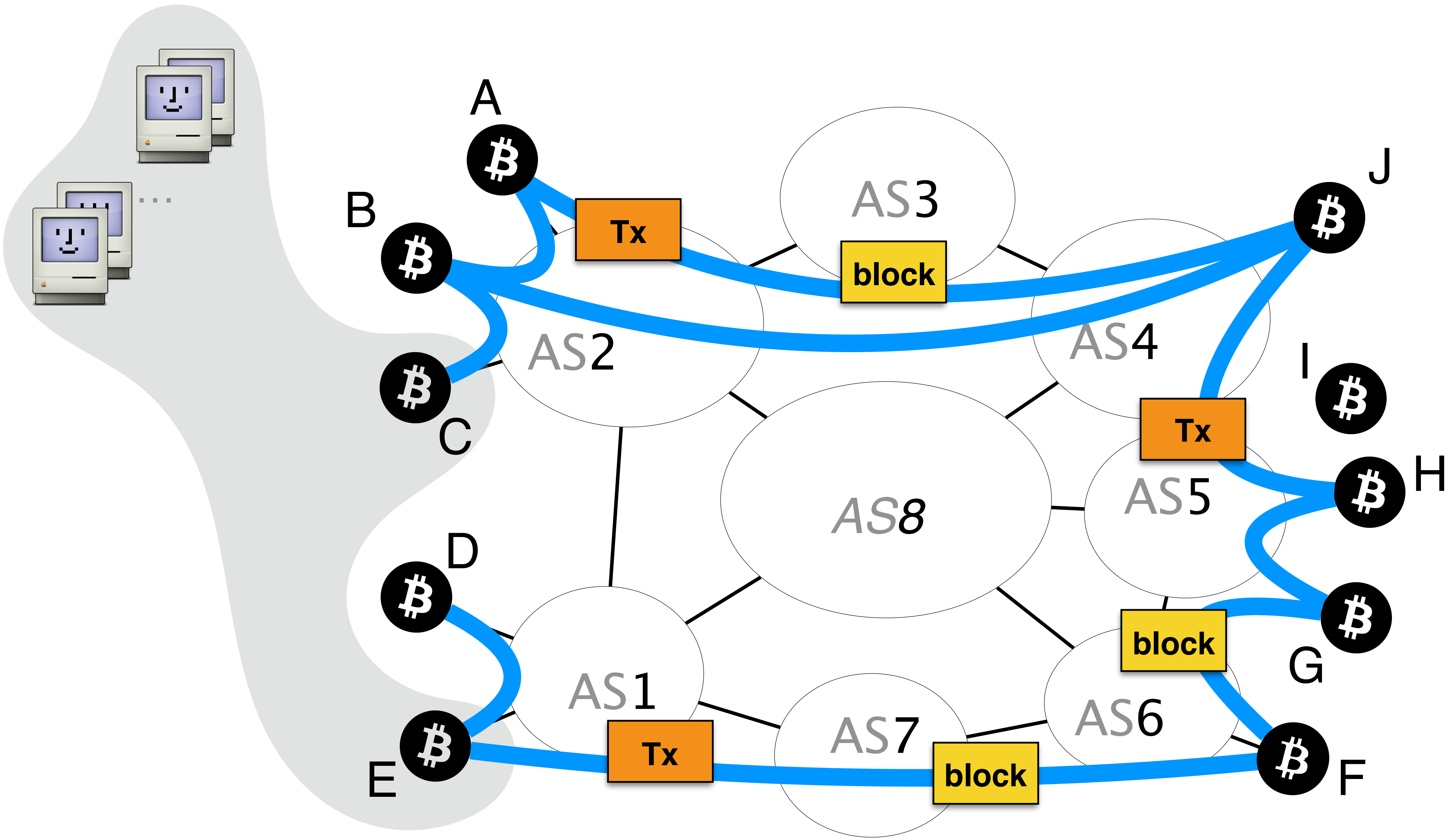


The Internet is composed of Autonomous Systems (ASes).

BGP computes the forwarding path across them



Bitcoin messages are propagated unencrypted and without any integrity guarantees



Hijacking Bitcoin

Routing Attacks on Cryptocurrencies

1 **Background**

BGP & Bitcoin

2 **Partitioning attack**

splitting the network

4 **Countermeasures**

short-term & long-term

The goal of a partitioning attack is to split the Bitcoin network into two disjoint components

The impact of such an attack is worrying

Denial of Service

Revenue Loss

Double spending

The impact of such an attack is worrying

Denial of Service

Bitcoin clients and wallets cannot secure or propagate transactions

Revenue Loss

Double spending

The impact of such an attack is worrying

Denial of Service

Revenue Loss

Blocks in component with less mining power are discarded

Double spending

The impact of such an attack is worrying

Denial of Service

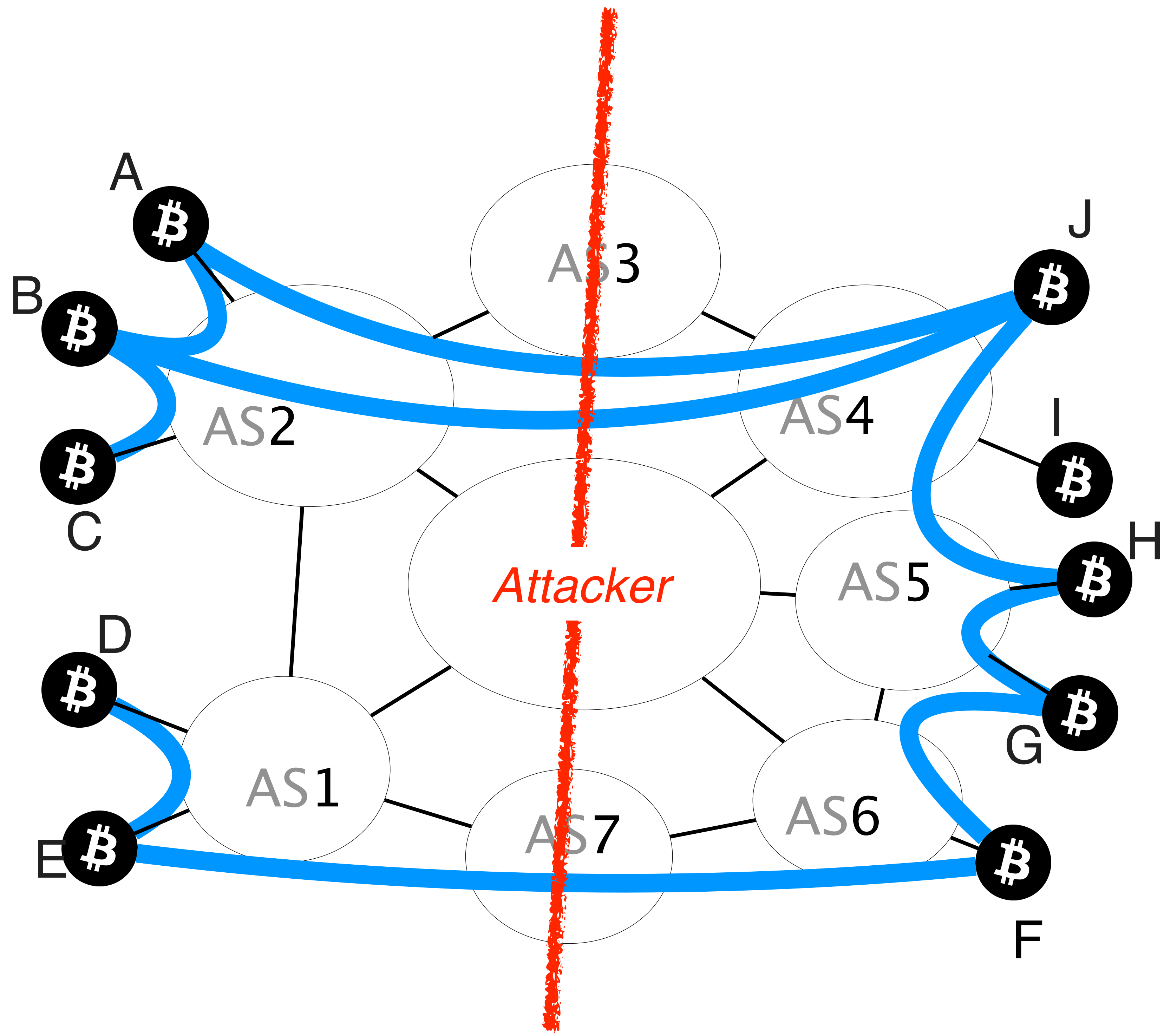
Revenue Loss

Double spending

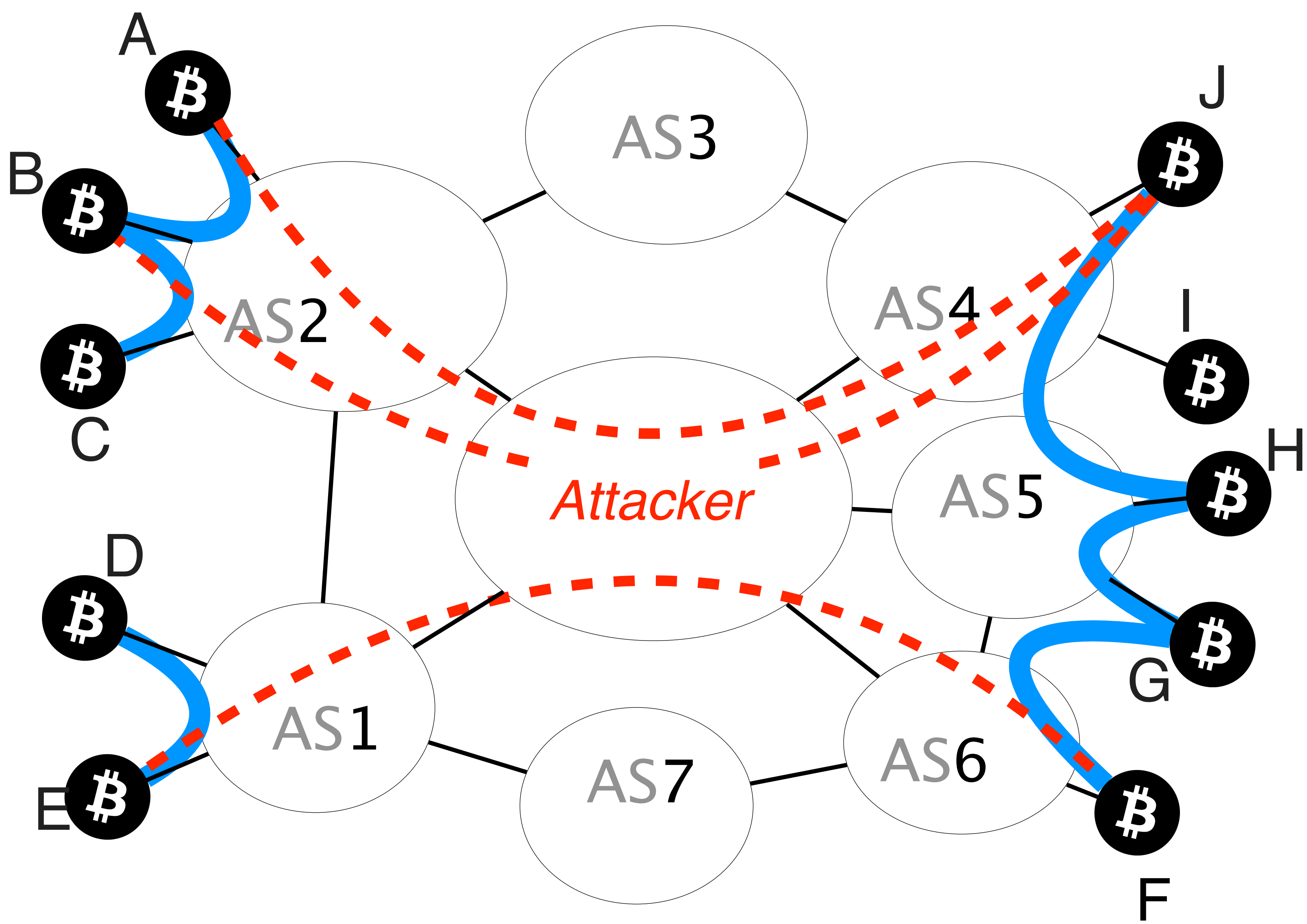
Transactions in components with less mining power can be reverted

How does the attack work?

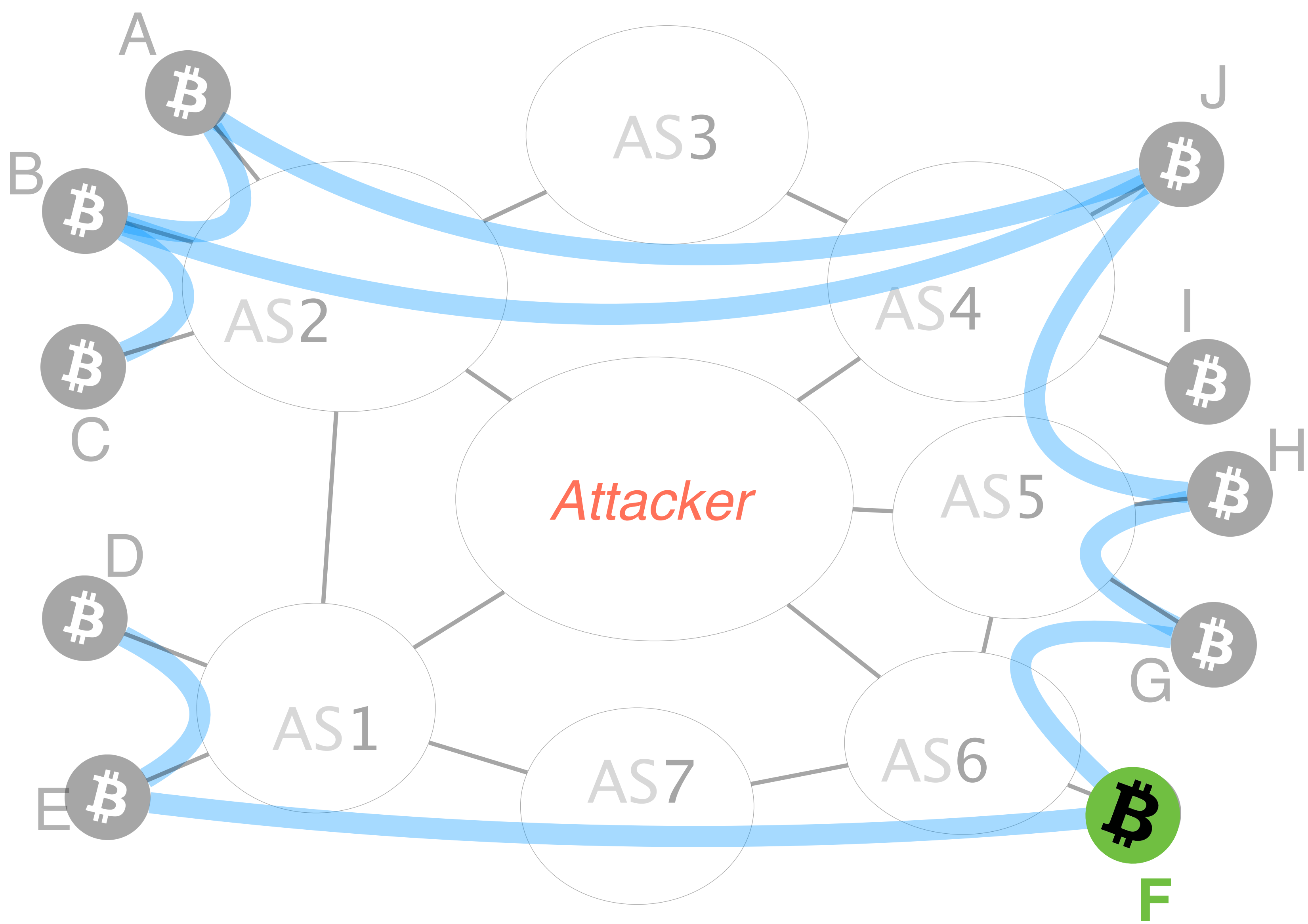
Let’s say an attacker wants to partition the network into the left and right side



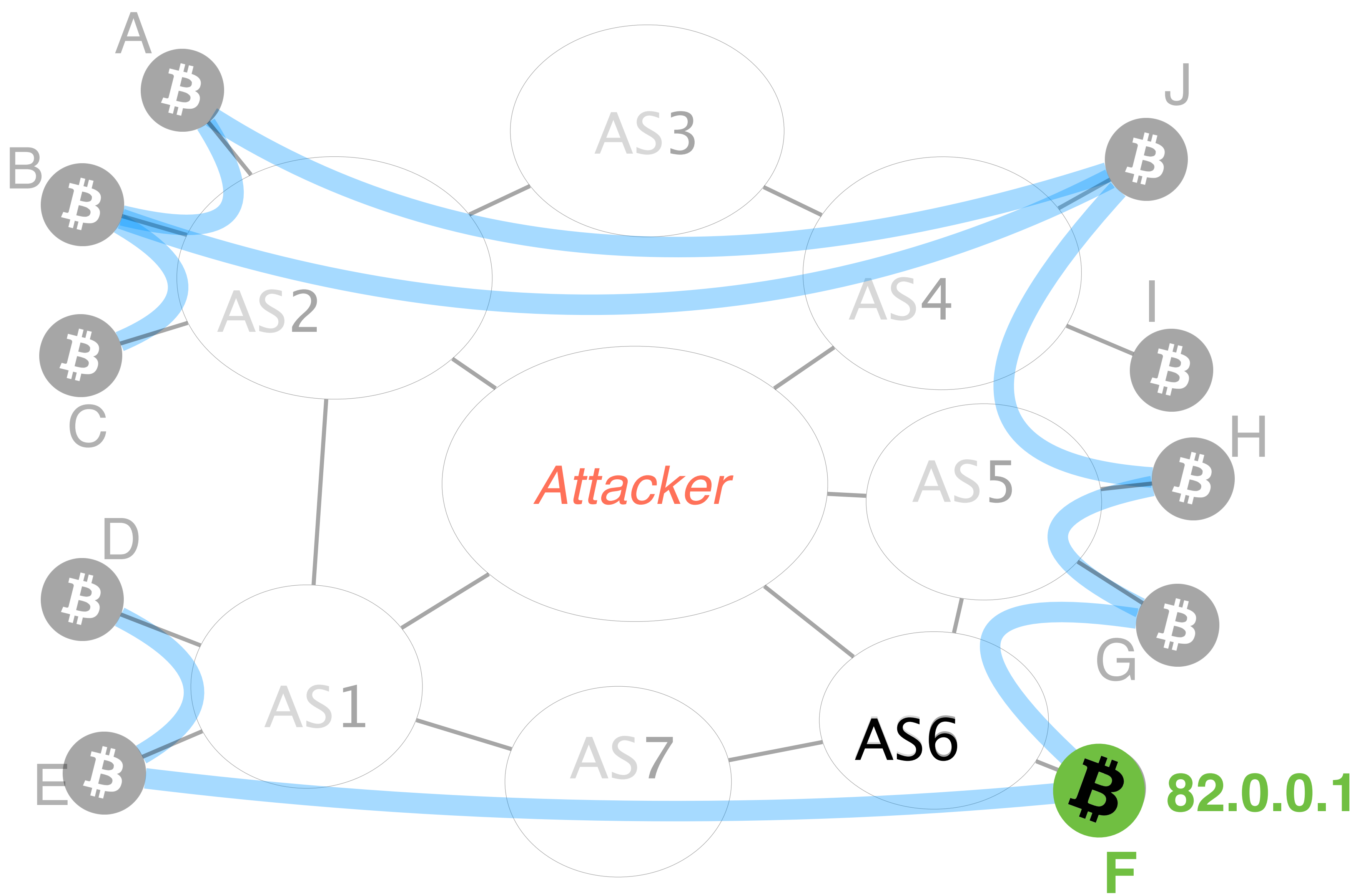
For doing so, the attacker will manipulate BGP routes to intercept any traffic to the nodes in the right



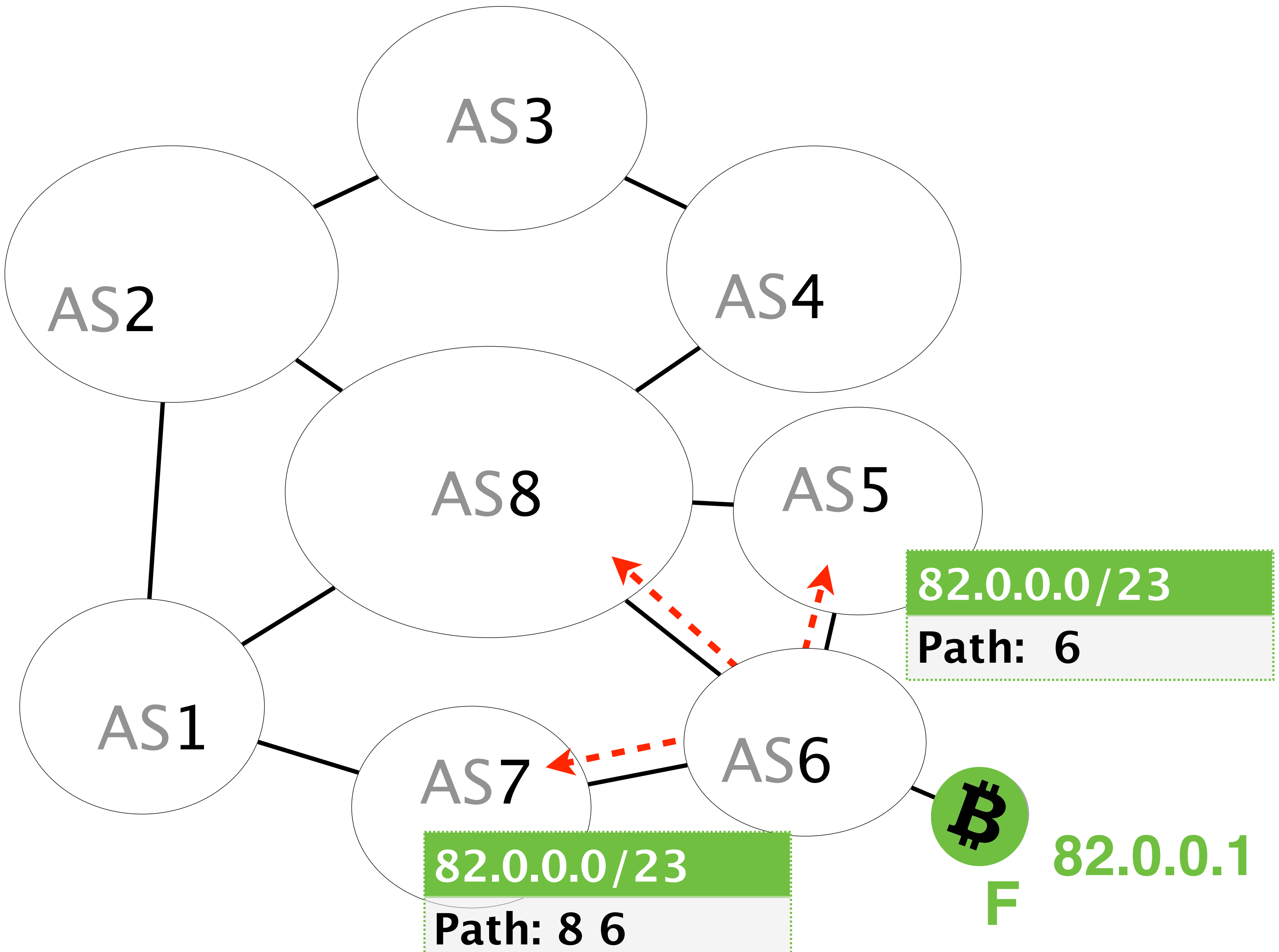
Let us focus on node F



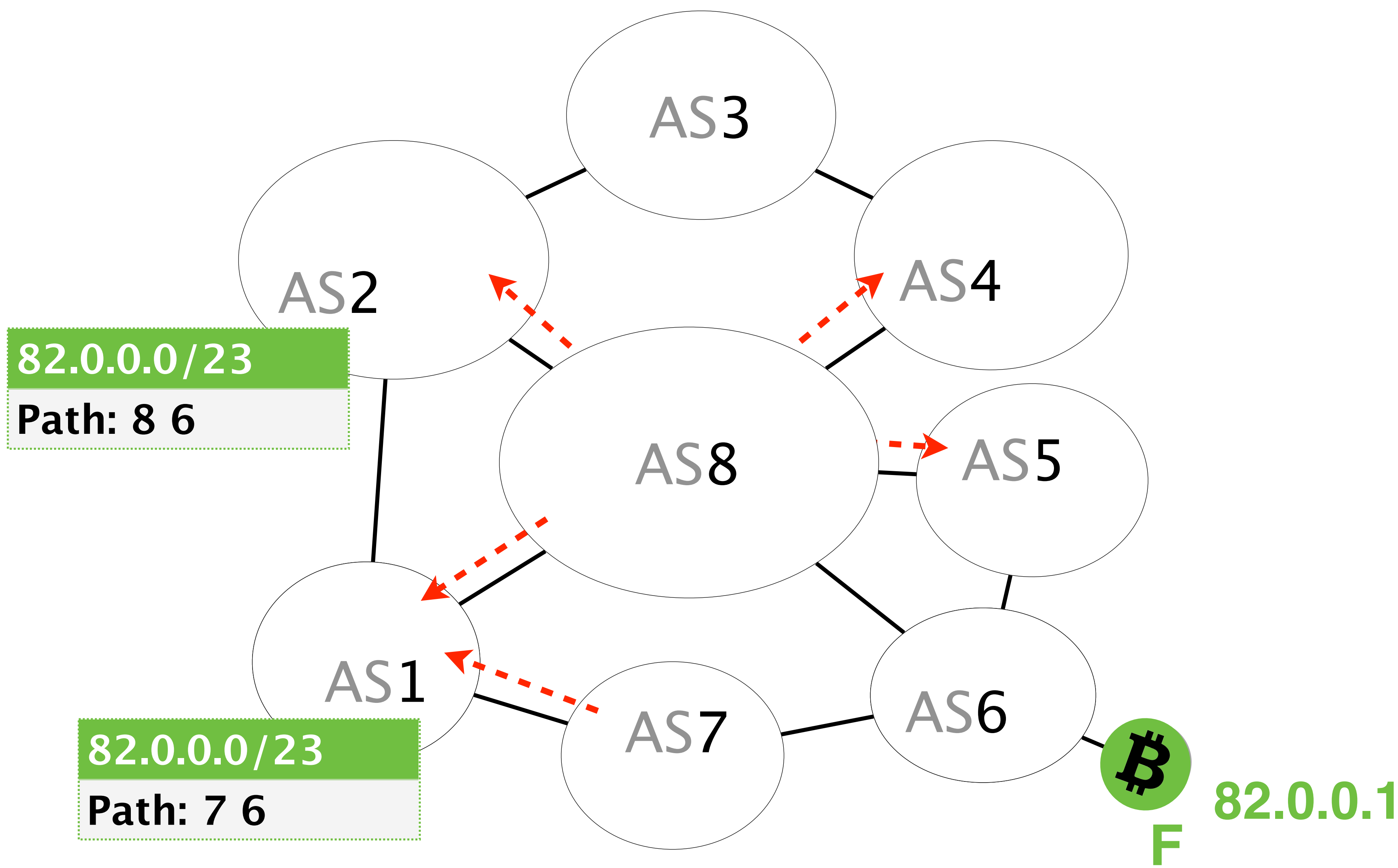
F’s provider (AS6) is responsible for IP prefix



AS6 will create a BGP advertisement



AS6's advertisement is propagated AS-by-AS until all ASes in the Internet learn about it



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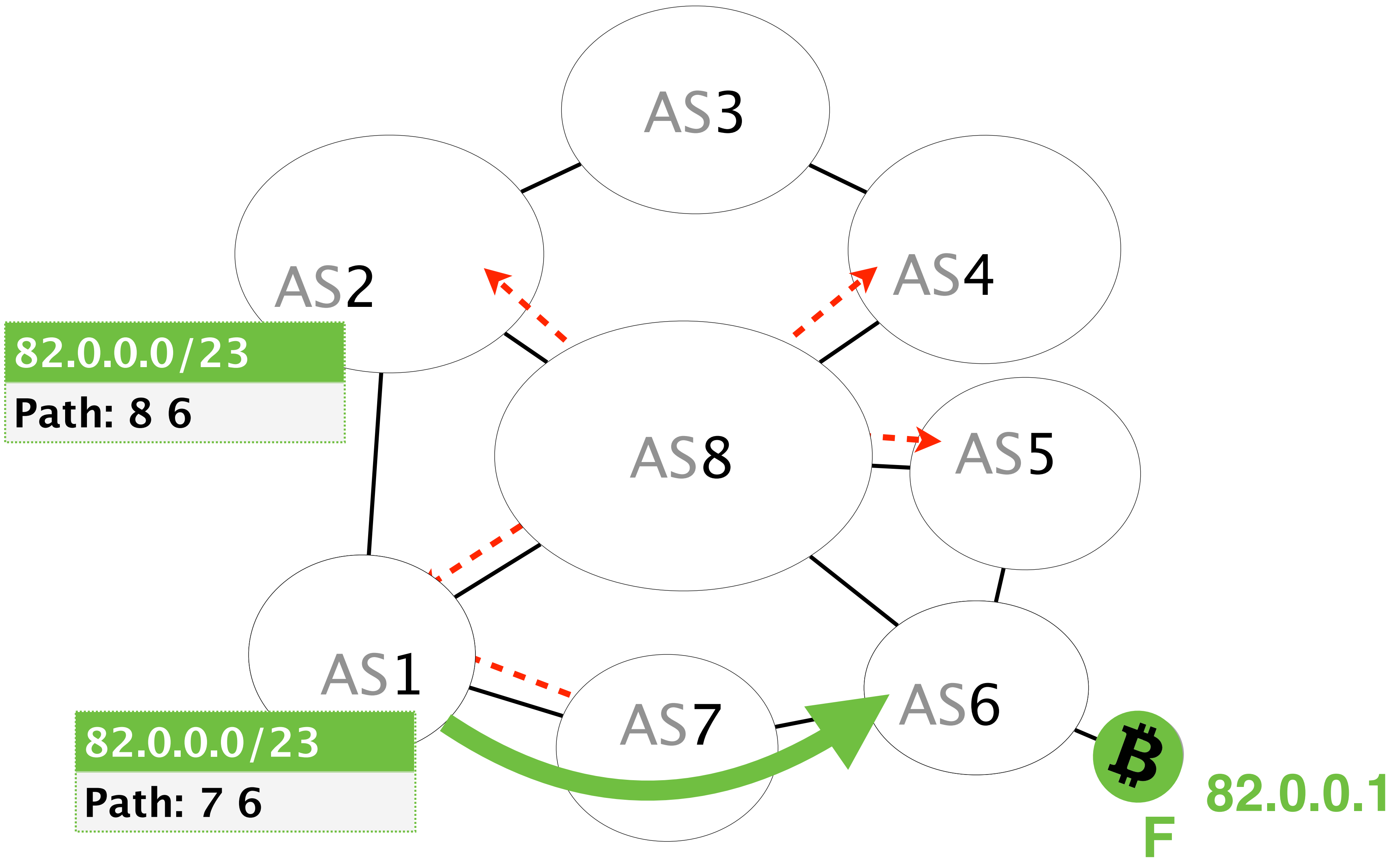
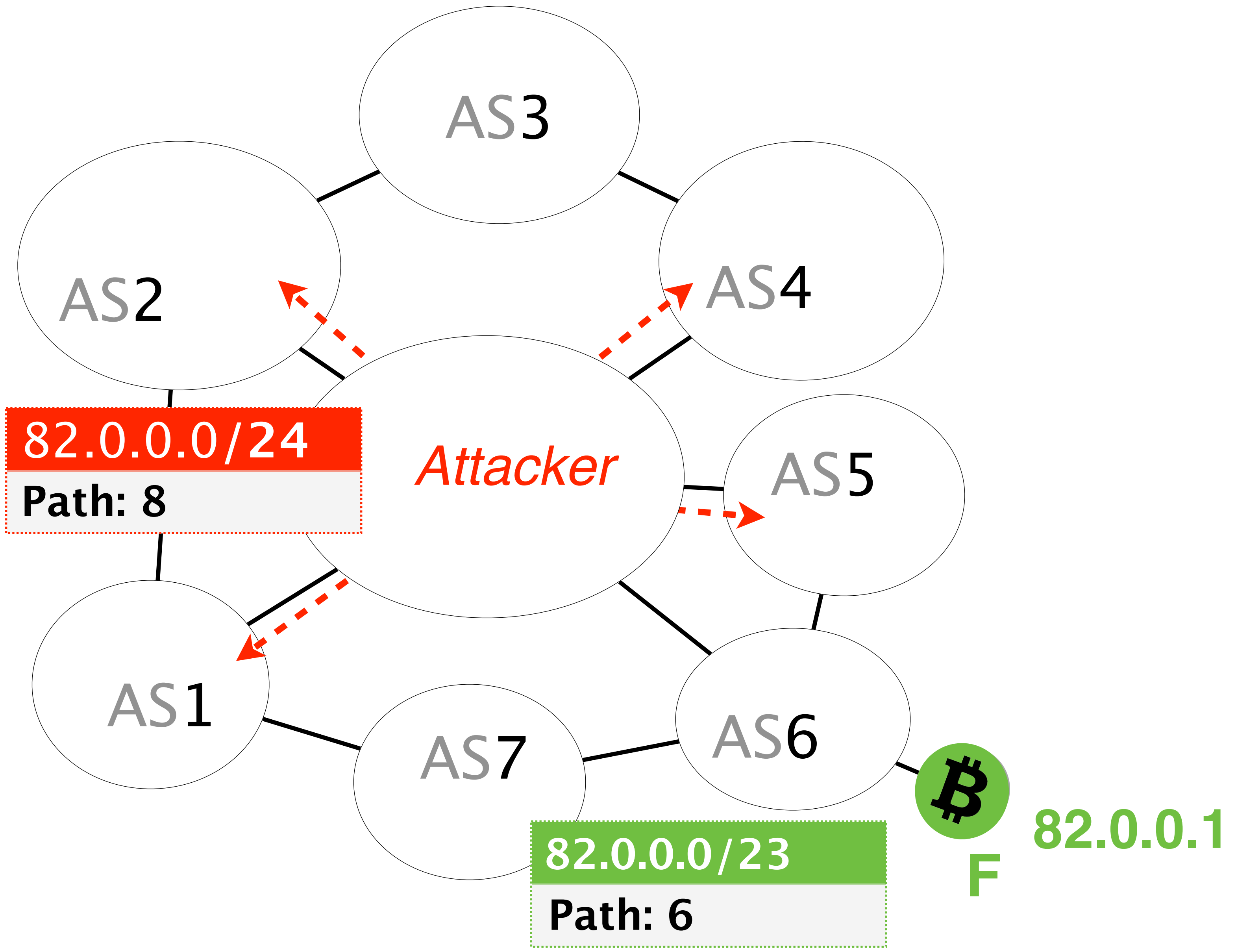
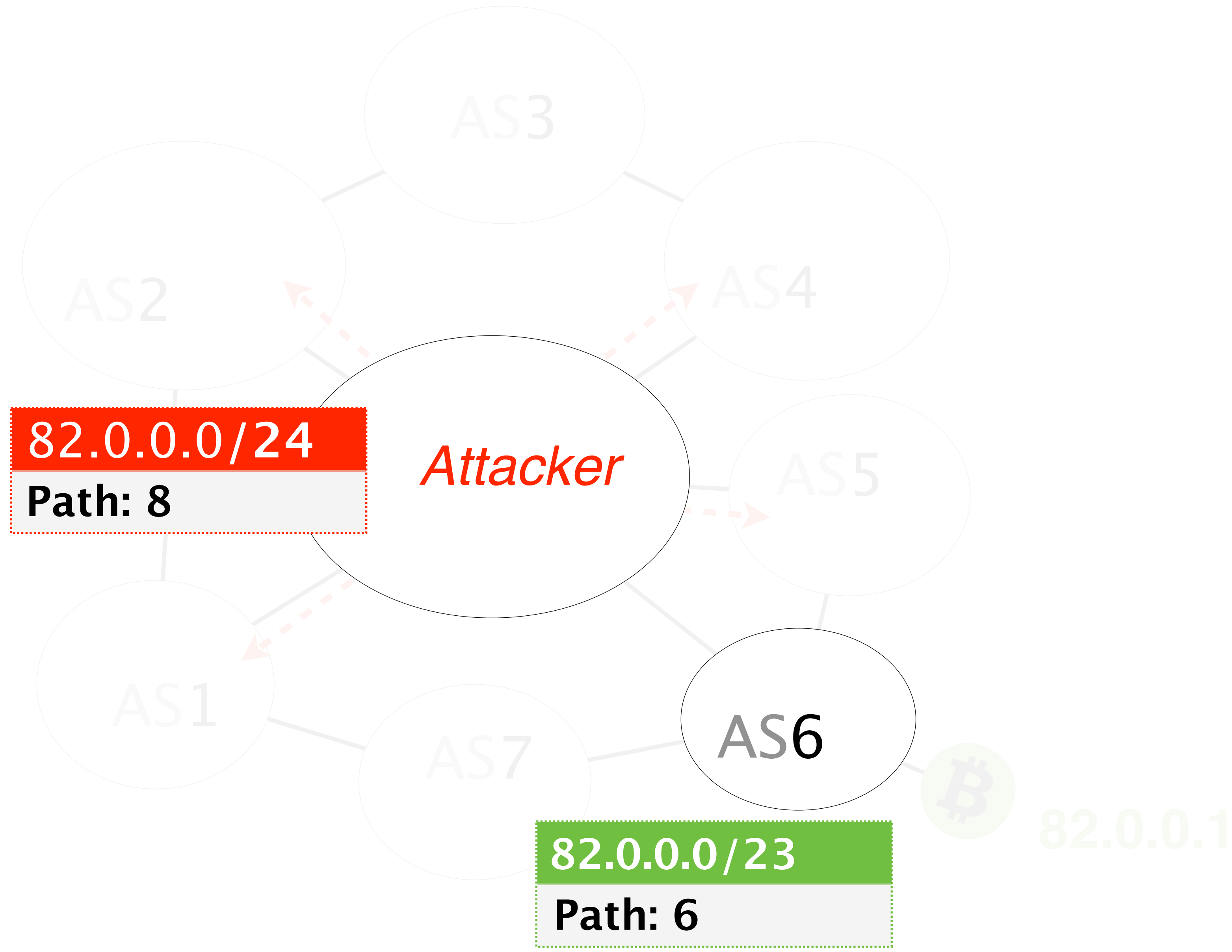


BGP does not check the validity of advertisements, meaning any AS can announce any prefix

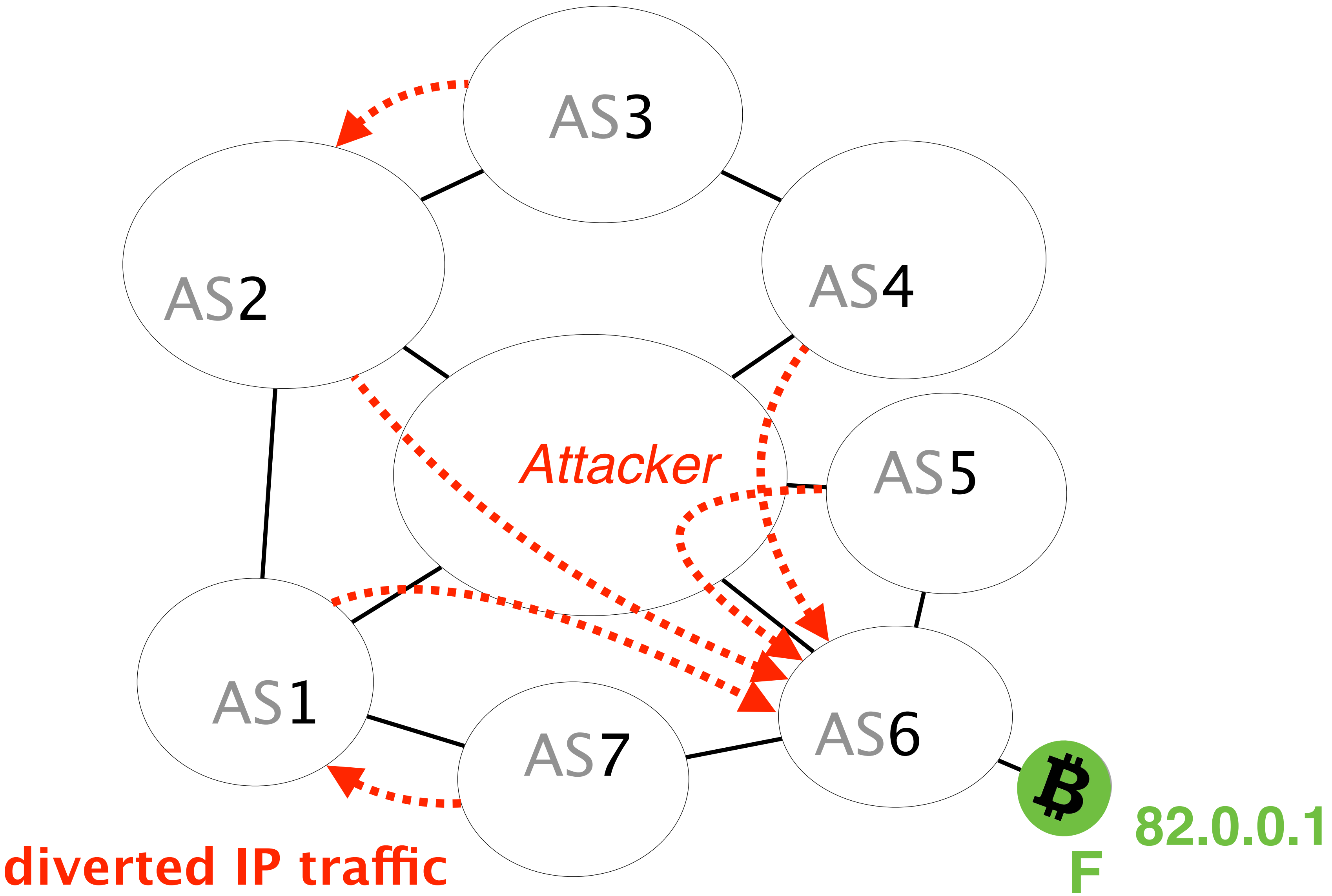
Consider that the attacker advertises a more-specific prefix covering F's IP address



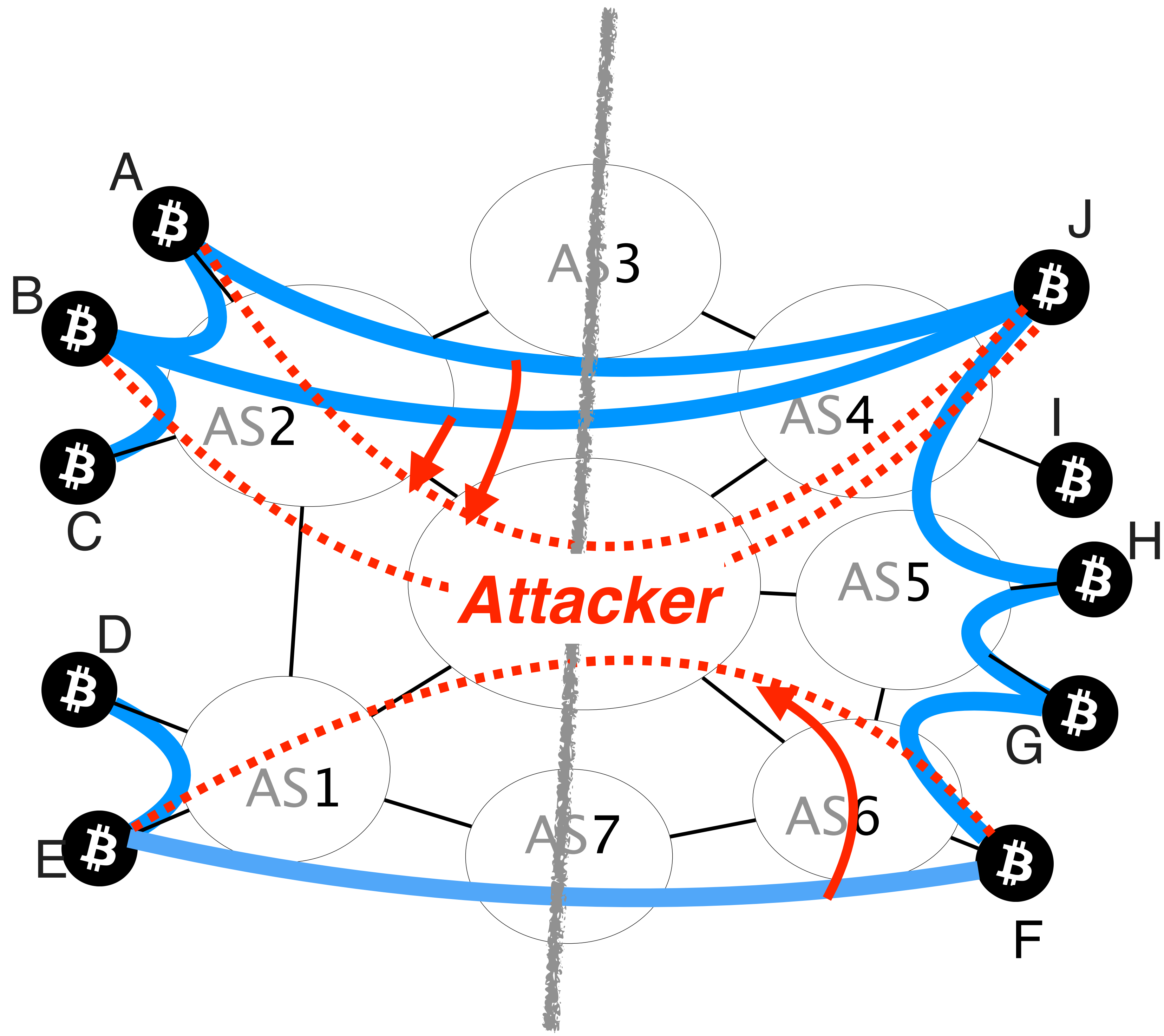
As IP routers prefer more-specific prefixes, the attacker route will be preferred



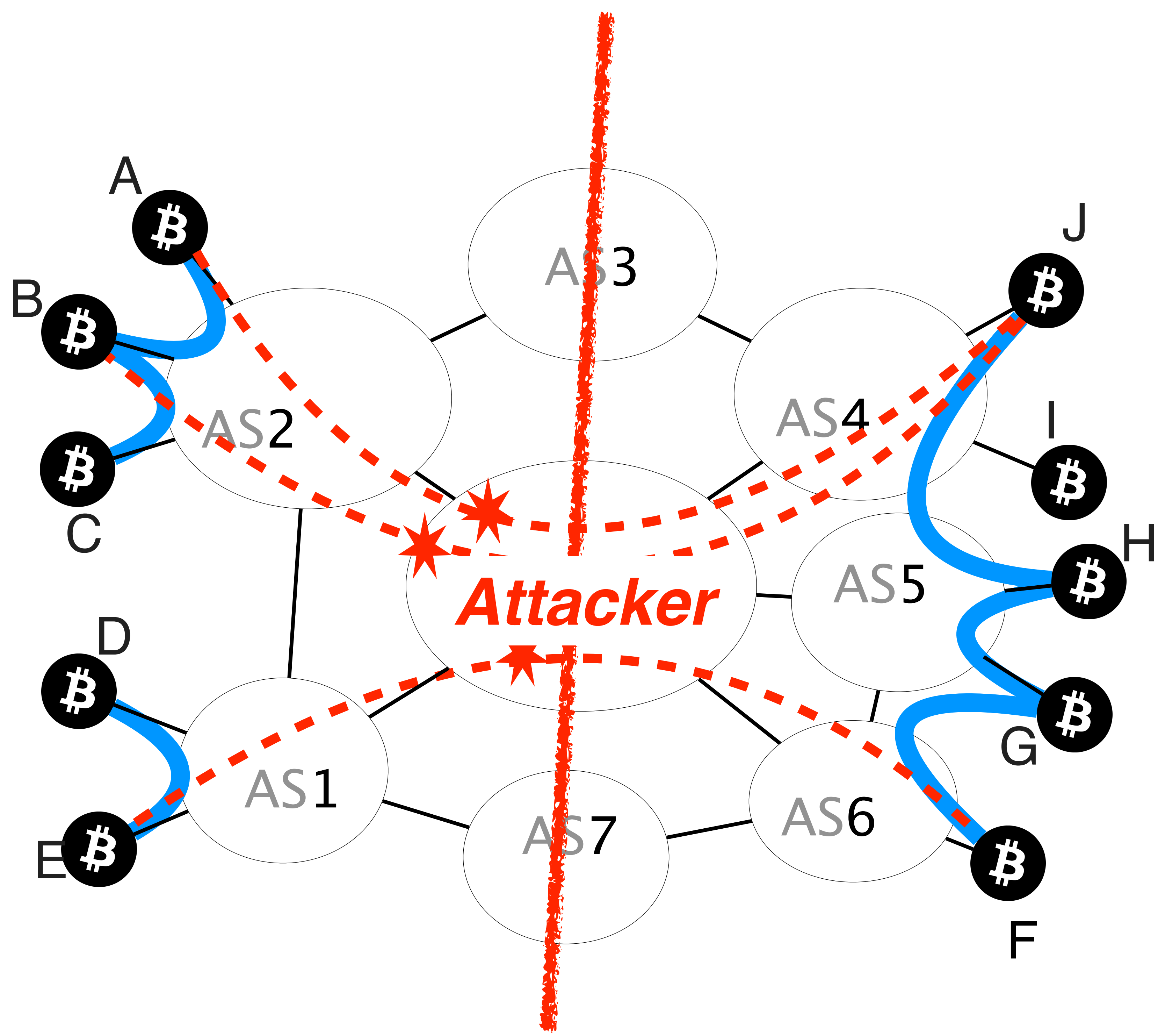
Traffic to node F is hijacked



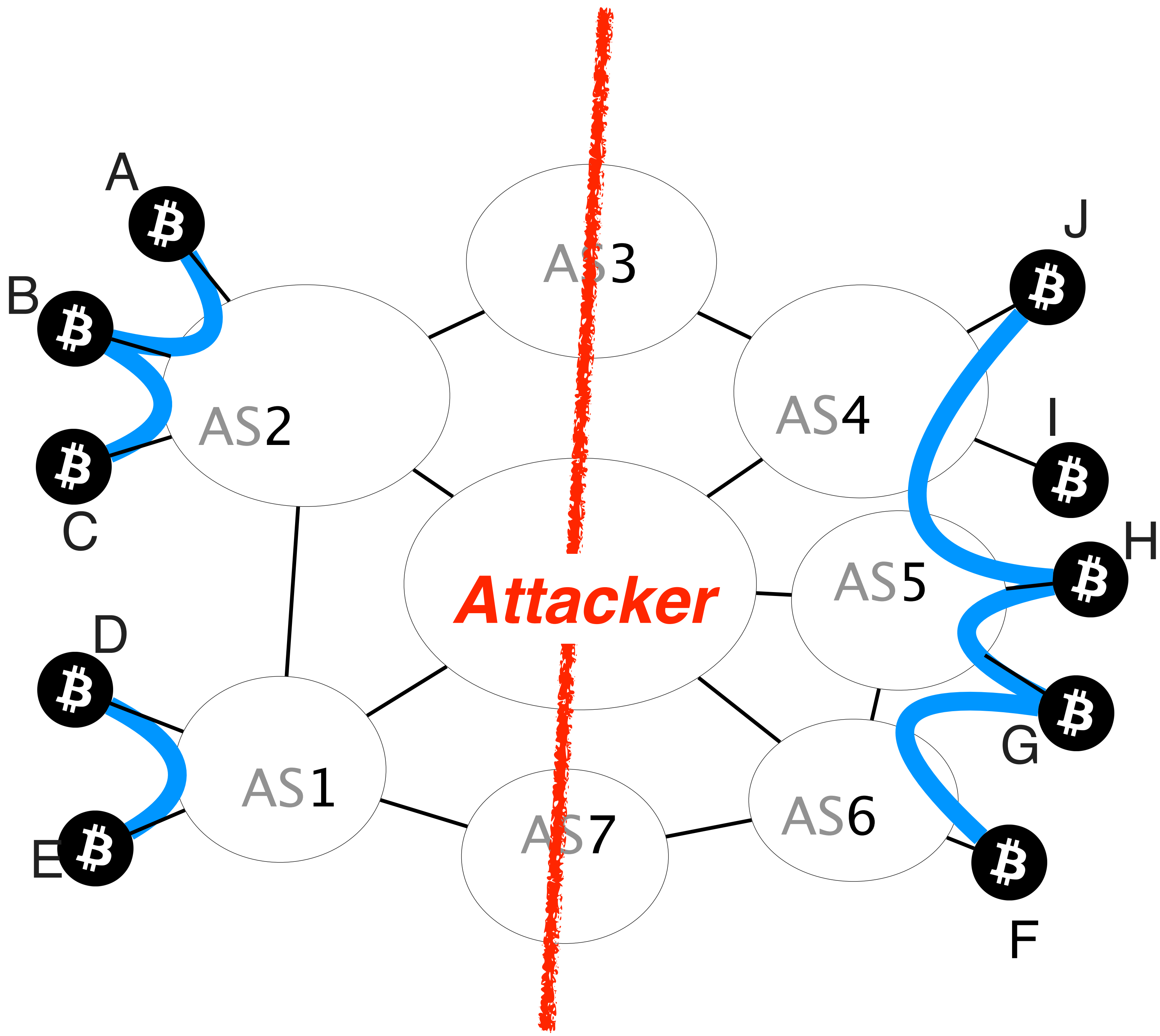
By hijacking the IP prefixes pertaining to the right nodes, the attacker can intercept all their connections



Once on-path, the attacker can drop all connections crossing the partition



The partition is created



Not all partition are feasible in practice:
some connections cannot be intercepted

Bitcoin connections established…

- within a mining pool
- within an AS
- between mining pools with private agreements

cannot be hijacked (usually)

Bitcoin connections established…

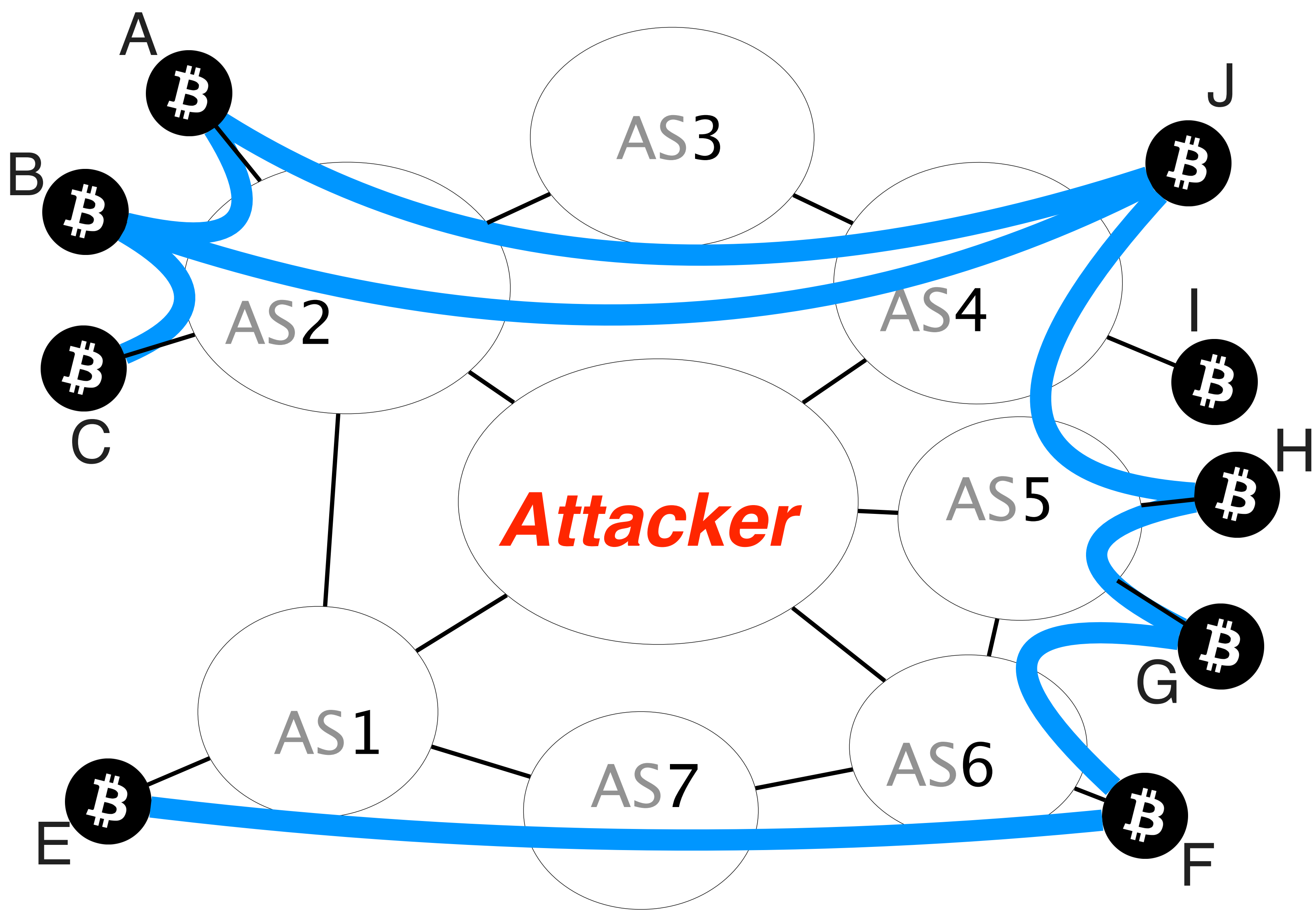
- within a mining pool
- within an AS
- between mining pools

cannot be hijacked (usually)

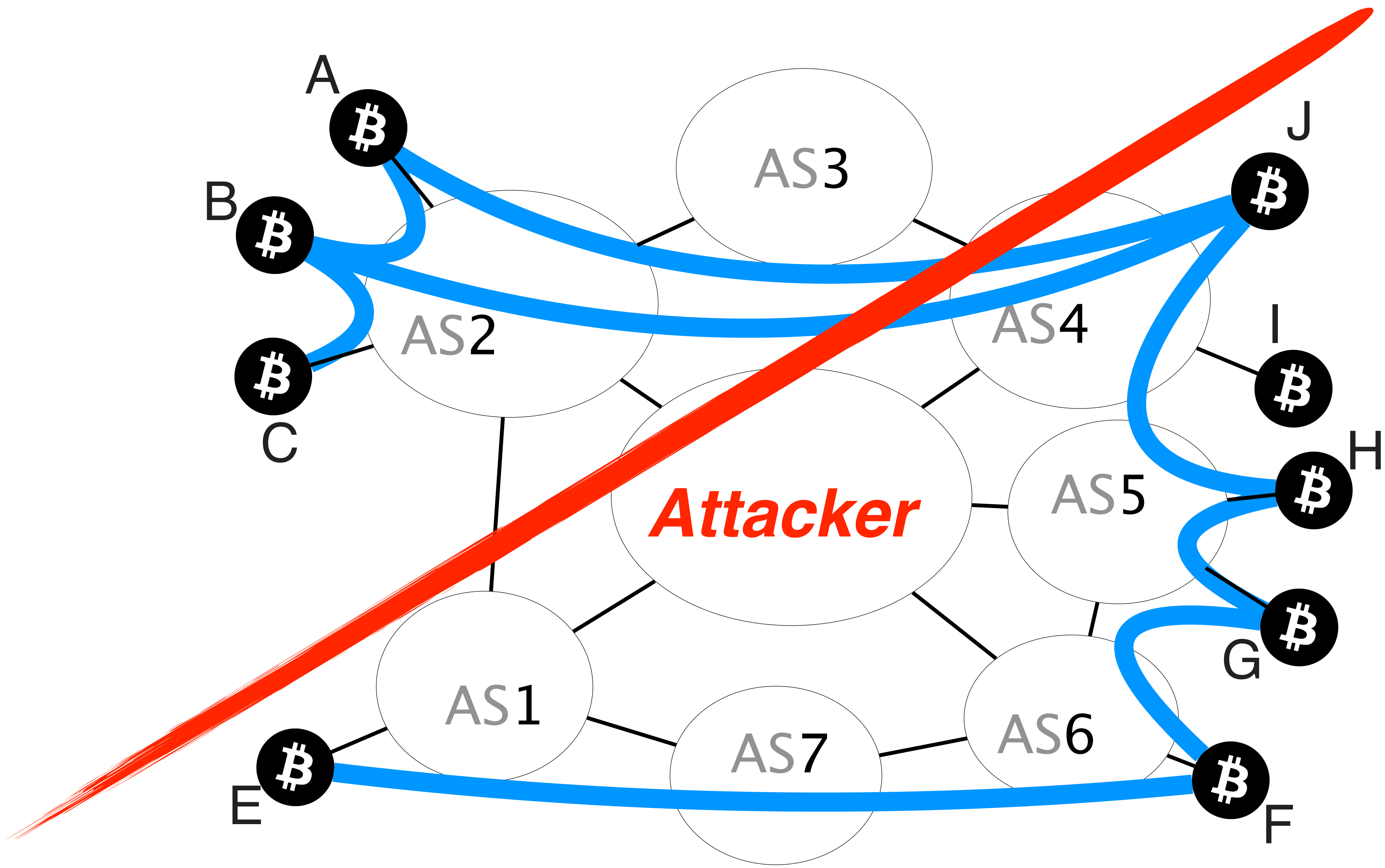
but can be *detected* and *located* by the attacker

enabling her to build a similar but feasible partition

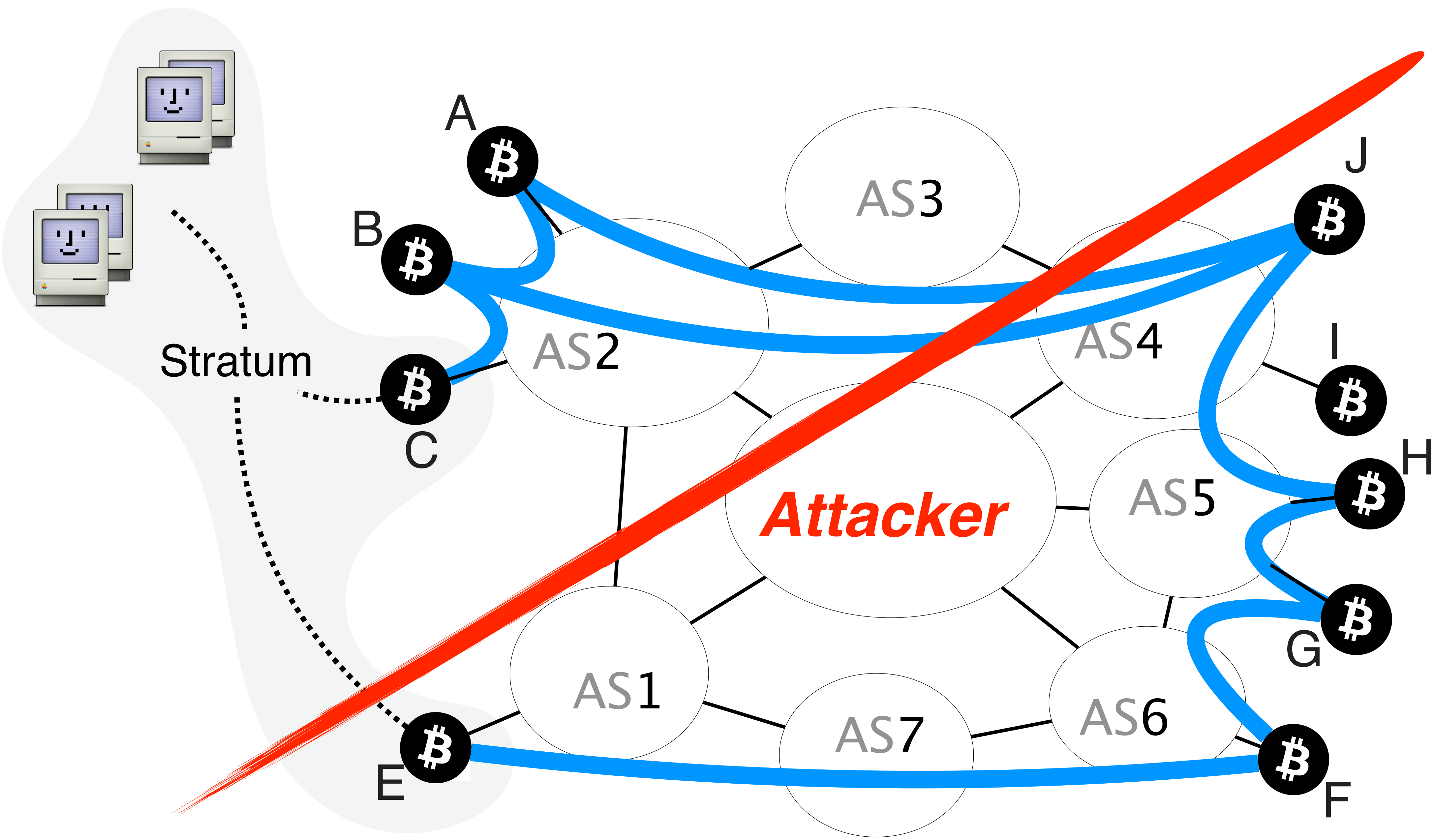
Same attacker wants to create a different partition



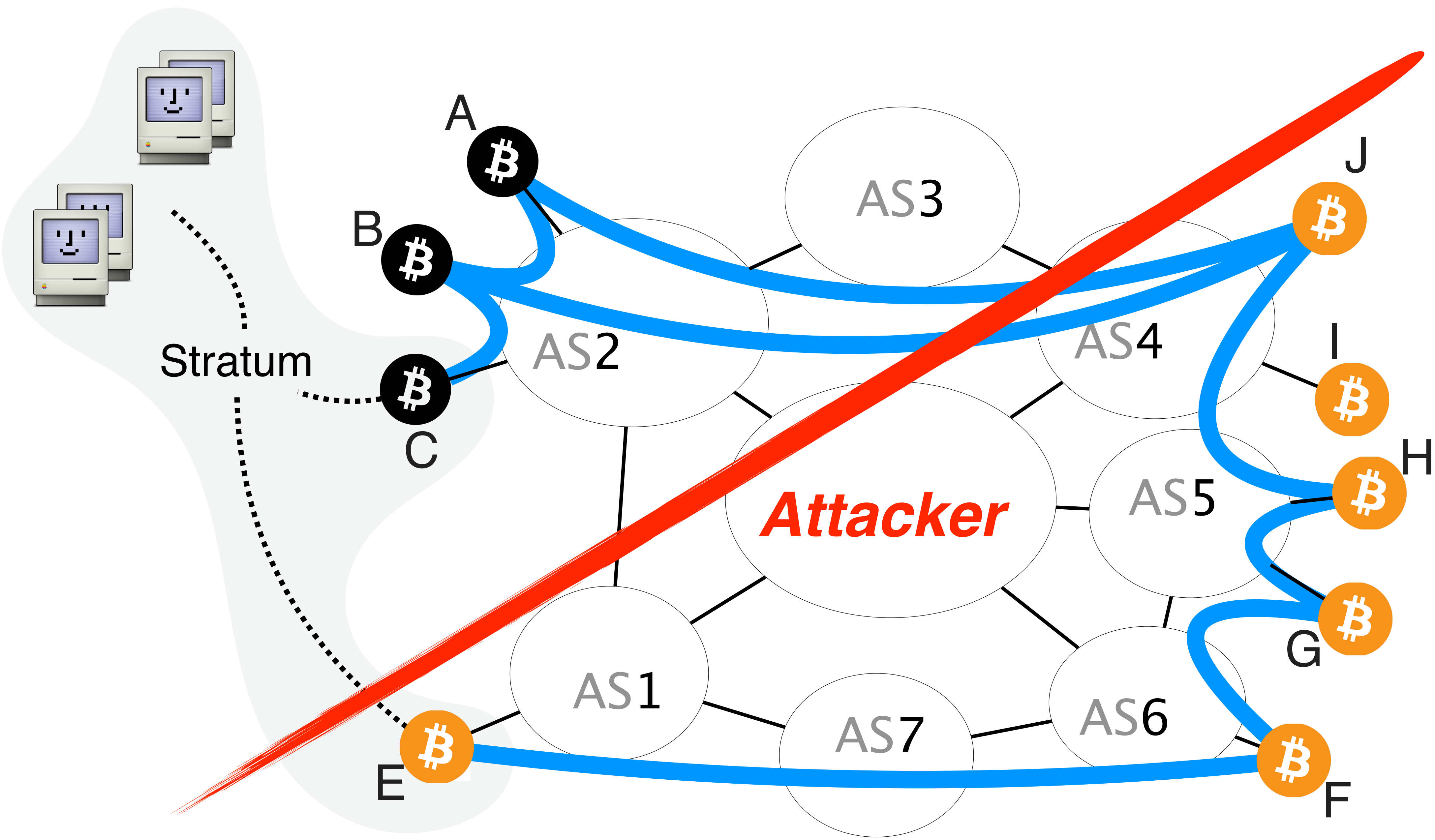
Same attacker wants to create a different partition



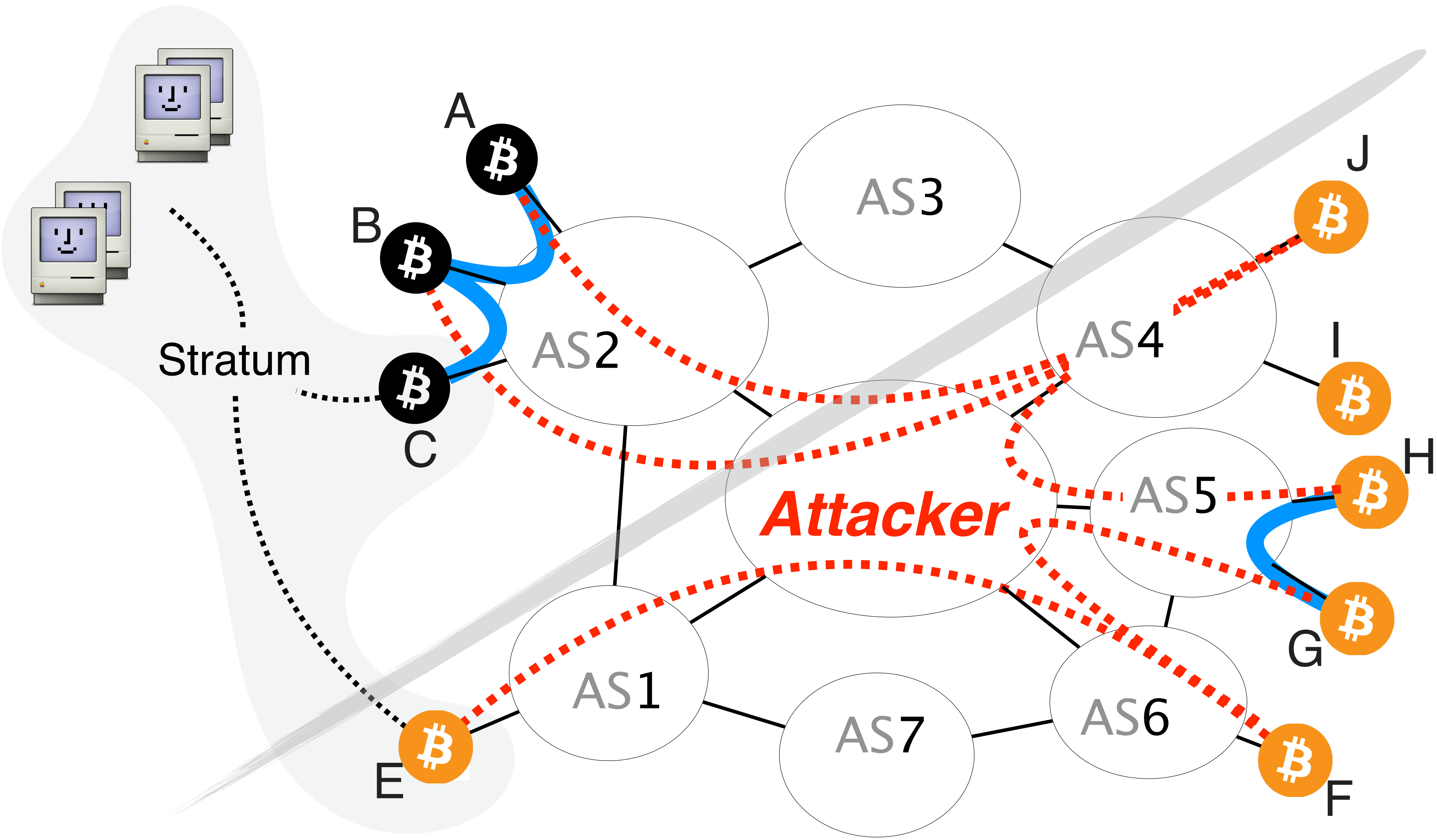
There is a mining pool in the topology



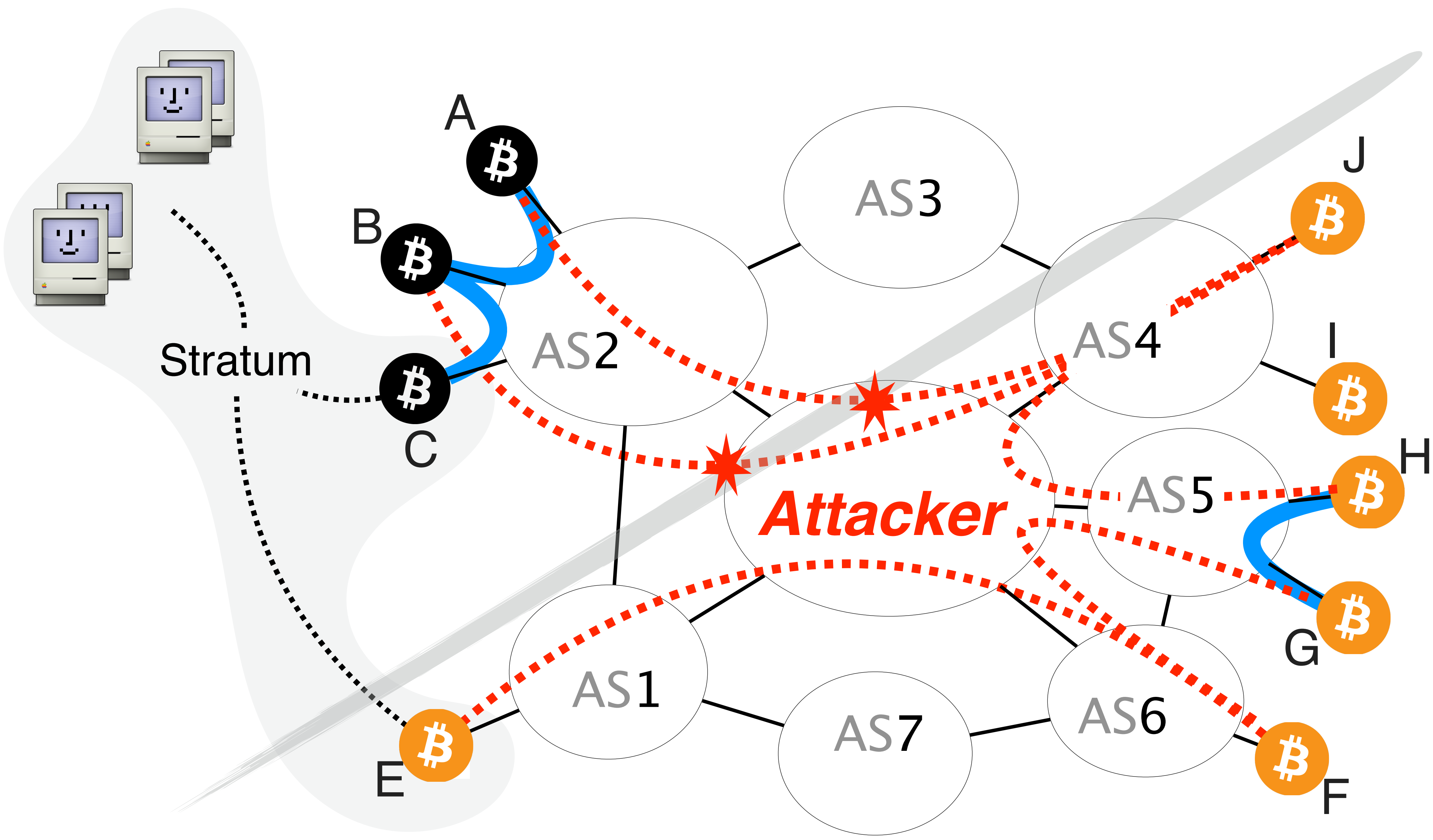
Attacker hijacks all prefixes pertaining to nodes in the orange side



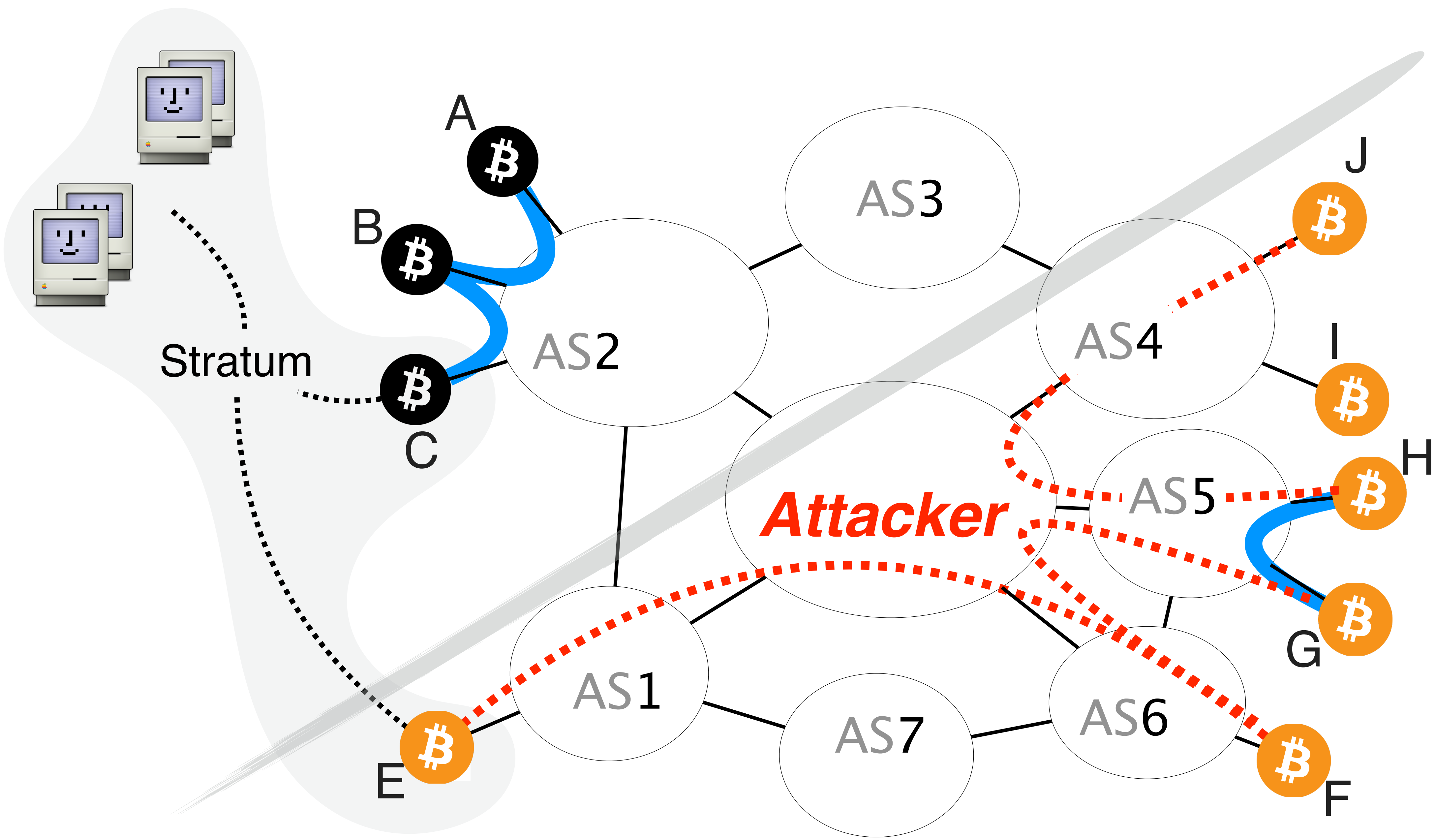
Attacker hijacks all prefixes pertaining to nodes in the orange side



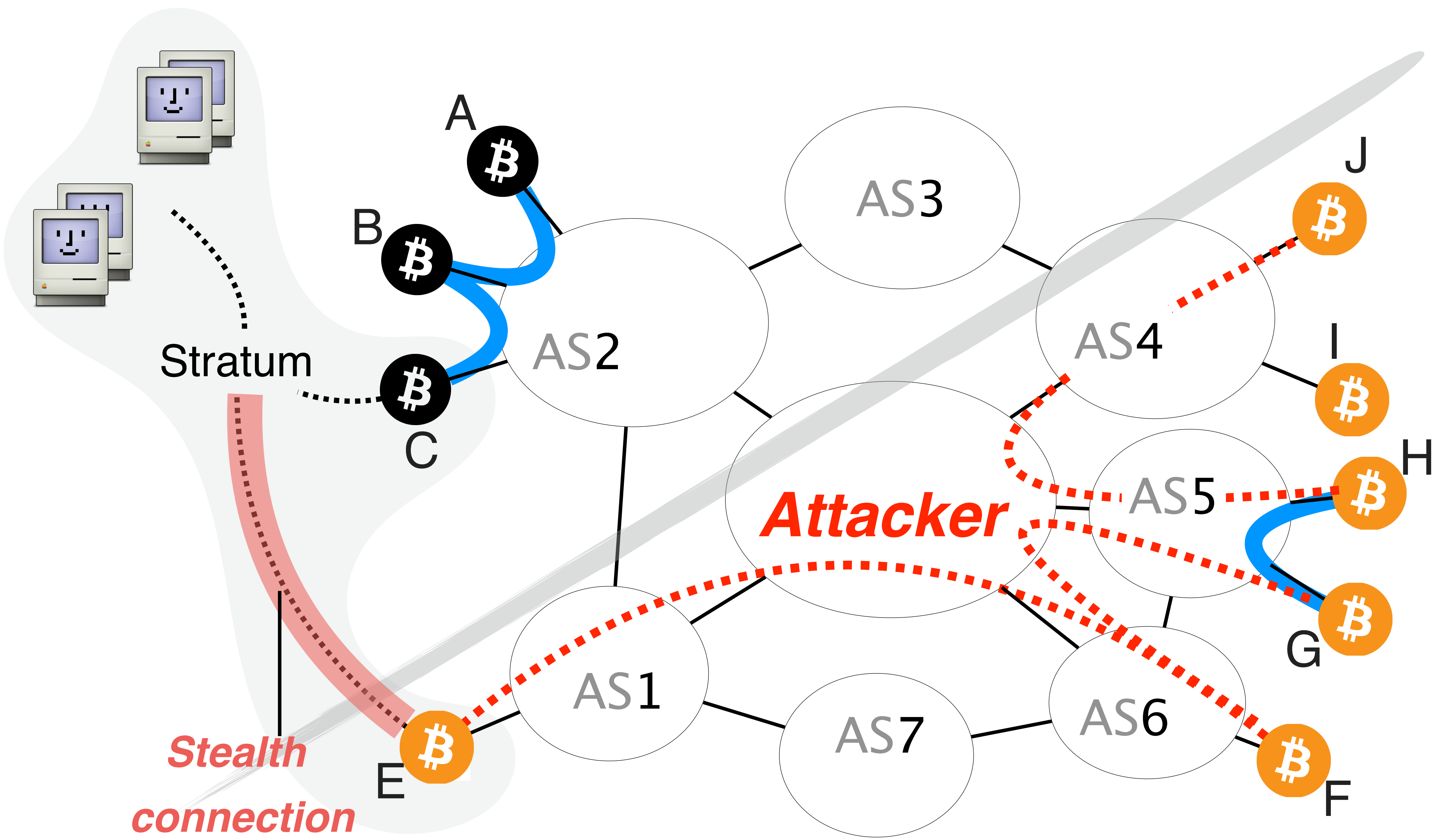
The attacker drops connections



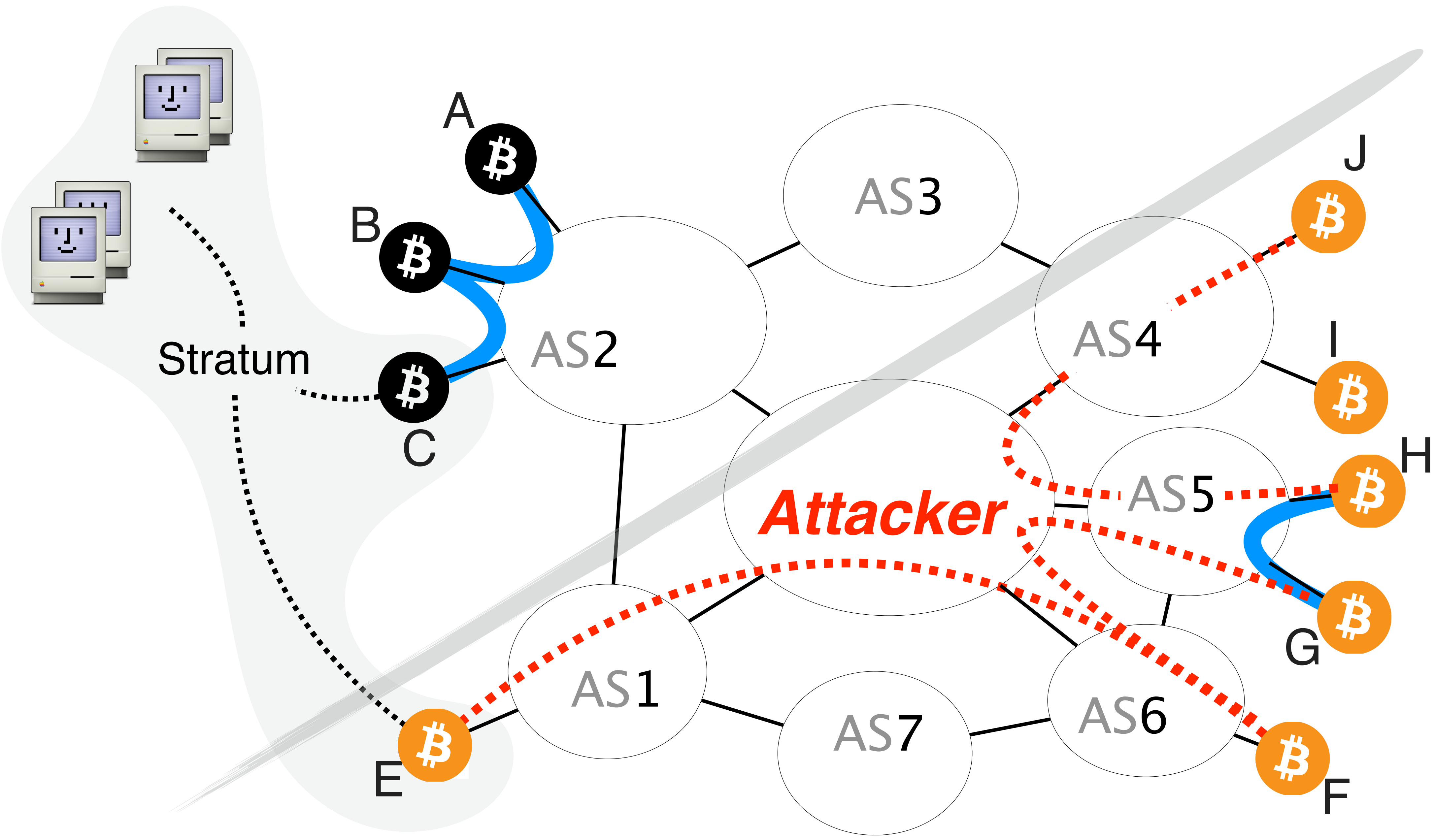
The partition is created but is ineffective



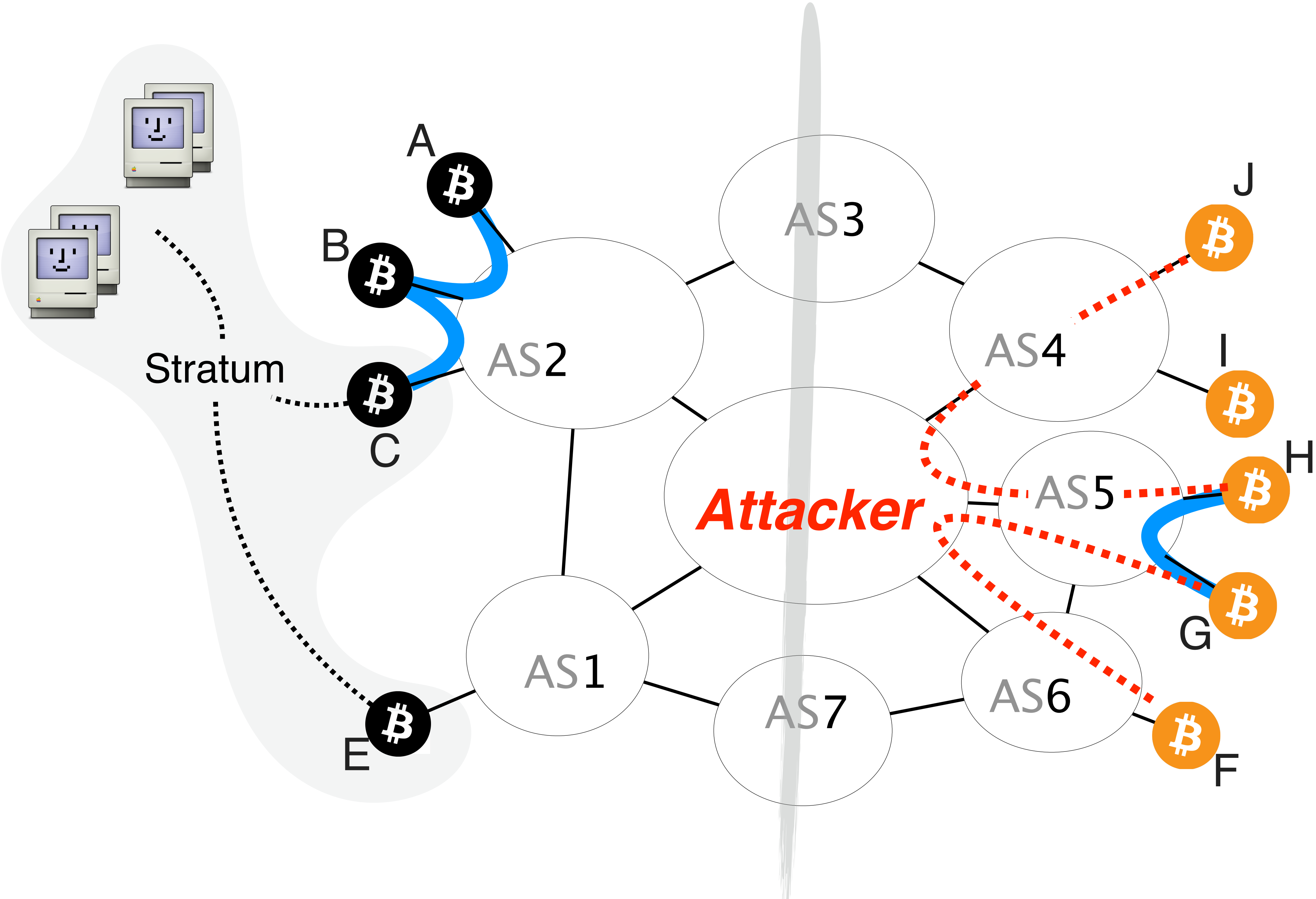
The partition is infeasible



The attacker monitors the connections and detects leakage



The attacker monitors the connections



Theorem

Given a set of nodes to disconnect from the network, there exist a unique maximal subset that can be isolated and that the attacker will isolate.

see paper for proof

We evaluated the partition attack in terms of practicality and time efficiency

Practicality	Time efficiency
Can it actually happen?	How long does it take?

We evaluated the partition attack in terms of **practicality** and **time efficiency**

Practicality

Time efficiency

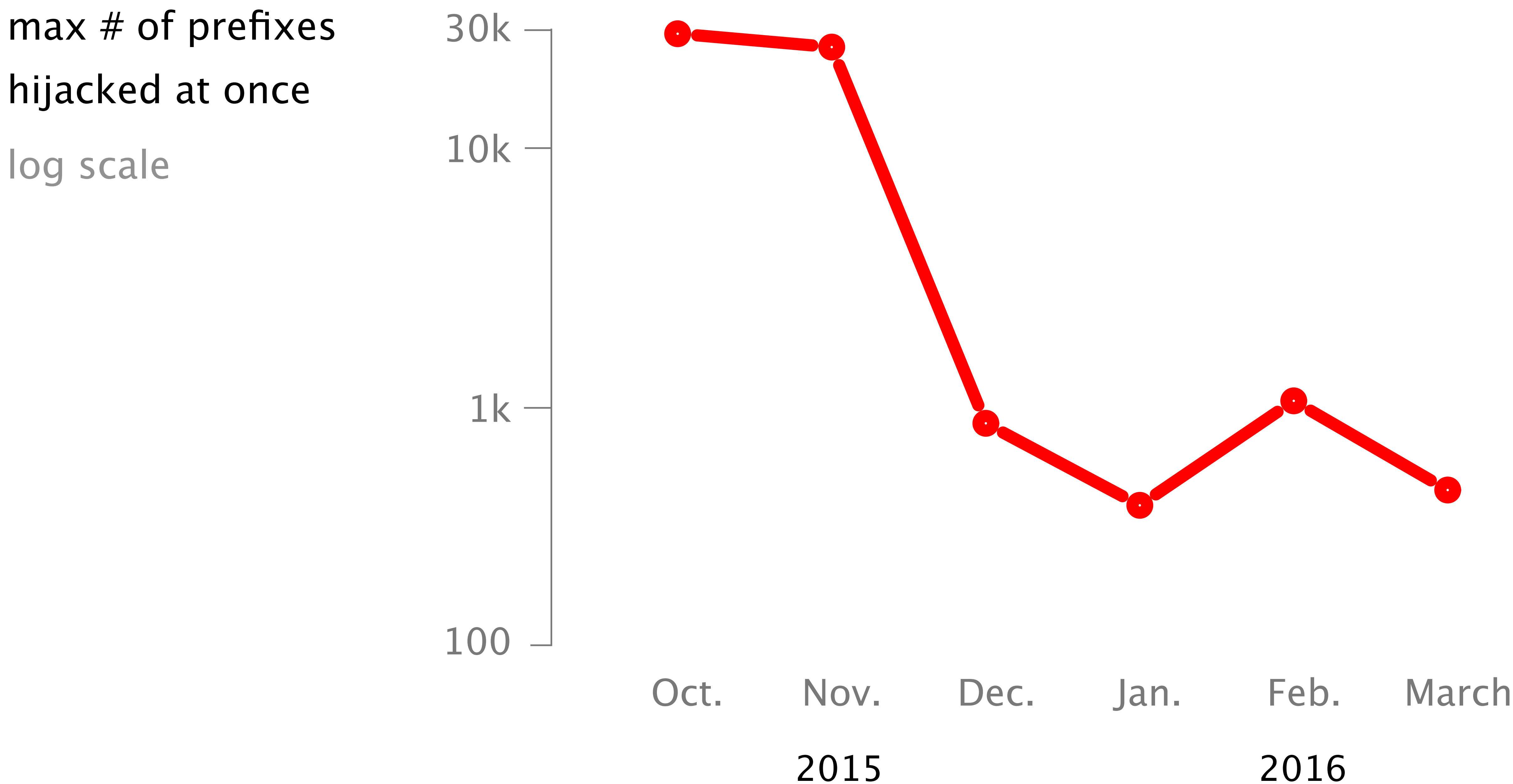
Can it actually happen?

Splitting the mining power even to half can be done by hijacking less than 100 prefixes

Splitting the mining power even to half can be done by hijacking less than 100 prefixes

negligible with respect to routinely observed hijacks

Hijacks involving up to 1k of prefixes are frequently seen in the Internet today

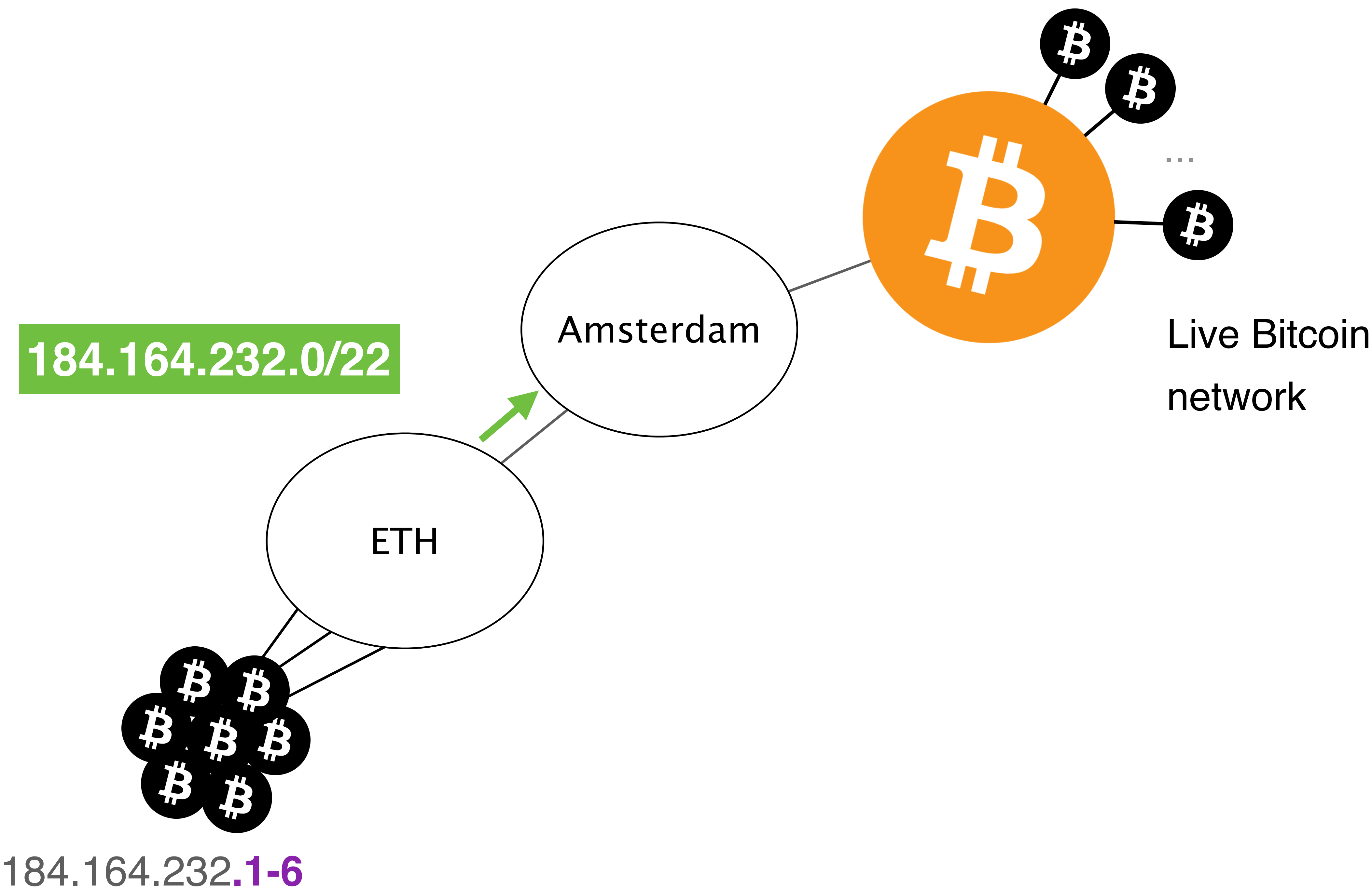


We also evaluated the partition in terms of time efficiency

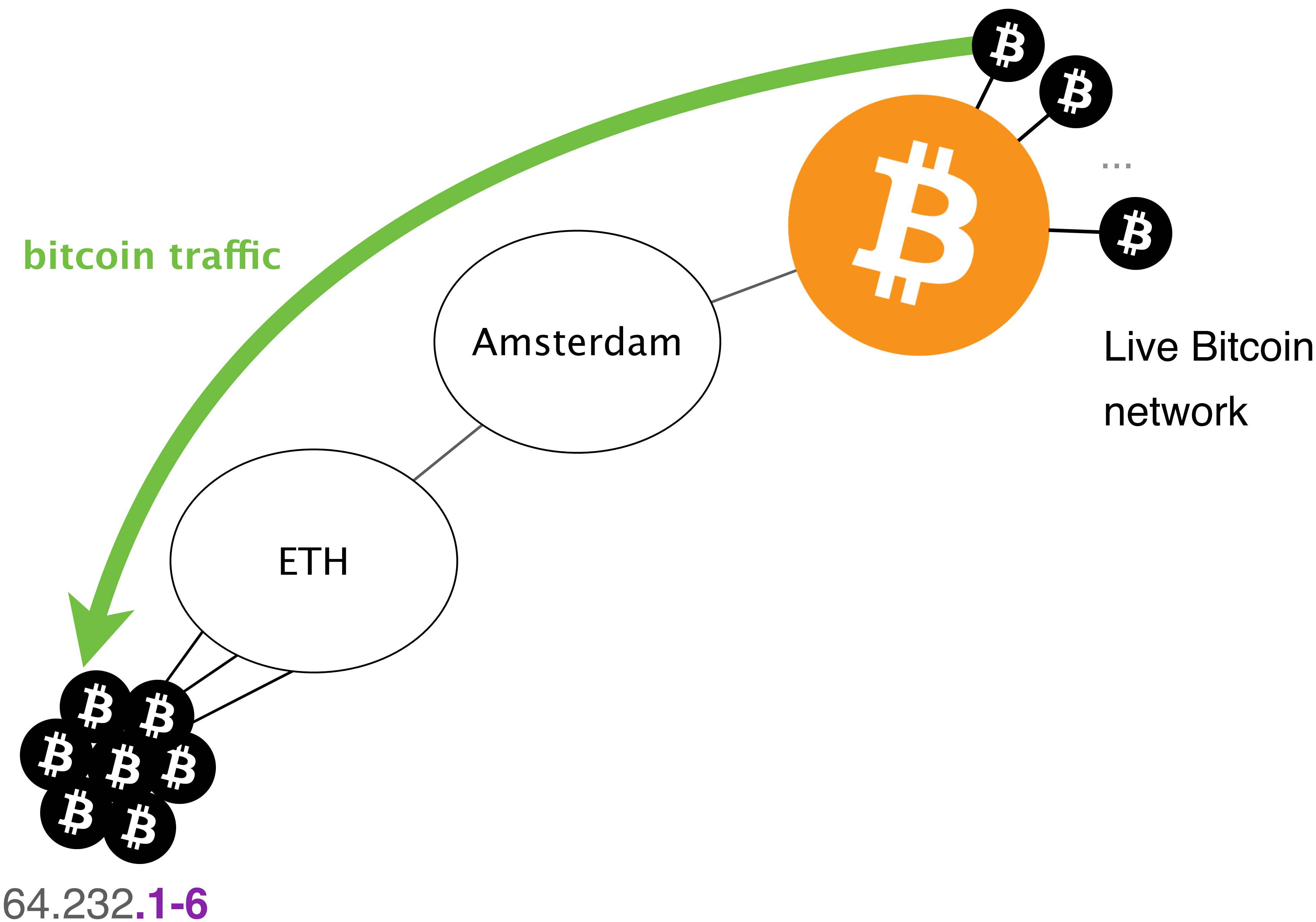
Practicality	Time efficiency
	How long does it take?

We measured the time required to perform a partition attack by attacking our own nodes

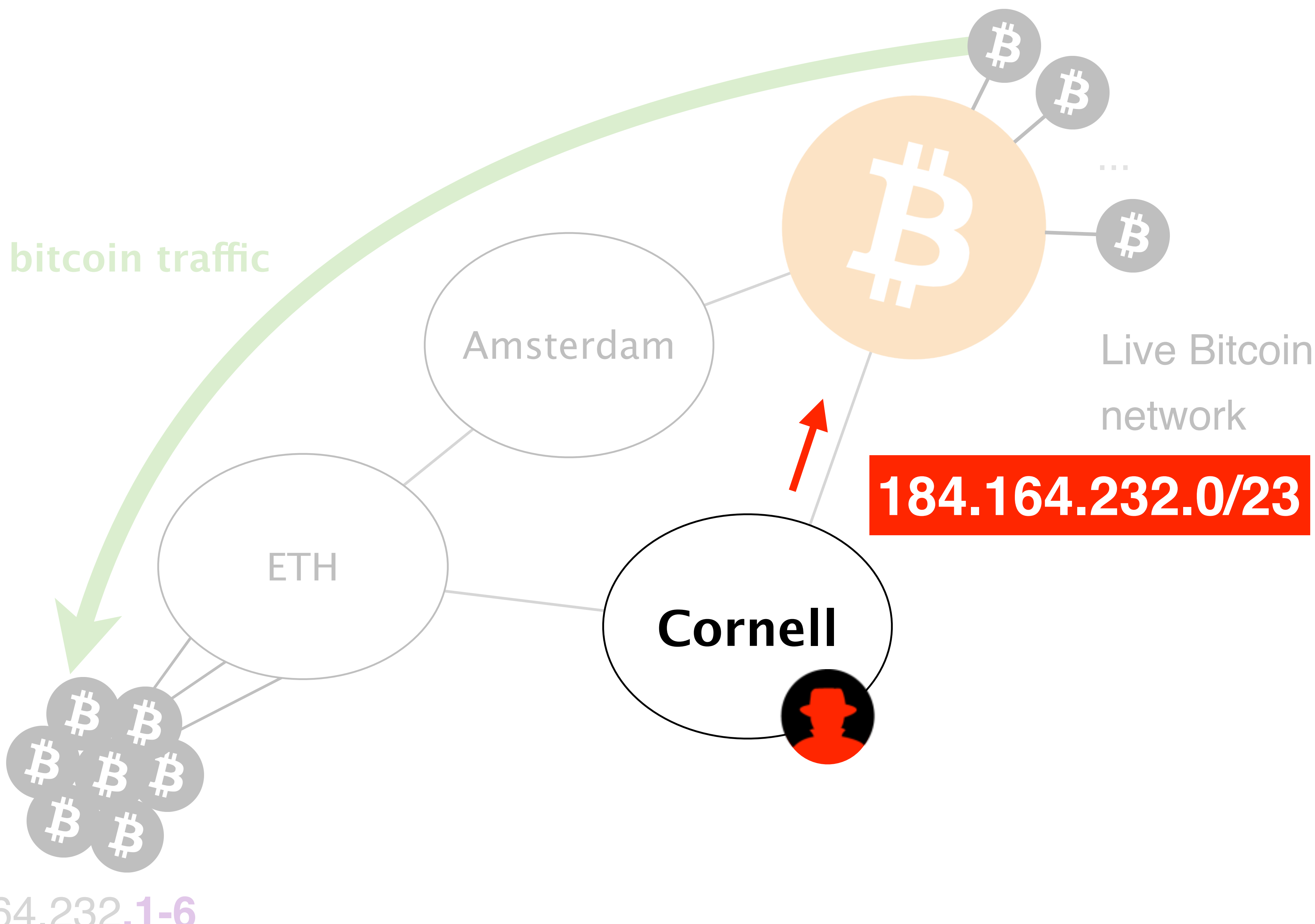
We hosted a few Bitcoin nodes at ETH and advertised a covering prefix via Amsterdam



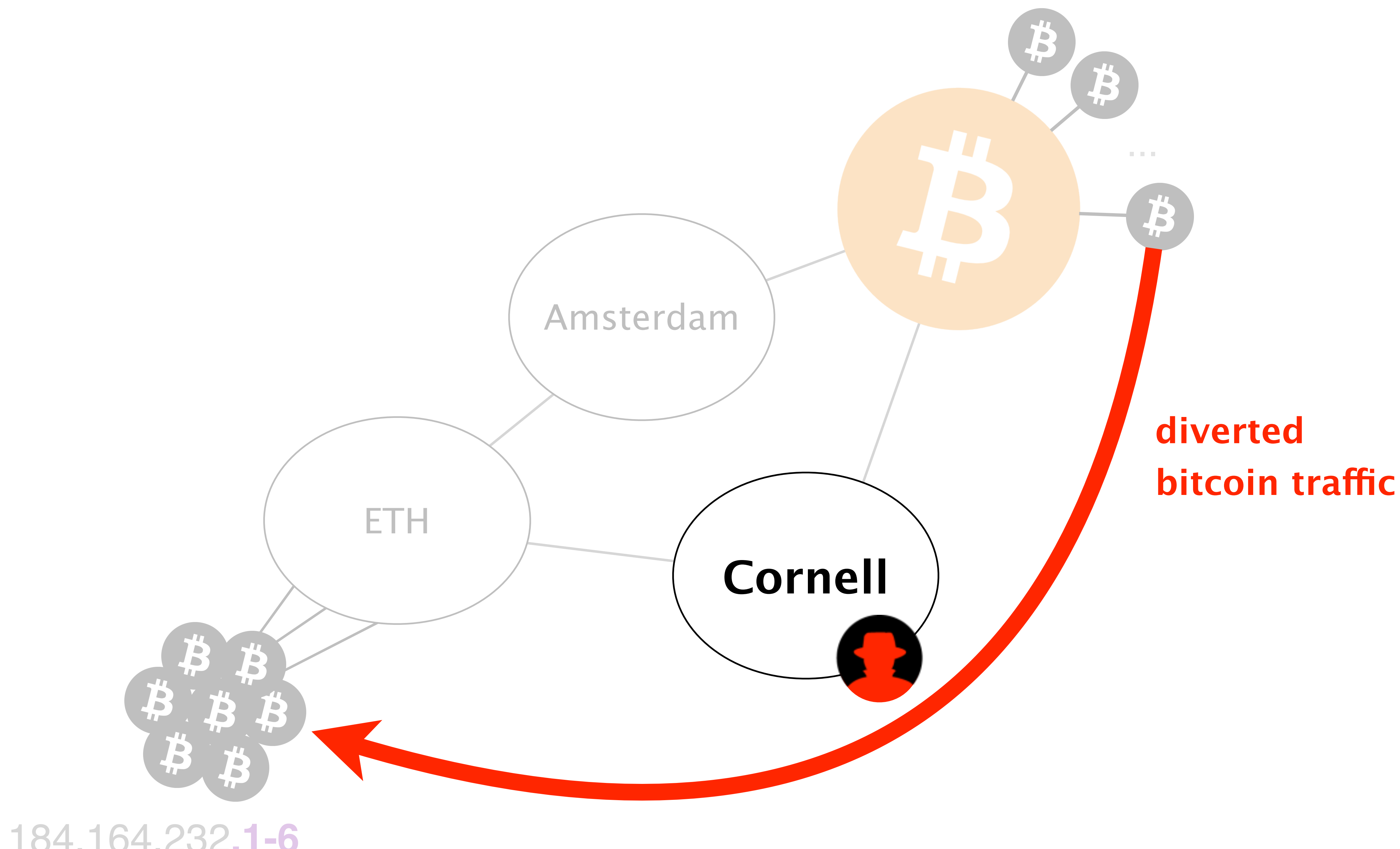
Initially, all the traffic to our nodes transits via Amsterdam

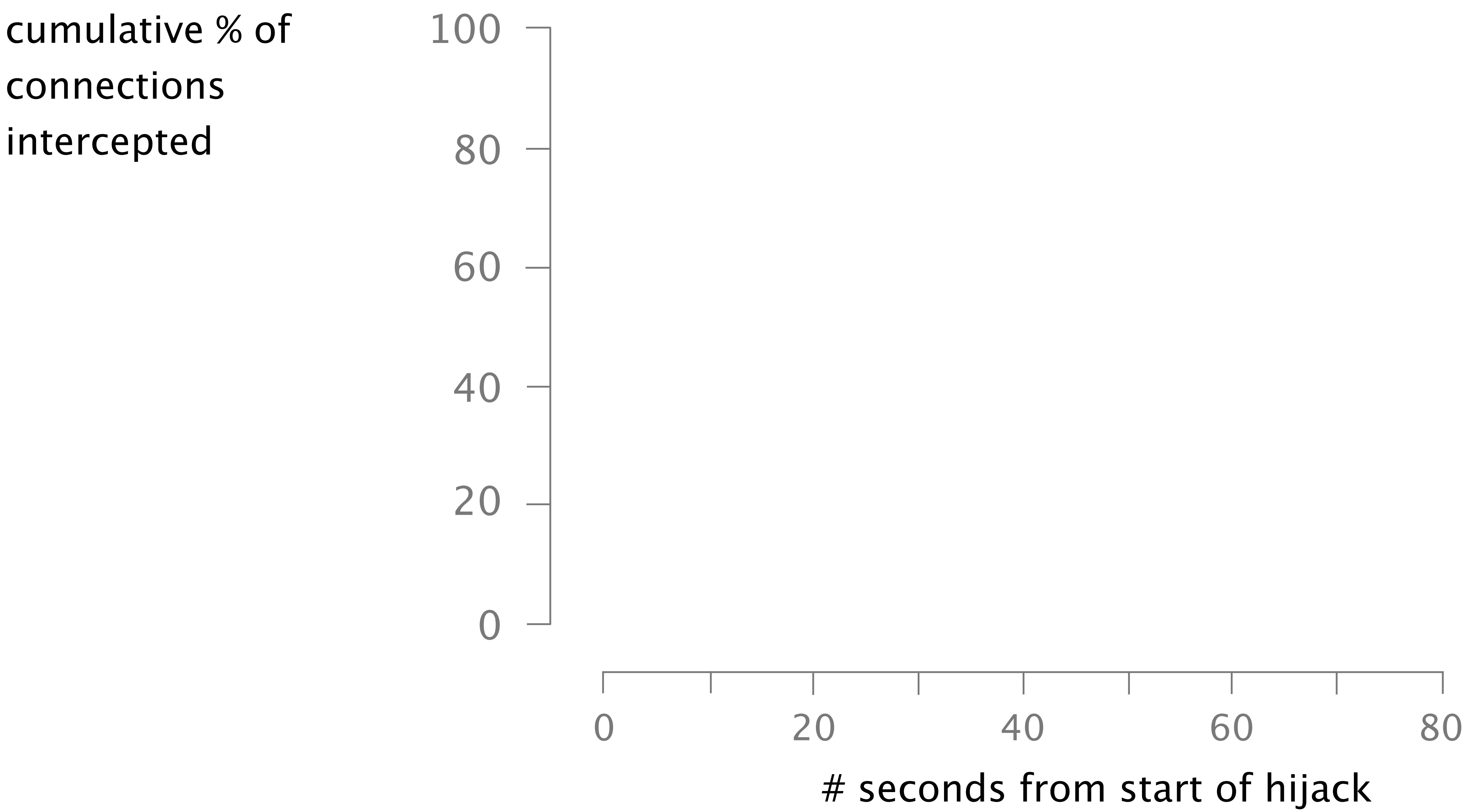


We hijacked our nodes

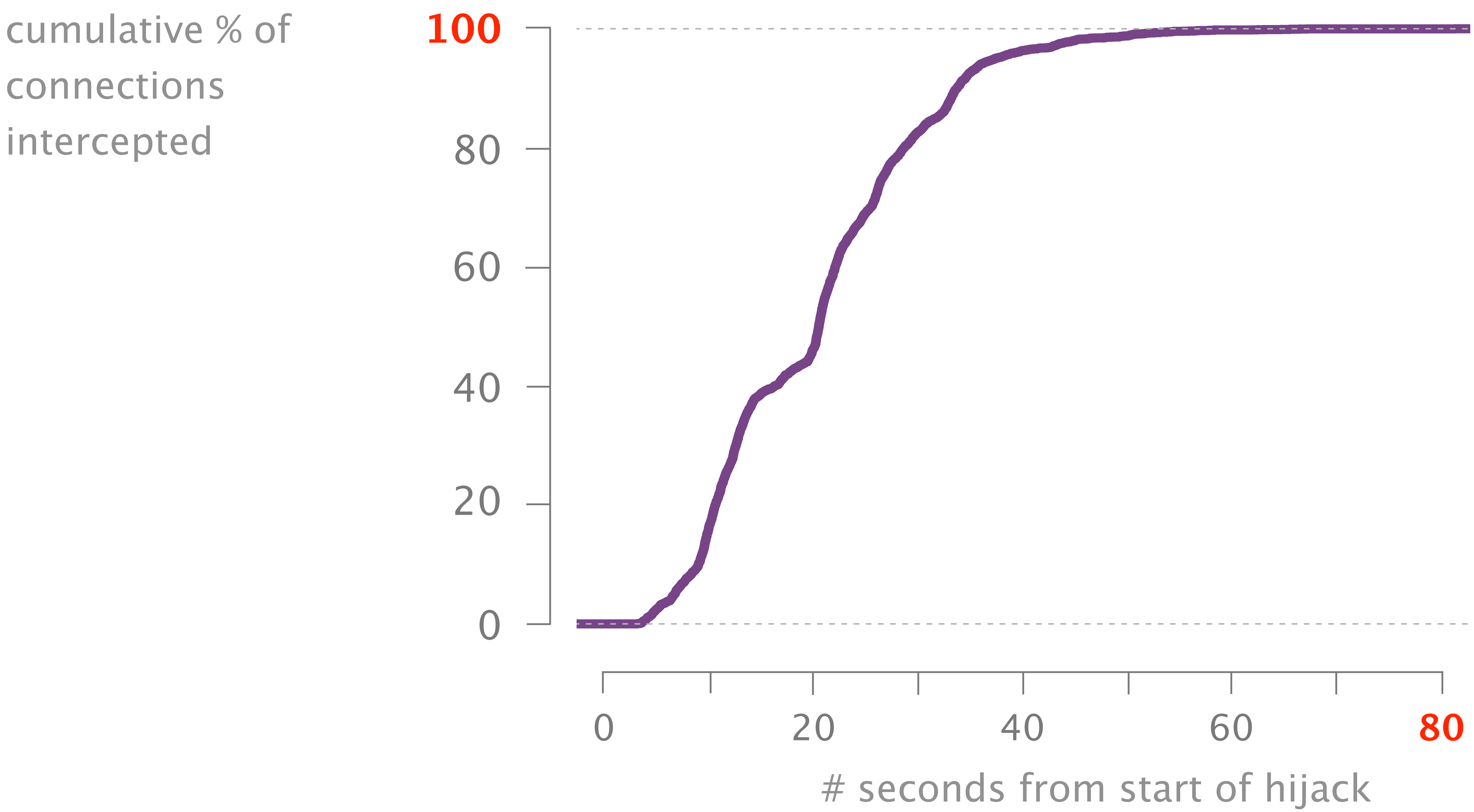


We measured the time required for a rogue AS to divert all the traffic to our nodes




cumulative % of connections intercepted
100
80
60
40
20
0
0
20
40
60
80
seconds from start of hijack

It takes less than 2 minutes for the attacker to intercept all the connections



Mitigating a hijack is a human-driven process, as such it often takes hours to be resolved

Mitigating a hijack is a human-driven process, as such it often takes hours to be resolved

It took Google close to 3h
to mitigate a large hijack in 2008 [6]

(same hold for more recent hijacks)

Hijacking Bitcoin

Routing Attacks on Cryptocurrencies

1 **Background**

BGP & Bitcoin

2 **Partitioning attack**

splitting the network

4 **Countermeasures**

short-term & long-term

Countermeasures exist for both types of attacks

Countermeasures against partition attacks exist

Short-term	Host all Bitcoin clients in /24 prefixes reduce chances of a successful hijack

Countermeasures against partition attacks exist

Short-term	Host all Bitcoin clients in /24 prefixes reduce chances of a successful hijack
Long-term	Deploy secure routing protocols (S-BGP, RPKI) prevent partition attacks

Countermeasures against partition attacks exist

But are impractical

Host all Bitcoin clients in /24 prefixes

Deploy secure routing protocols

Countermeasures against partition attacks exist

But are impractical

Host all Bitcoin clients in /24 prefixes

increase BGP routing tables

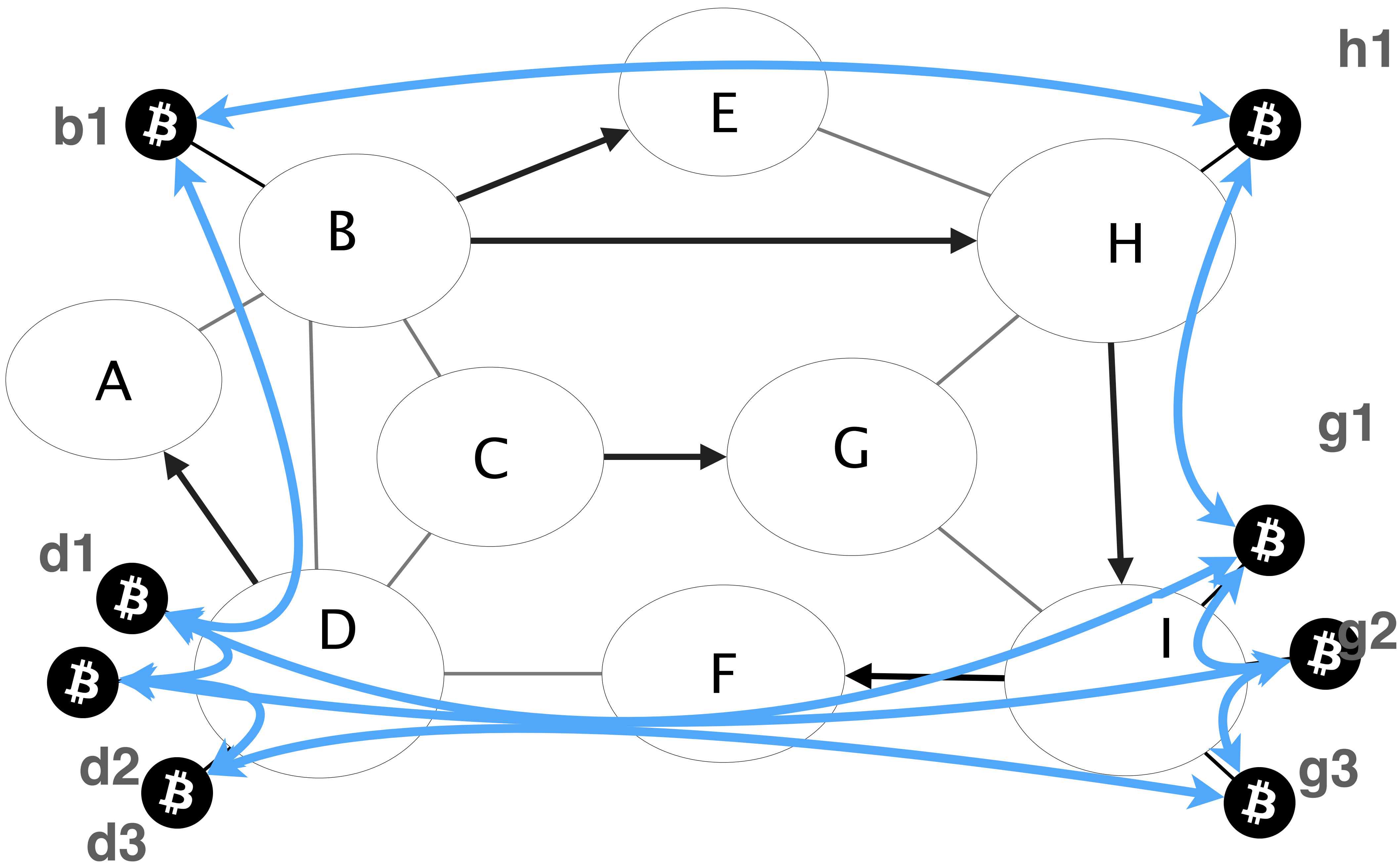
Deploy secure routing protocols

ISP collaboration required

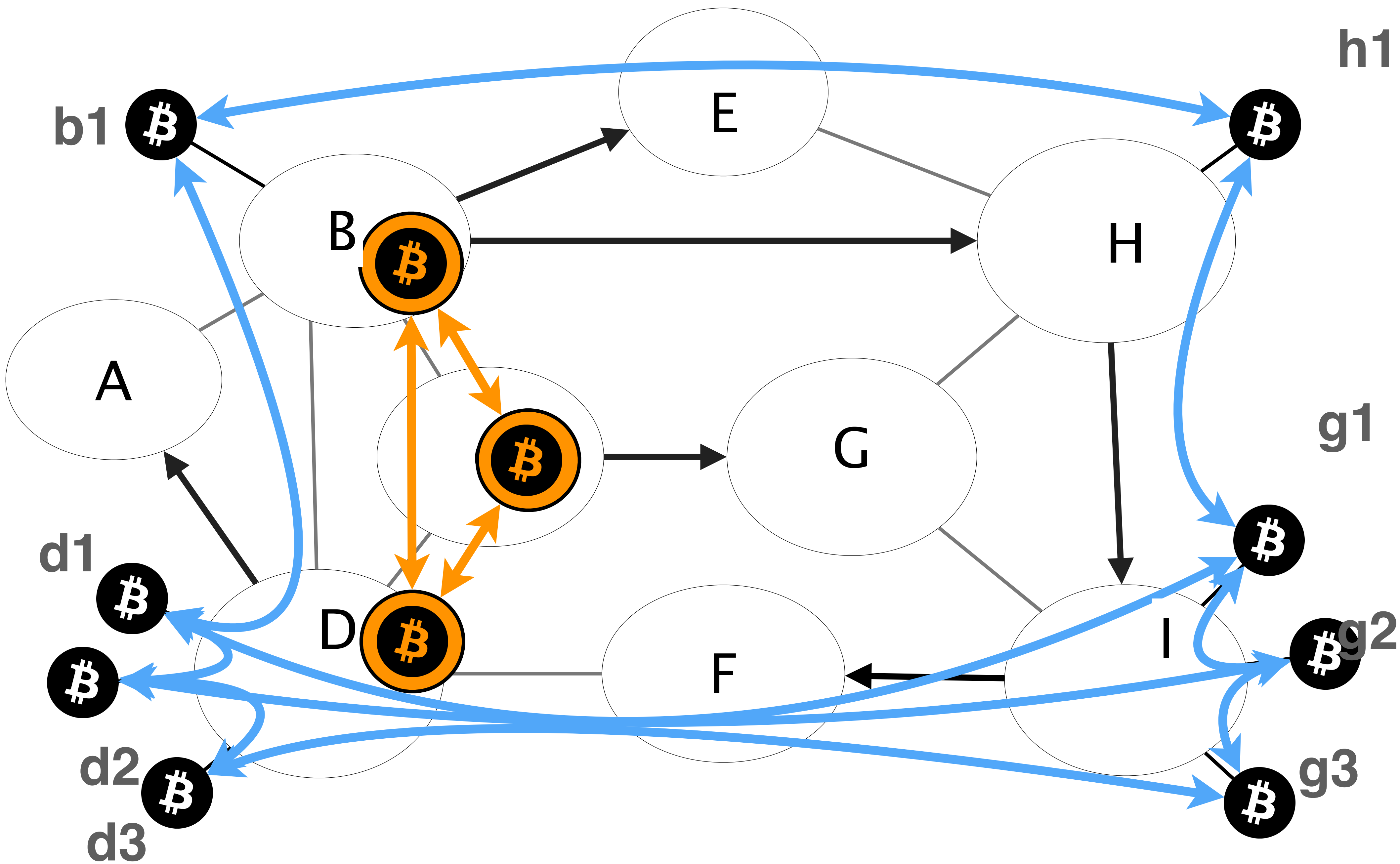
Build additional secure channel to allow communication even if the Bitcoin network is partitioned

SABRE = Secure Relay Location + Robust Design

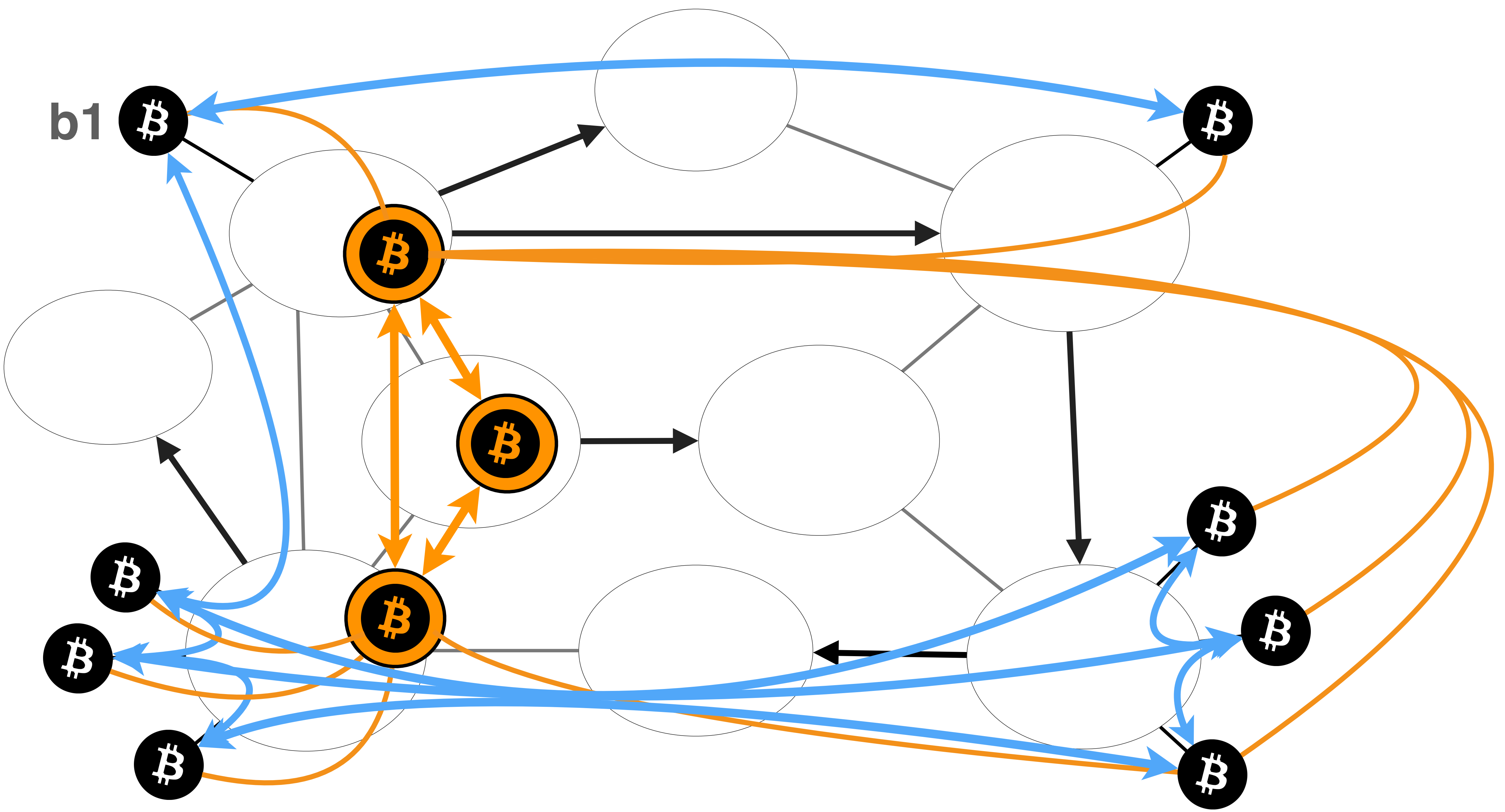
add few clients that connect to each other and to all other clients


h1
b1
E
B
H
A
g1
C
G
d1
D
I
g2
F
d2
g3
d3

SABRE: Additional relay network of relay nodes



Clients connect to at least one relay node



SABRE = Secure Relay Location + Robust Design

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additional nodes protected
against hijacking attacks

SABRE = Secure Relay Location + Robust Design

Open and Resilient against DDoS attacks

Secure Relay Placement

nodes in /24 prefix

peering ASes with no customers

k-connected graph of relays

relays cover most clients

Secure Relay Placement

nodes in /24 prefix

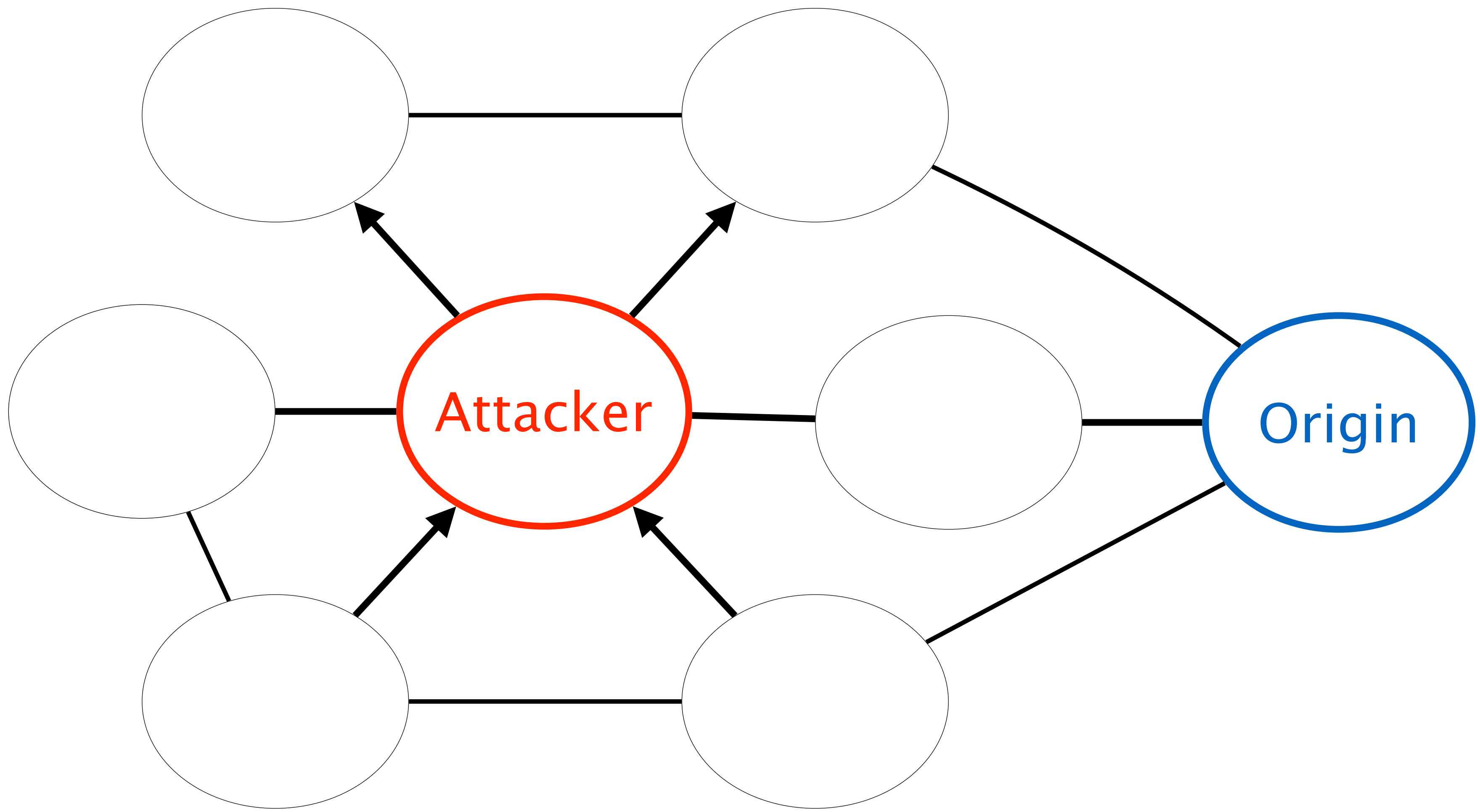
malicious prefix in competition with legitimate ones

peering ASes with no customers

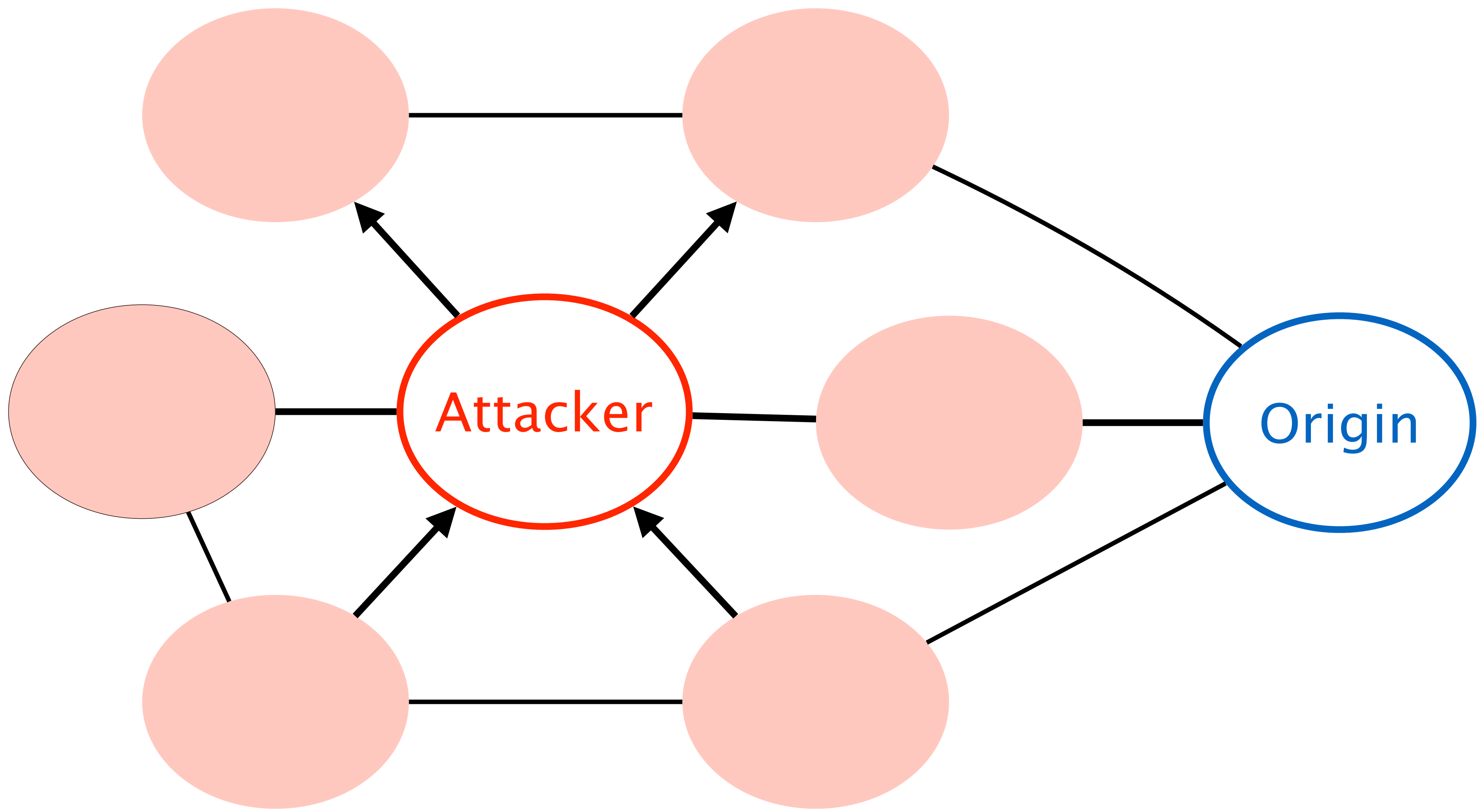
k-connected graph of relays

relays cover most clients

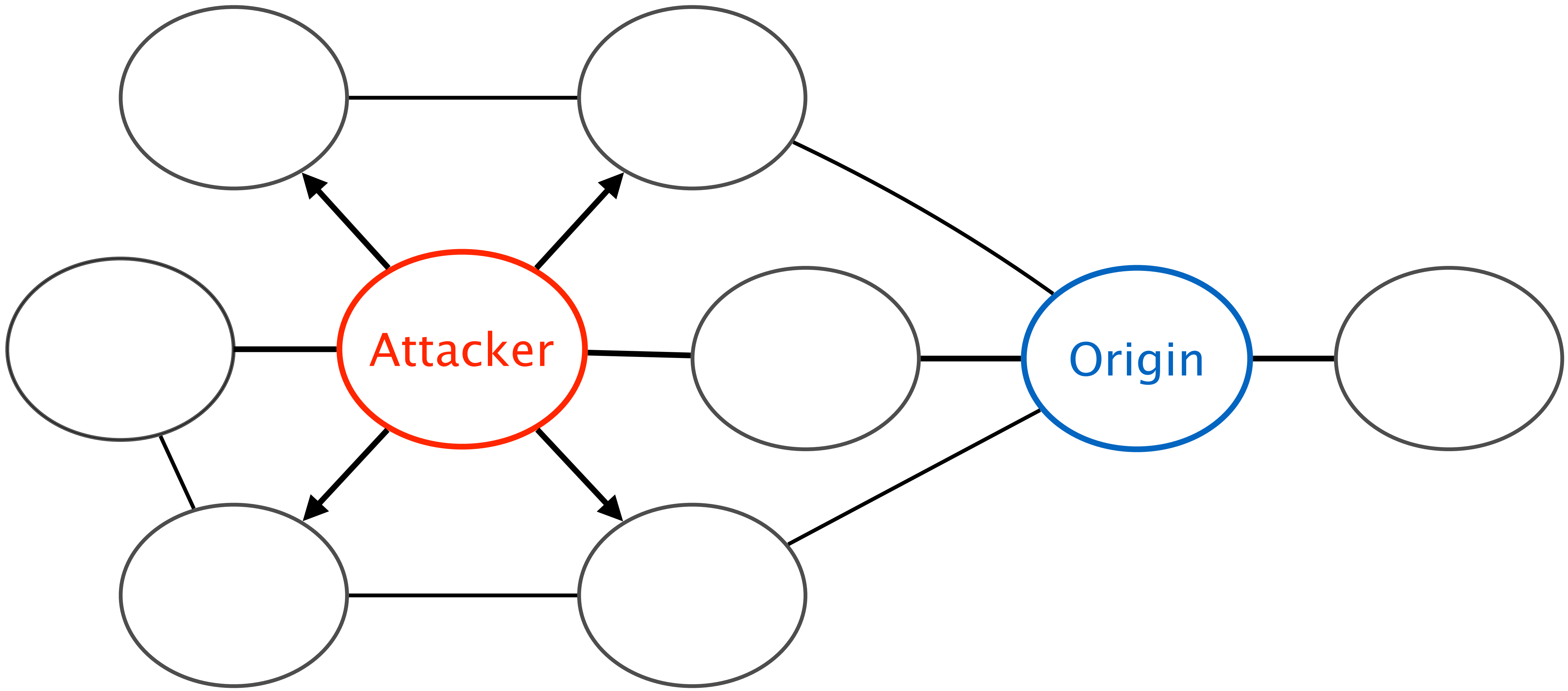
If the attacker advertises a longer prefix than the origin



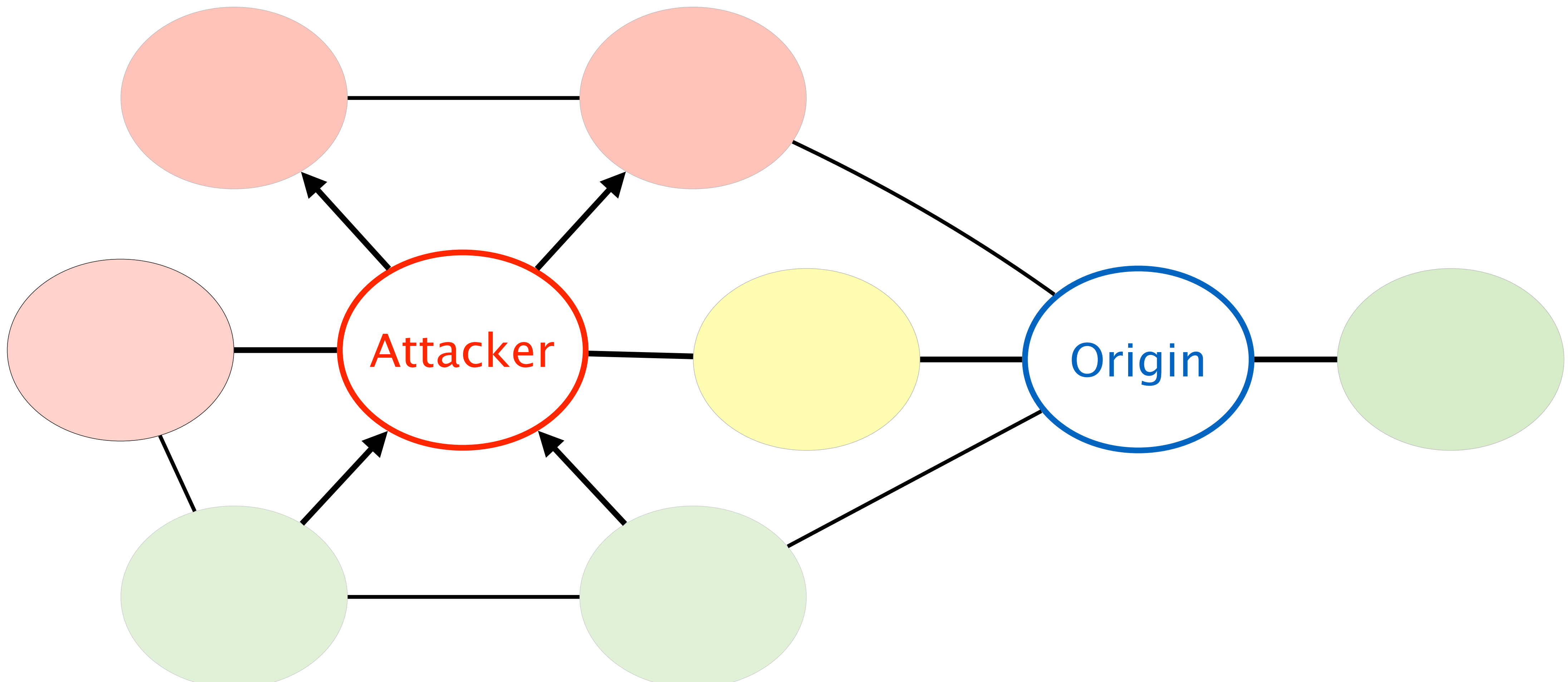
If the attacker advertises a longer prefix all ASes will be vulnerable



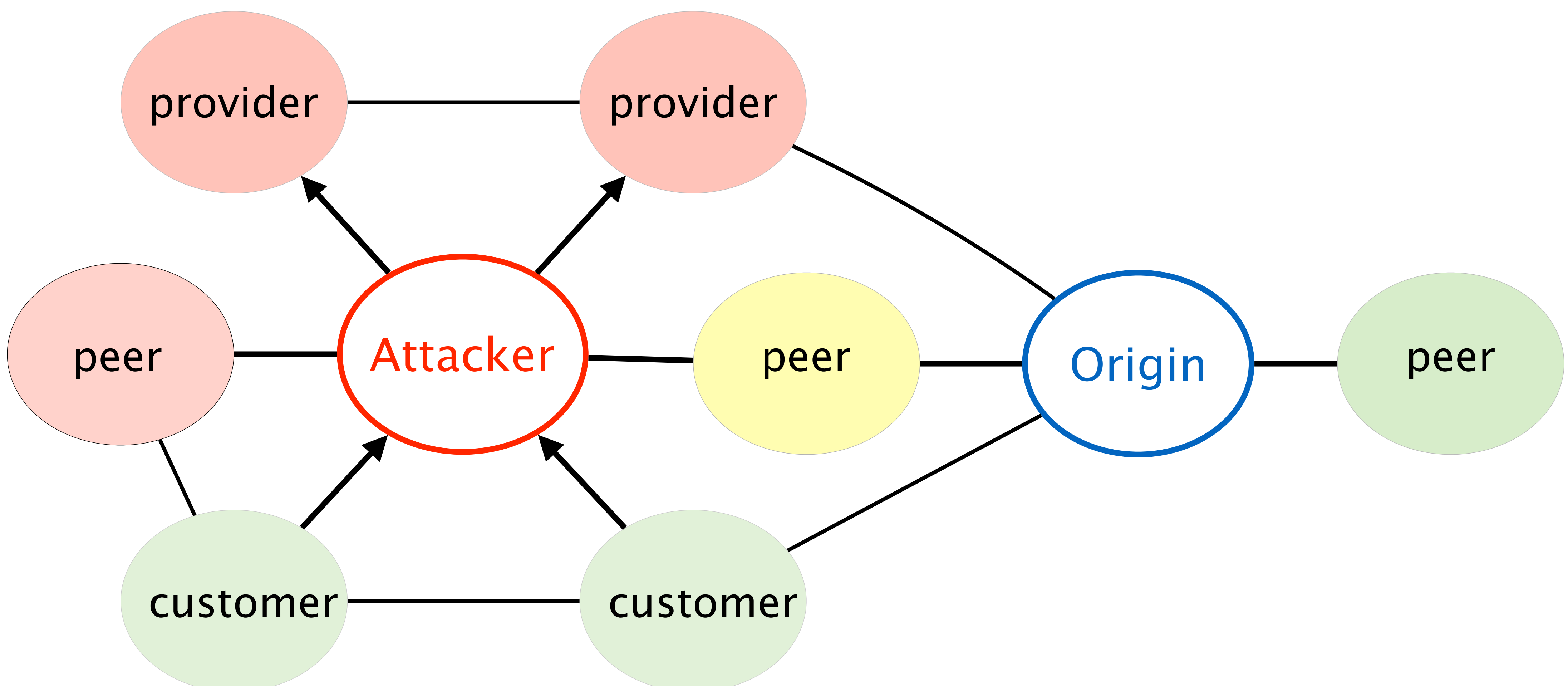
The attacker advertises same length prefix as the origin



~50% ASes would follow the attacker's advertisement



Business relations define which AS will follow the attackers advertisement



Secure Relay Placement

nodes in /24 prefix

peering ASes with no customers

k-connected graph of relays

relays cover most clients

Secure Relay Placement

nodes in /24 prefix

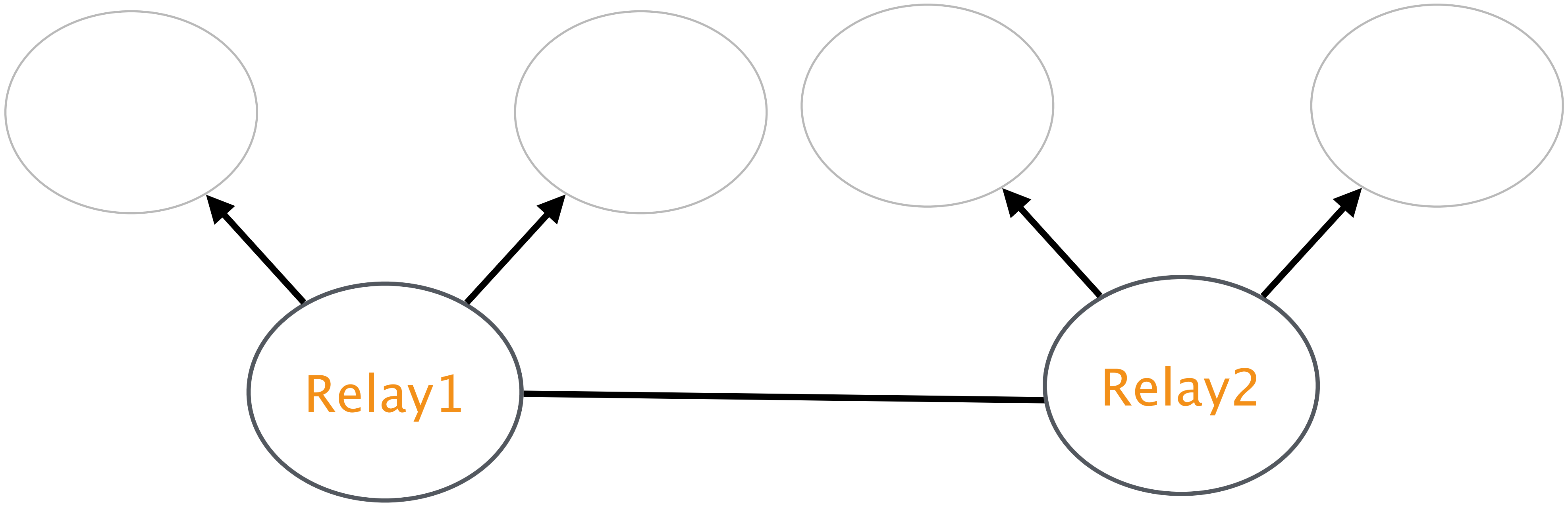
peering ASes with no customers

no strictly better prefix
advertisement exists

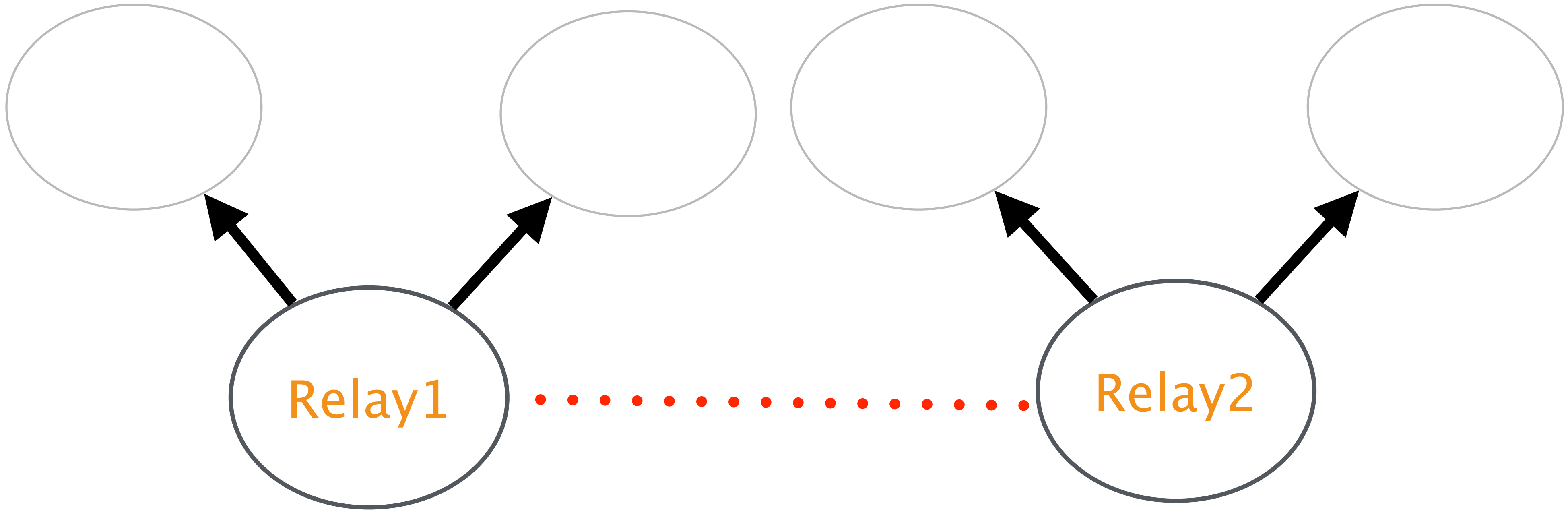
k-connected graph of relays

relays cover most clients

No strictly better advertisement exist



Peering agreement can be revoked



Secure Relay Placement

nodes in /24 prefix

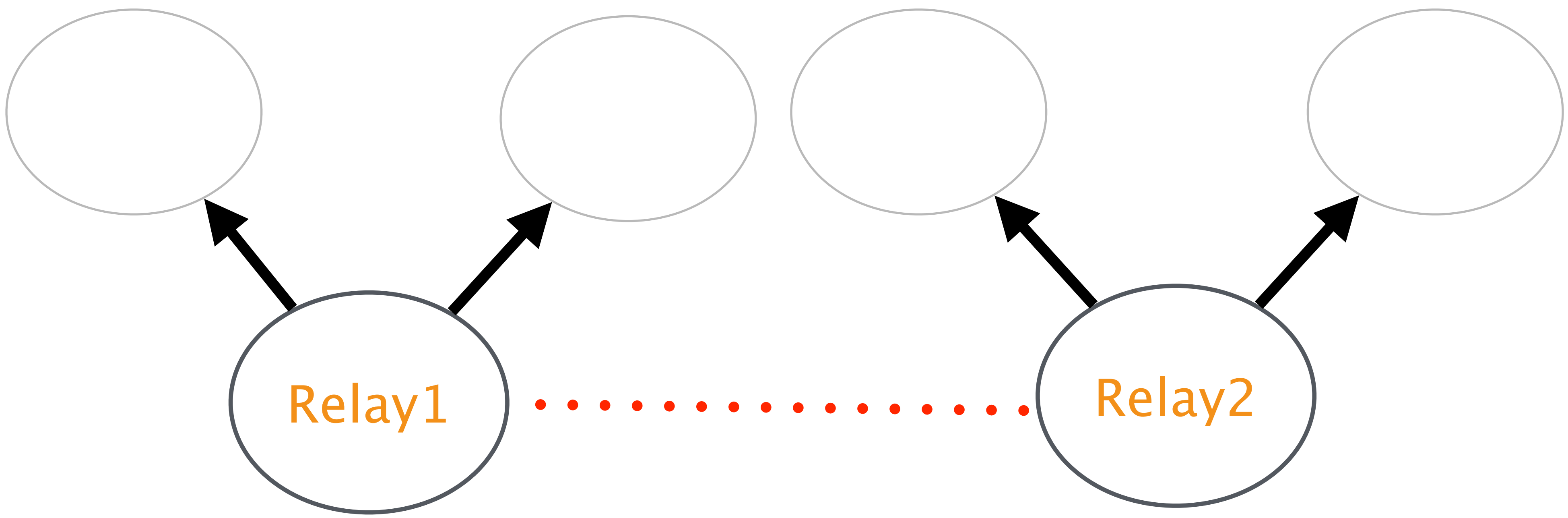
peering ASes with no customers

k-connected graph of relays

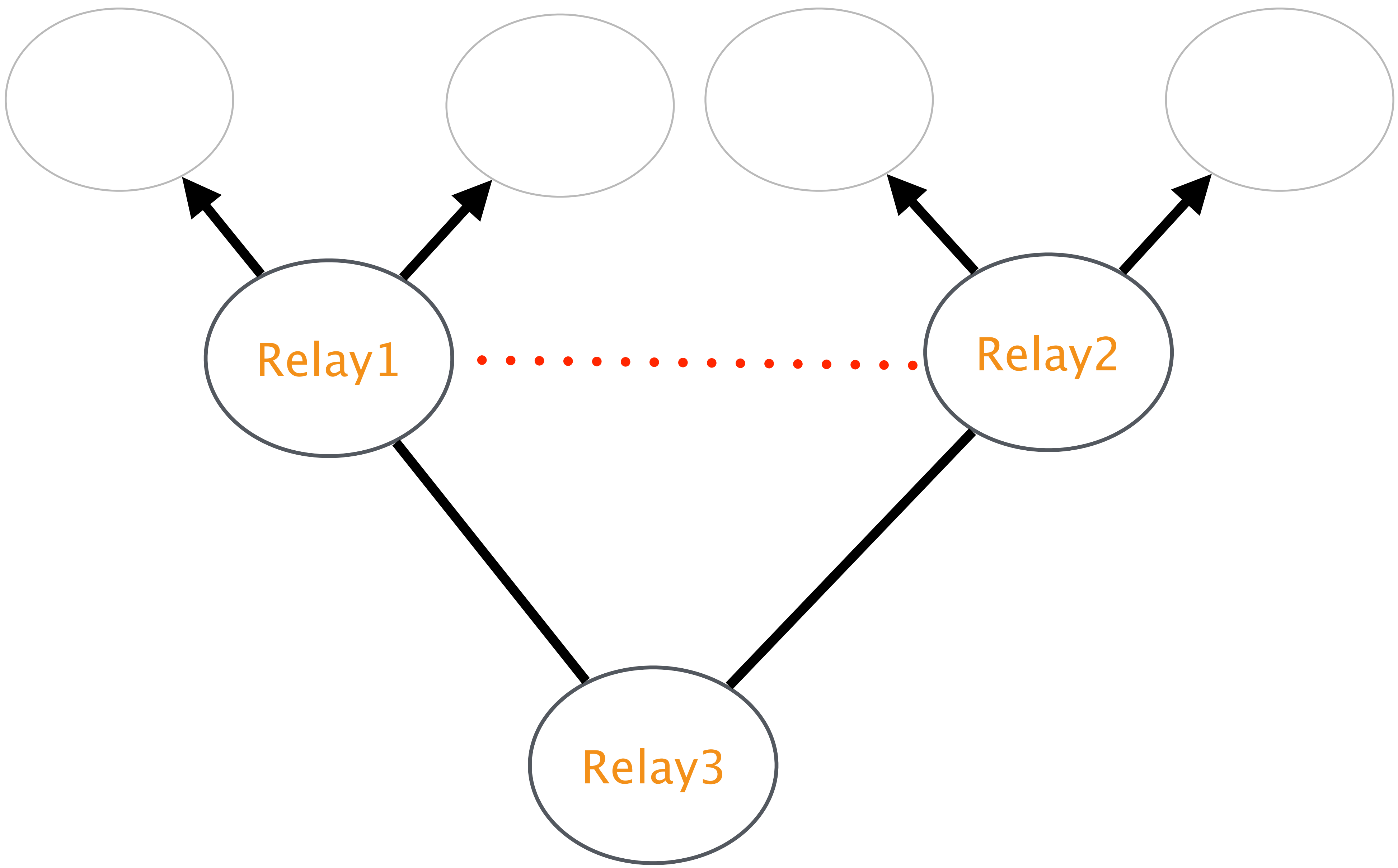
relays cover most clients

relay connectivity
is not affected by any k cuts

Peering agreement can be revoked



2-k connected graph retains connectivity



Secure Relay Placement

nodes in /24 prefix

peering ASes with no customers

k-connected graph of relays

relays cover most clients

relays are in path that are more preferred than any alternative

Secure Relay Placement

nodes in /24 prefix

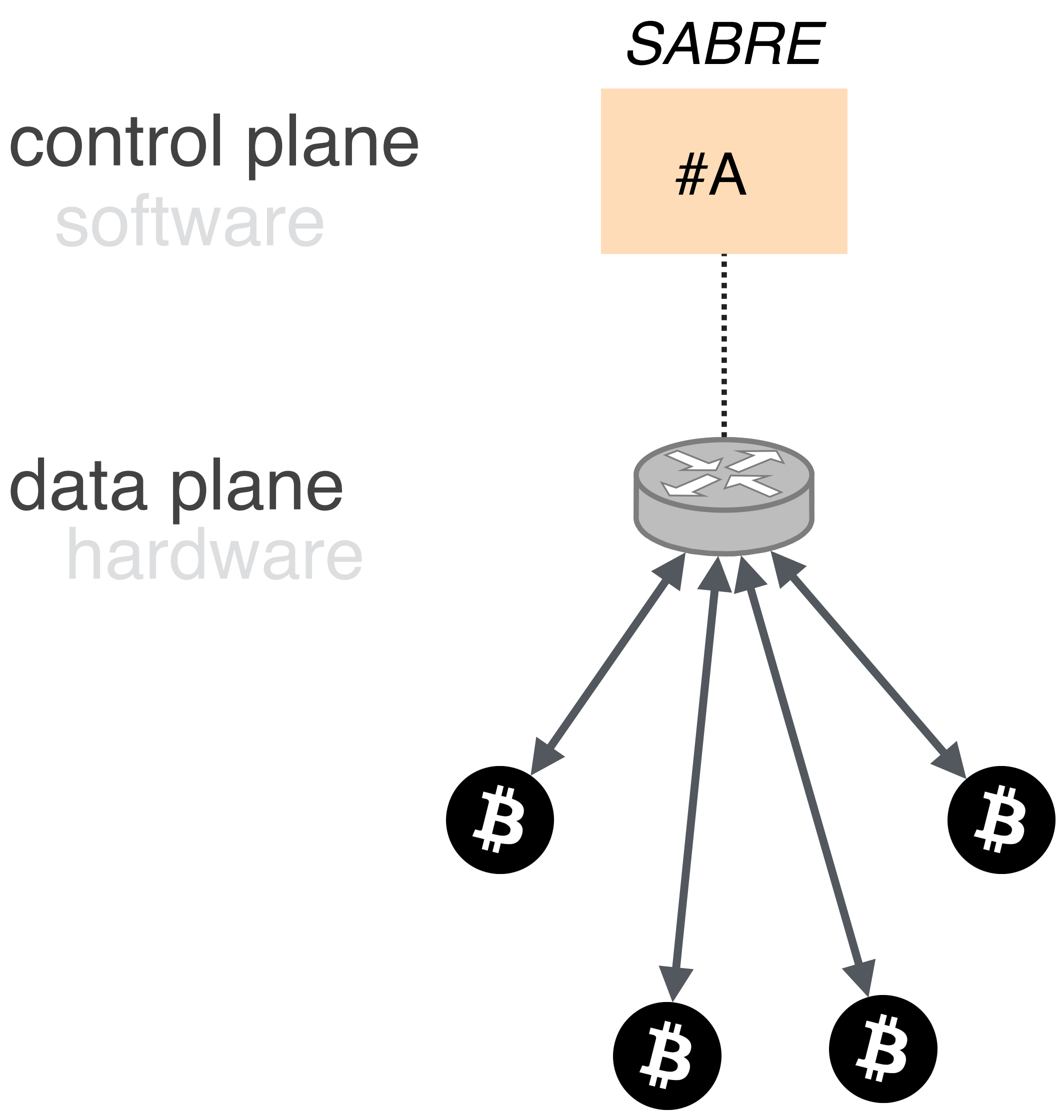
peering ASes with no customers

k-connected graph of relays

relays cover most clients

SABRE = Secure Relay Location + Robust Design

Software/Hardware co-design



Software/Hardware co-design is possible because...

programmable hardware

rarely updated state

communication heavy protocol

Software/Hardware co-design is possible because…

programmable hardware

flexible and expressive

data plane pipeline

rarely updated state

communication heavy protocol

Software/Hardware co-design is possible because...

programmable hardware

rarely updated state

new Blocks are mined every 10 minutes

communication heavy protocol

Software/Hardware co-design is possible because...

programmable hardware

rarely updated state

communication heavy protocol

simple computations,

many message exchanges

Software/Hardware co-design is suitable because...

keep up with high demand

dynamic network defenses

Software/Hardware co-design is suitable because…

keep up with high demand

Tbps of traffic at line rate

sustain DDoS attacks

dynamic network defenses

Software/Hardware co-design is suitable because…

keep up with high demand

dynamic network defenses

Whitelists, BlackLists.

Spoofing Detection,

Amplification mitigation

Hijacking Bitcoin

Routing Attacks on Cryptocurrencies

Bitcoin is vulnerable to routing attacks

both at the network and at the node level

The potential impact on the currency is worrying

DoS, double spending, loss of revenues, etc.

Countermeasures exist

Secure routing is best; SABRE is a good alternative

https://btc-hijack.ethz.ch