

Internet Security

51.502 Systems Security
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Internet Security

- End-to-end communication through the Internet
 - Applications are usually service-oriented
 - Services are associated with names
- How to define a service (with the OSI model)?

Internet Security

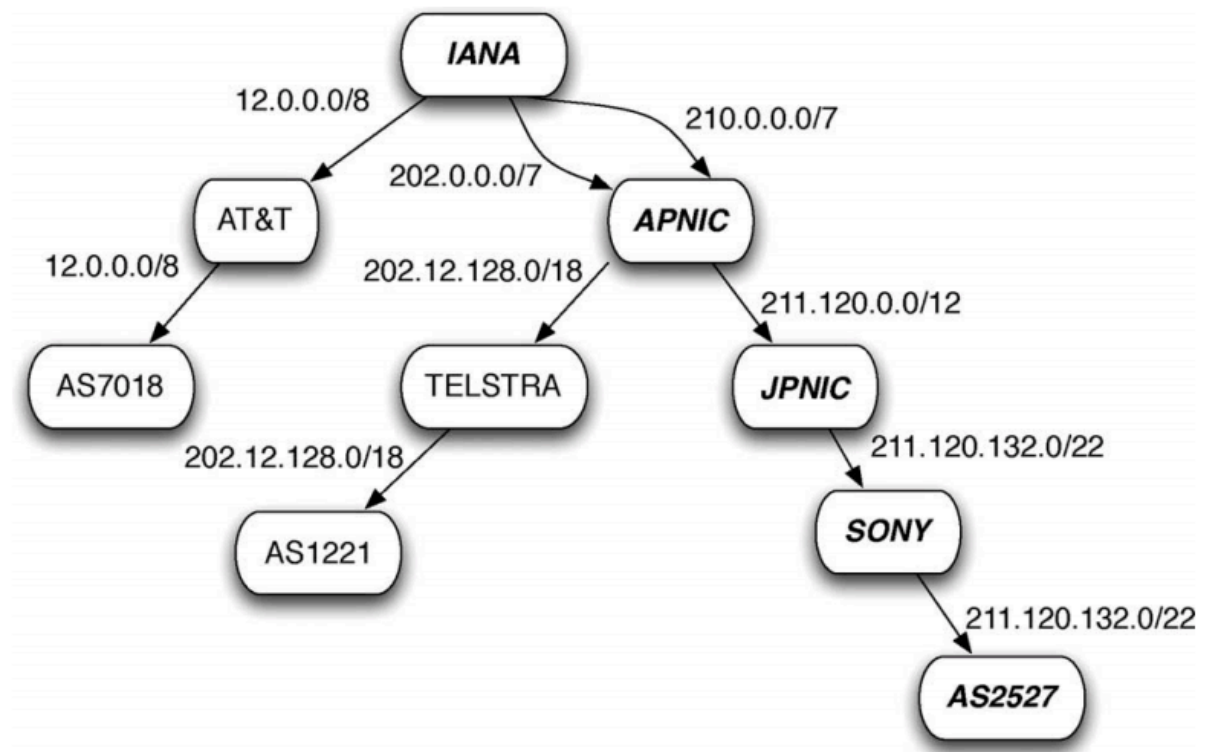
- What protocols are involved?
 - How to translate names to addresses?
 - How to reach addresses?
 - How to talk securely to the service/endpoint?
- Desired properties
 - Make sure what is an authentic address
 - Make sure that traffic is sent via an authentic path
 - Make sure that the service/endpoint is authentic and data is protected

Border Gateway Protocol (BGP)

- Dominant Inter-domain routing protocol
 - Need of a dynamic Internet routing protocol
- Determines how packets traverse the Internet
- Autonomous Systems (ASes) are the protocol parties
- Allows to express routing policies

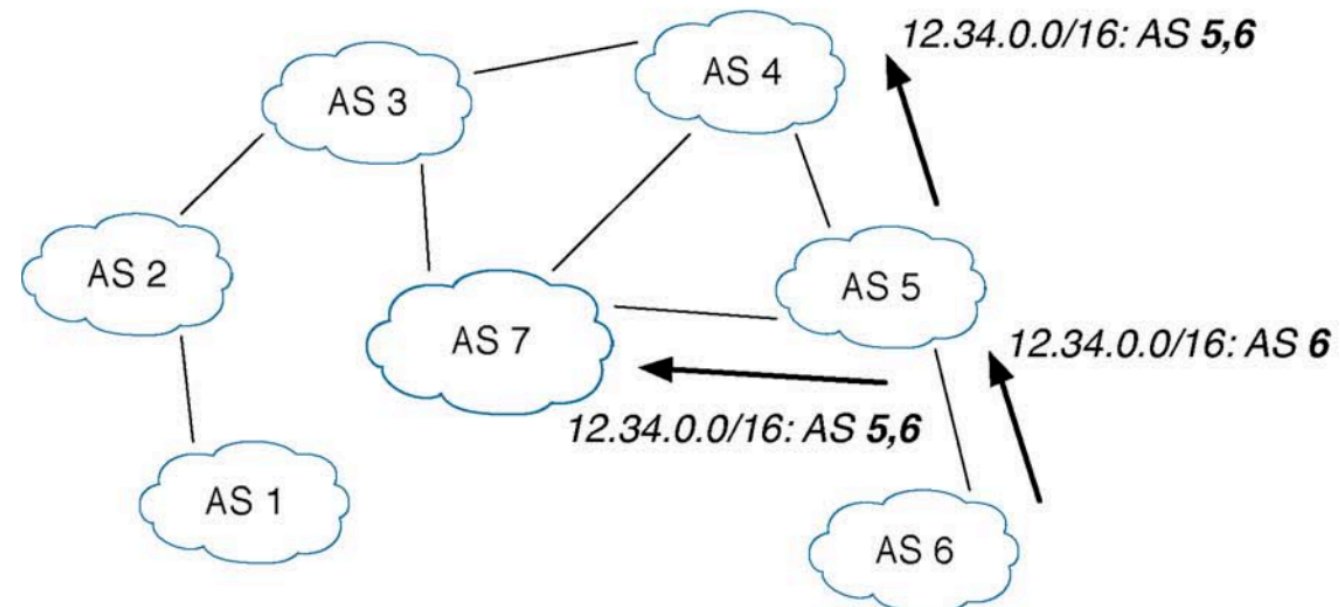
BGP

- AS-level entities
 - Each AS has a unique number associated (ASN)
- IP address blocks are assigned/delegated to ASes
- Scalability reasons
- IANA is the root



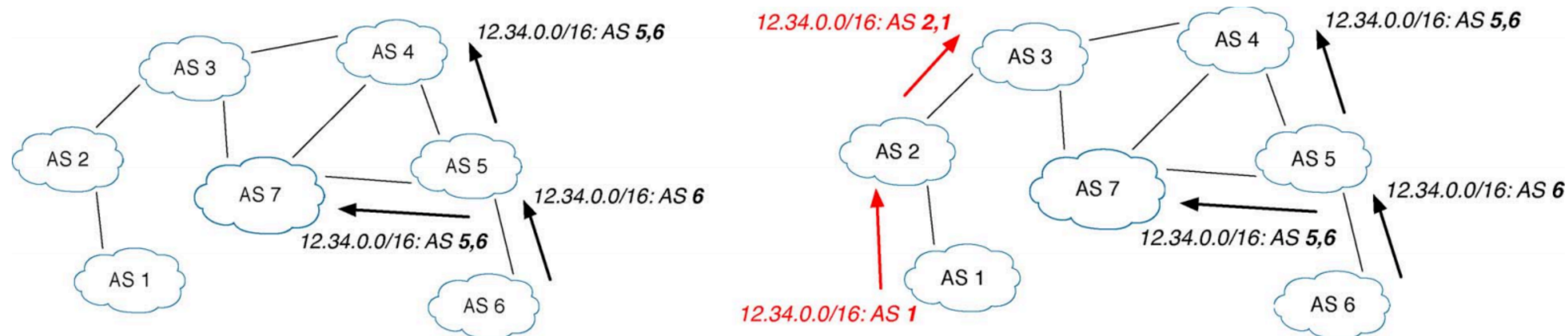
BGP

- Route origination
 - Border routers announce prefixes
 - Longest prefix match
 - More specific prefix is preferable
 - Storage overhead
- Business relationships
 - Valley-free routing



BGP Security

- Attacks on TCP
- Path manipulation
- Misconfigurations
- Malicious Route Origination
 - Route hijacking
 - Targeted attacks
 - Blackholing



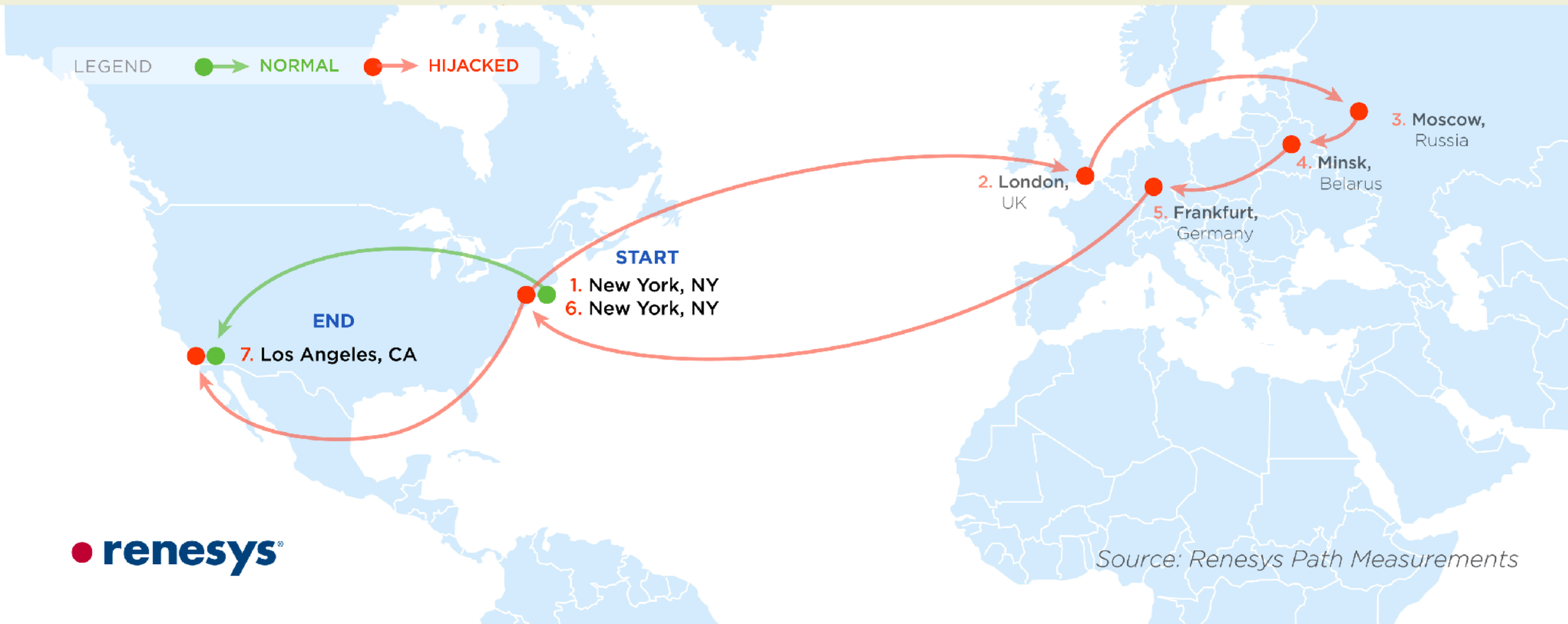
Denver to Denver

Traceroute Path 2: from Denver, CO to Denver, CO via *Iceland*



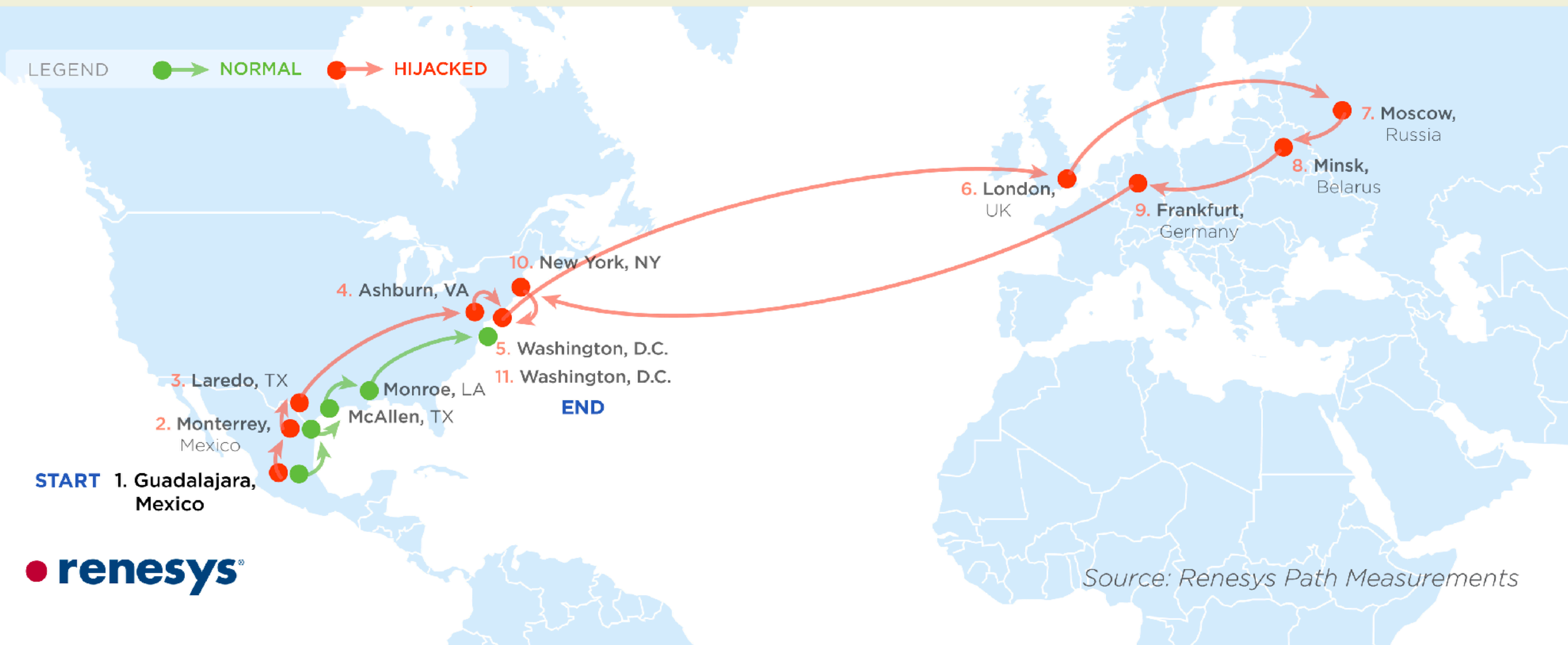
NYC to LA

Traceroute Path 3: from New York, NY to Los Angeles, CA via *Belarus*



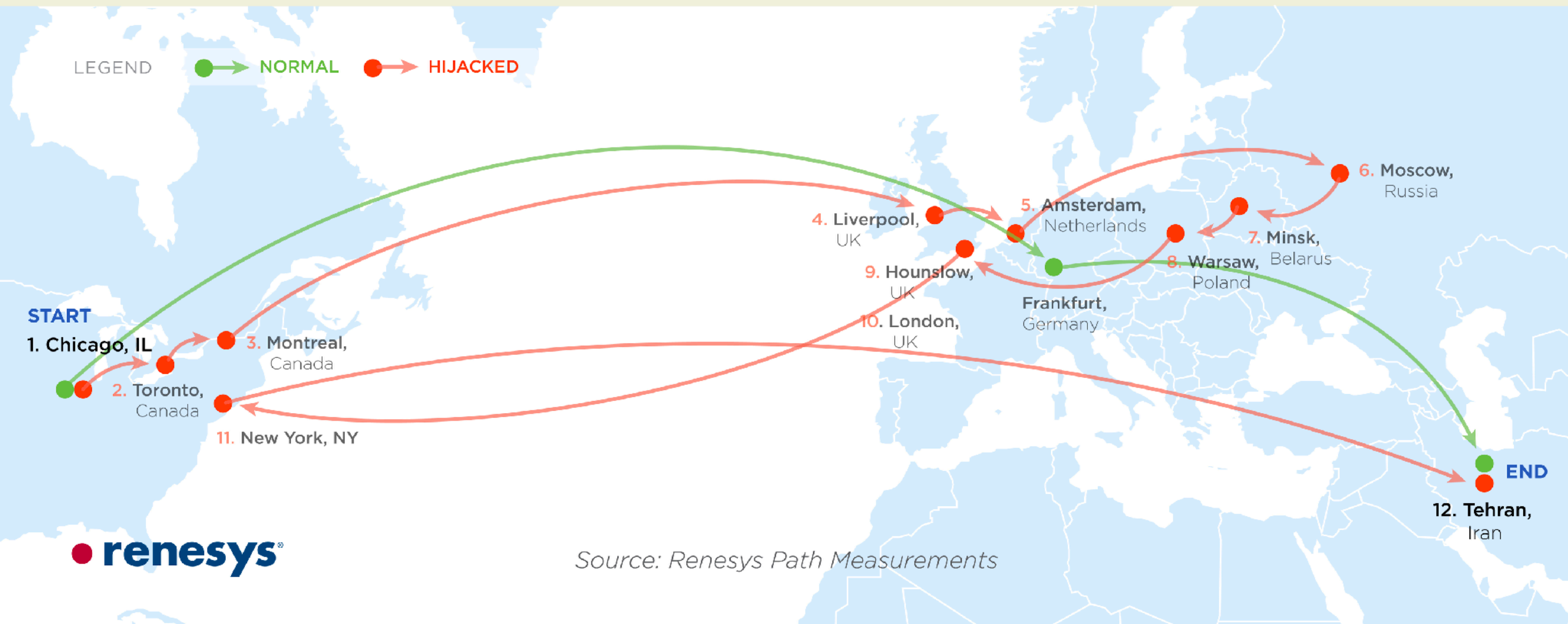
Guadalajara to Washington DC

Traceroute Path 1: from Guadalajara, Mexico to Washington, D.C. via *Belarus*



Chicago to Tehran

Traceroute Path 4: from Chicago, IL to Tehran, Iran



Frankfurt to Fremont

Traceroute Path 5: from Frankfurt, Germany to Fremont, CA via *Iceland*



Proposals

- Secure BGP (S-BGP)
- Secure Origin BGP (soBGP)
- Interdomain Route Validation (IRV)
- ...

S-BGP

- Introduces public-key infrastructure (PKI)
- Address allocation hierarchy is authenticated
- Certificates are used to authenticate AS
 - Address attestation proves that AS can originate an address
 - Route attestation proves what ASes are on the path

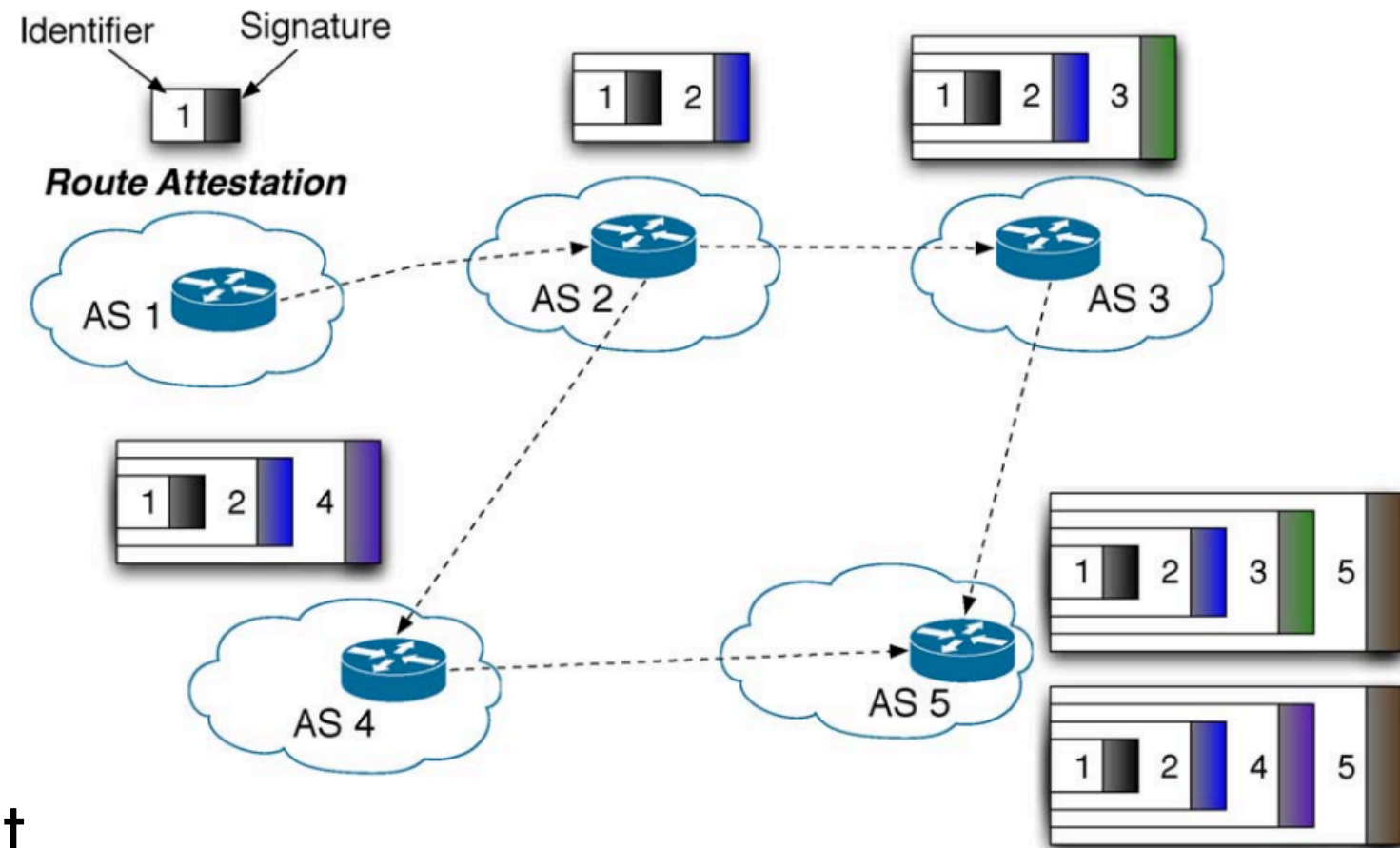


Fig: Butler et al.

S-BGP

- New infrastructure needed to facilitate it
 - Network Operation Center (NOC)
 - Regional Registry (e.g., APNIC)
 - Repositories of certificates, revocations, ...
 - Routers

S-BGP

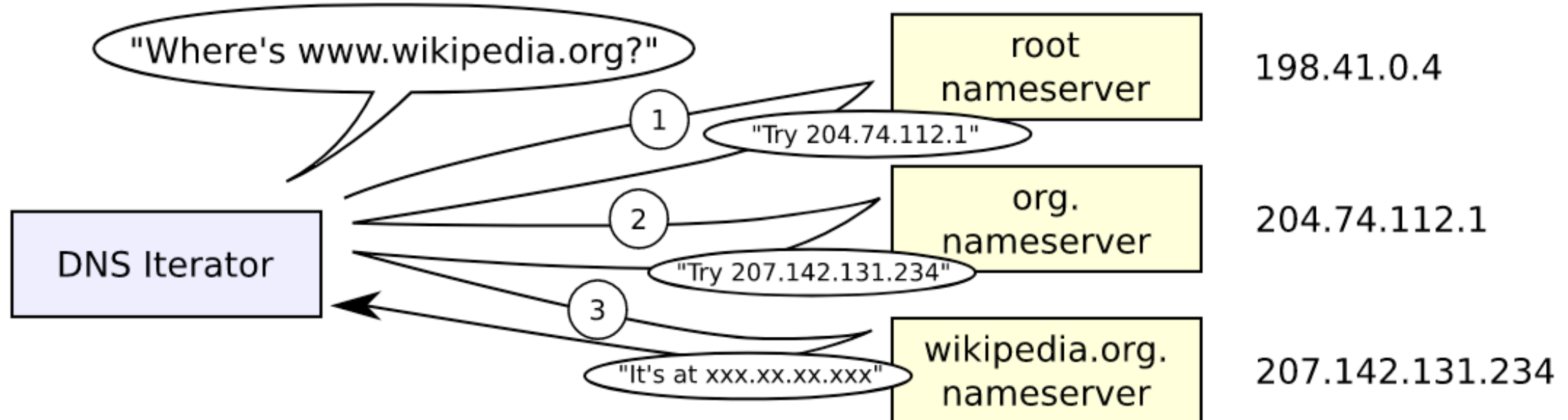
- Not widely deployed
 - Plain BGP still dominates
- Too complex for ASes
- CPU/mem/storage and SW/HW upgrades are necessary

Domain Name System (DNS)

- Hierarchical and decentralized naming systems
 - Name hierarchy with ICANN as the root
- Public database with different resource records (RRs)
 - A, AAAA, TXT, PTR, ...
- UDP used by default
 - Fallback to TCP for large responses

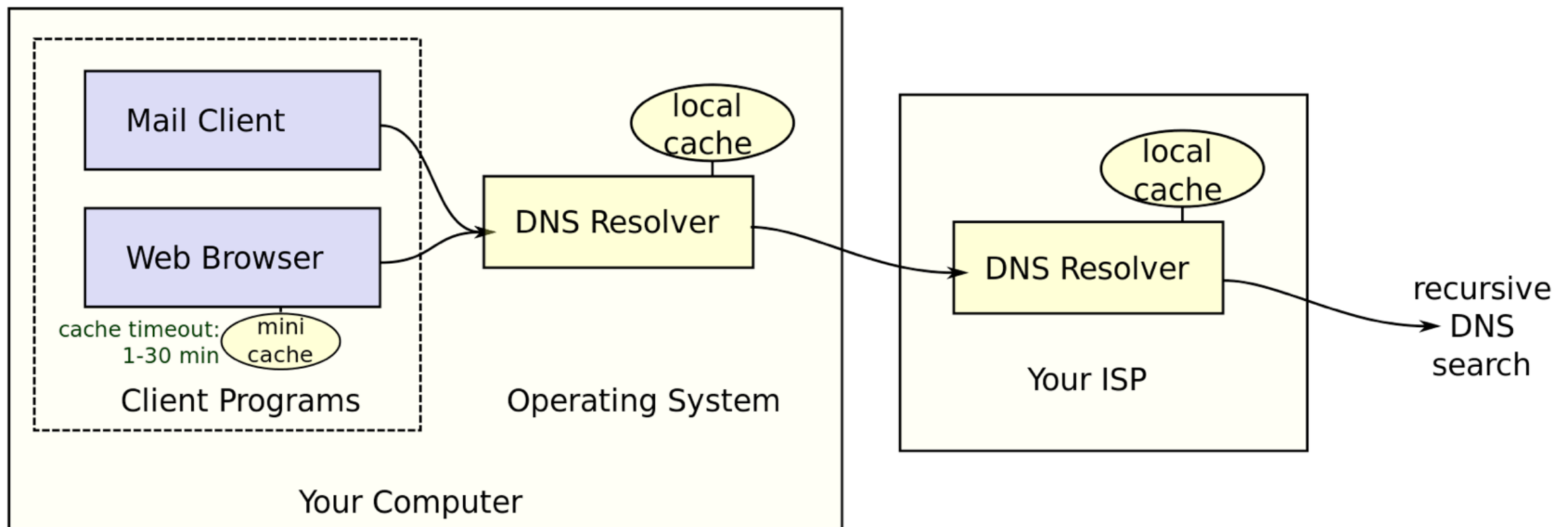
DNS resolution

- Domain zone
 - All DNS resources associated with the domain name
 - NXDOMAIN
- DNS resolvers, servers, clients, iterators, ...
- Responses contain sections (e.g., Authority and Additional Section)



DNS Caching

- Results are cached
 - Efficiency reasons
- Cache is kept at many places



DNS Security

- DNS does not provide security properties
- On-path adversary
 - Can freely manipulate DNS responses
- Off-path adversary
 - Kaminsky DNS Vulnerability (2008)

Kaminsky's Attack

- Scenario
 - Adversary can query a remote (open) resolver
- Query format
 - IPs, ports, ...
- Query ID
 - Has to be unique to associate queries&responses
 - Implemented sequentially (as counter)

Kaminsky's Attack

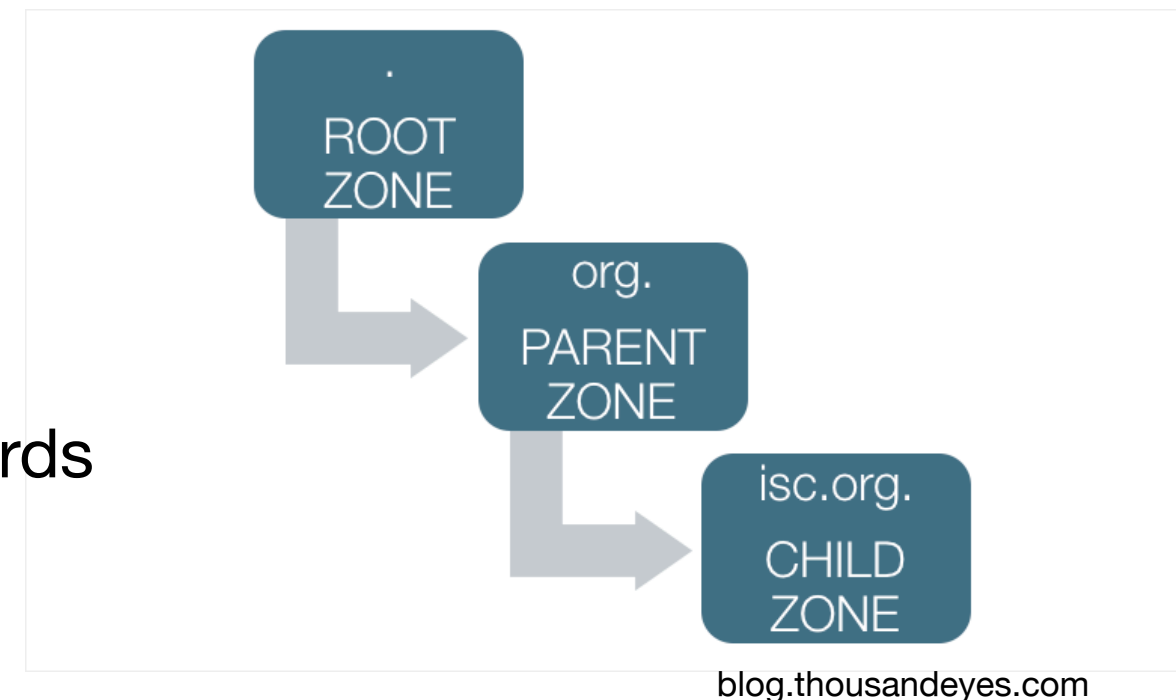
- Idea
 - With predicted Query ID and source port the adversary *could inject* a malicious DNS response
- Ports are usually random (need brute-force) but Query IDs are sequential. How to predict them?
 - The adversary can use the resolver to resolve own domain name
- With the Query ID predicted the adversary can flood the resolver with responses (try to brute-force the port)

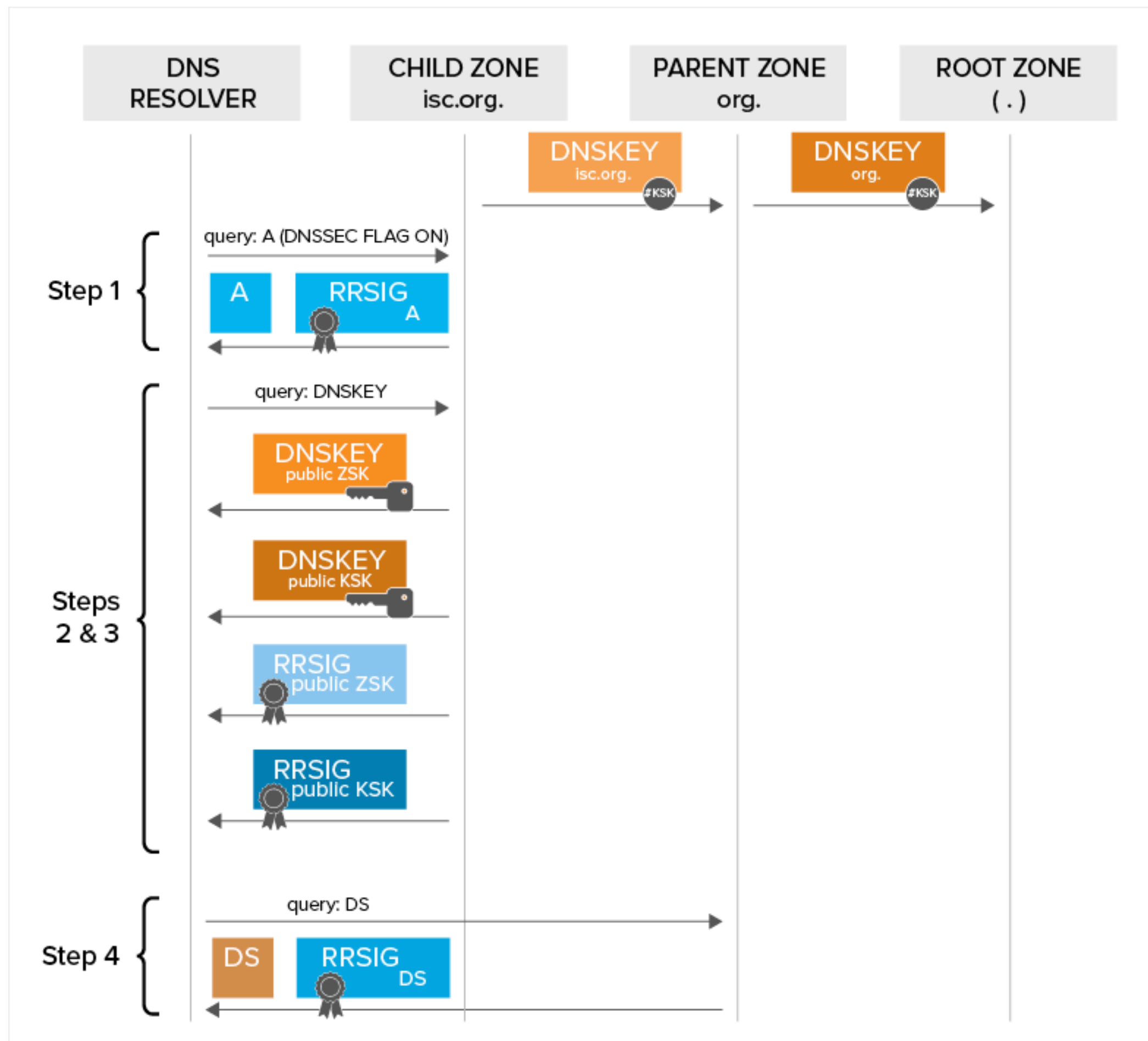
Kaminsky's Attack

- Many variants of the attack
 - Target the response (knowing that given domain will be queried)
 - Ask for a non-cached result and inject NS response
- Prevention
 - Randomization of the Query ID field
 - Do not expose resolvers if unnecessary
 - More comprehensive protection against DNS attacks?

DNS Security Extension (DNSSEC)

- Introduces PKI
 - Basing on namespace hierarchy
- Provides authentication for resource records
- New RRs
 - RRSIG: contains a signature for another RR
 - DNSKEY: stores a public key
 - DS: hash of a domain owner name and DNSKEY record
- Zone Signing Key (ZSK) and Key Signing Key (KSK)





DNSSEC

- Not widely deployed
 - Complex management, operation, overhead, ...
 - Can cause “problems”
- Increases amplification factor (when used via UDP)
- Difficult to modify/extend/patch
- Authenticating negative info (NXDOMAIN)

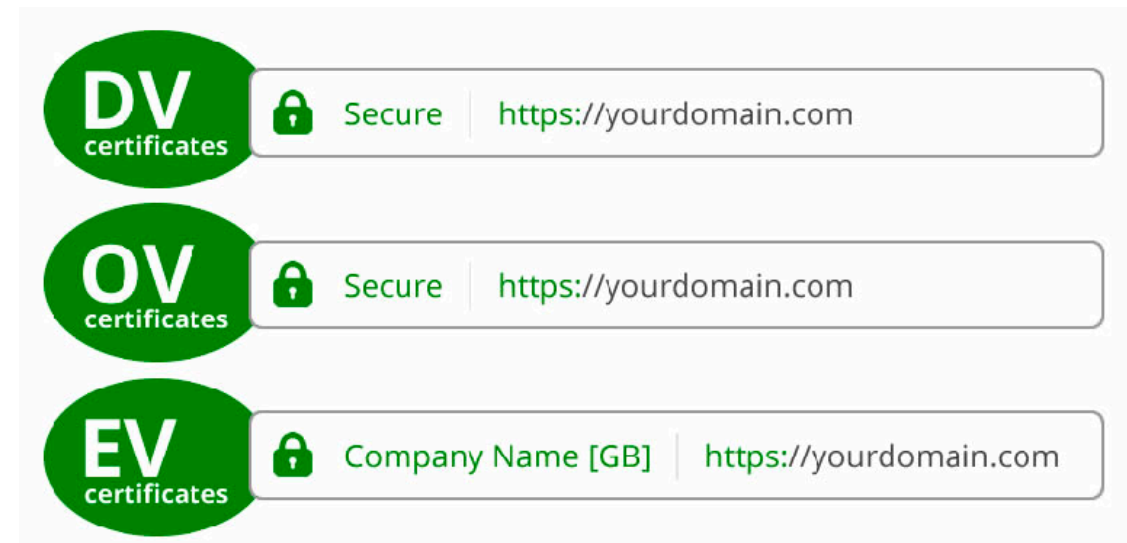
Why no one is concerned about that?

Transport Layer Security (TLS)

- Secure channel
- End-entity PKI
 - Entities are usually identified by domain names
- Orthogonal to DNSSEC
- Certification Authorities (CAs) are trusted entities
 - (Too) many root and intermediate CAs

TLS Certificates

- Domain-Validated (DV) Certificates
 - Proving ownership over domain name
 - Email, HTTP, or DNS
- Organization-Validated (OV) Certificates
 - Domain ownership + checking organization
- Extended-Validated (EV) Certificates
 - Domain ownership + checking organization + F2F meeting
- OV certs aren't popular, benefits of EV certificates are questioned

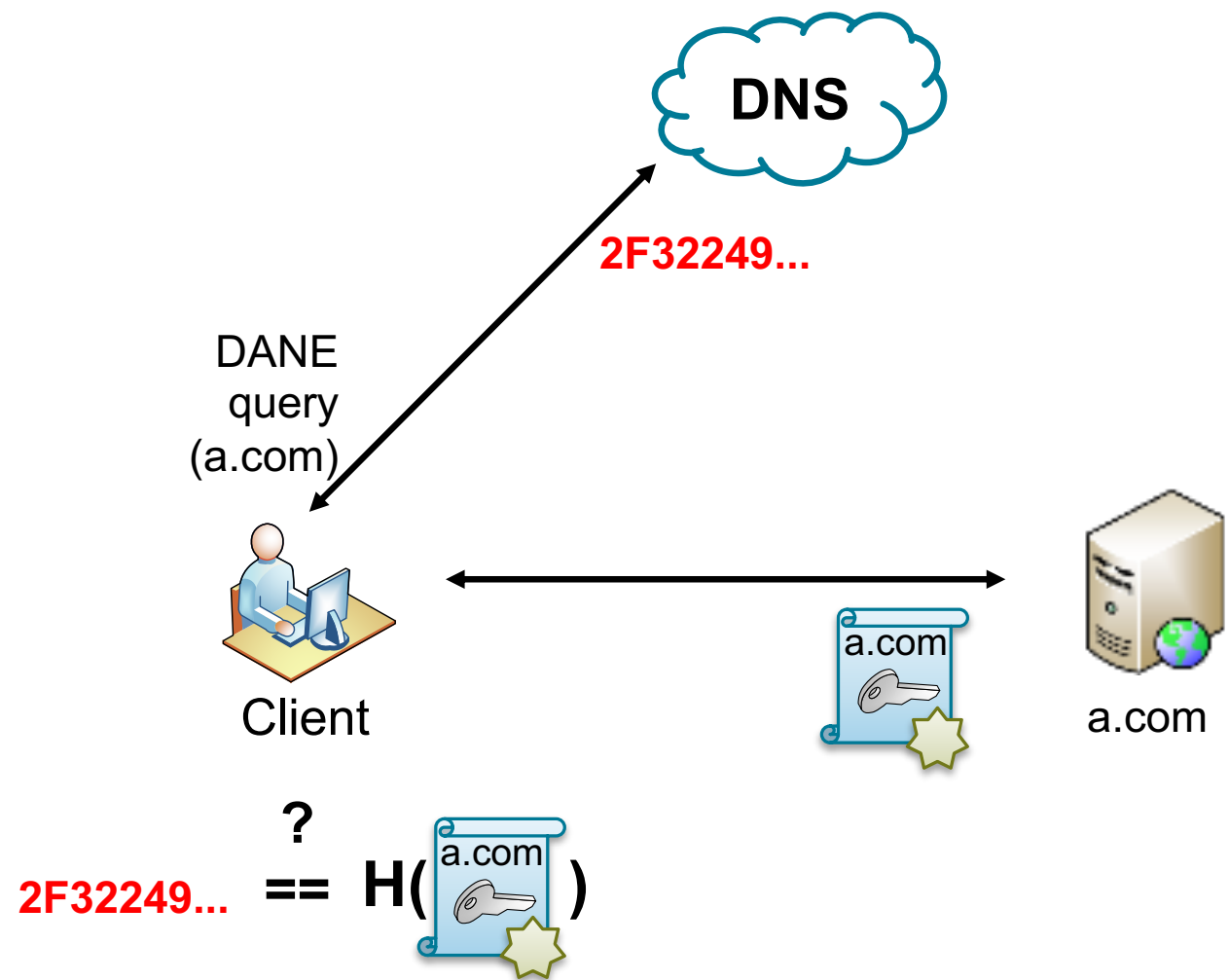


TLS

- Widely deployed
 - The Let's Encrypt project issues free certificates
- Downgrading attacks
 - SSL/TLS stripping, http:// vs https://, redirections
- Impersonation attacks
 - Attacked CAs: DigiNotar, Comodo, ...
- DNS-based PKI enhancements
 - DNS-based Authentication of Named Entities (DANE)
 - Certification Authority Authorization (CAA)

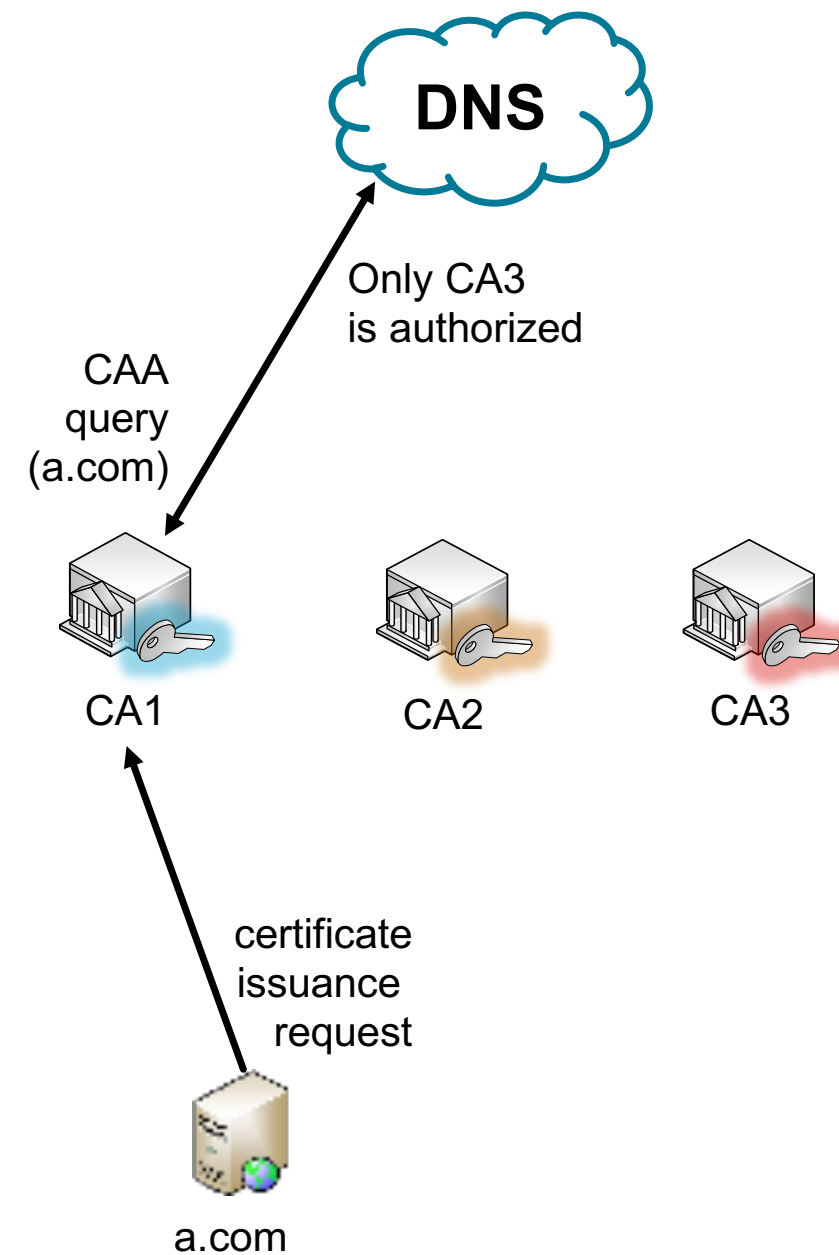
DANE

- Domains can specify keys they trust
 - Their keys
 - CAs' keys
- Requires DNSSEC



CAA

- Trust agility
 - Allows to list trusted CAs
- DNSSEC recommended
- Mandatory from Sep 2017



Reading

- <https://pdfs.semanticscholar.org/1331/5d952a43c391bf4910271fc2582858e86e9e.pdf>
- <https://pdfs.semanticscholar.org/fbb5/70fd509305d0bec9679bff16ea33630733fb.pdf>
- https://www.researchgate.net/profile/Jennifer_Rexford/publication/224092573_A_Survey_of_BGP_Security_Issues_and_Solutions/links/00b7d525f3efdb03af000000.pdf

Questions?