Security challenges in DNS

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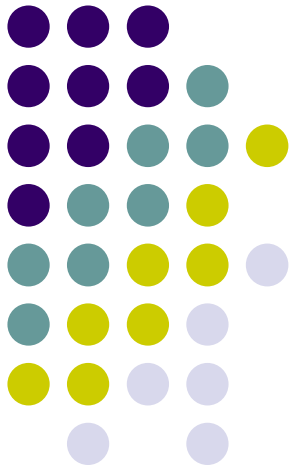
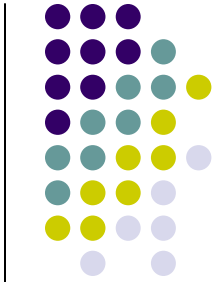


Workshop on Formal Methods in Cryptography

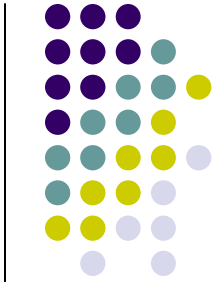
27-30 april 2009 / Campinas - Brazil

Outline



- DNS
- DNSSEC
  - Basics
  - Key Rollover
  - Problems and Limitations
- How to improve the Security of DNS?
  - Threshold Cryptography
  - Identity Based Cryptography

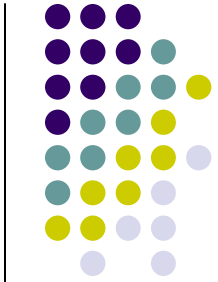
DNS
A (brief) history



- ARPANET in the 70's
  - Small, friendly network of a few hundreds of hosts.
  - A centralized HOSTS.TXT file was used to map host names to network adresses.
  - This file was updated once or twice a week.

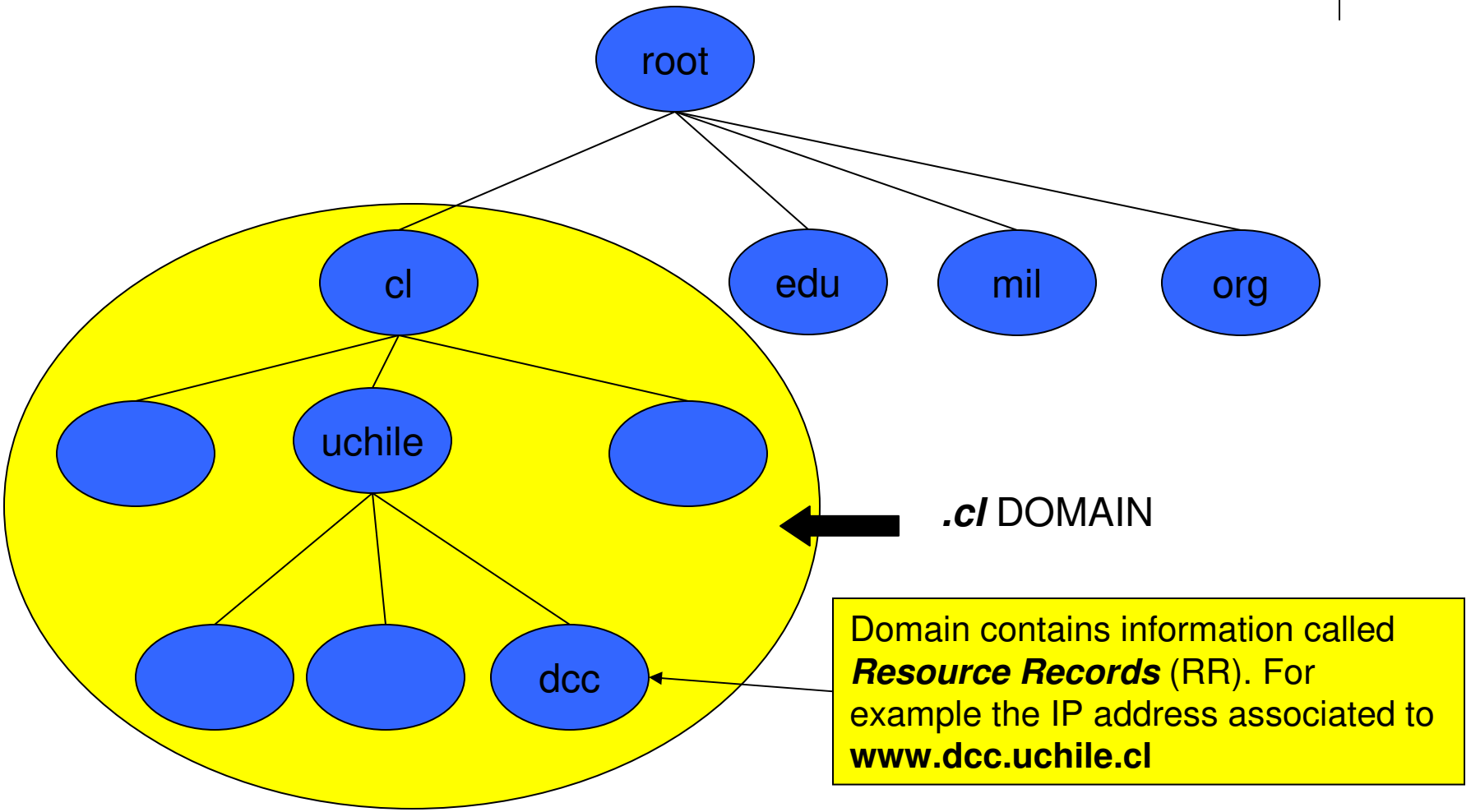
- BUT, with the growth of ARPANET this scheme became unpracticable
  - Traffic Load
  - Name Collision
  - Consistency

DNS Basics

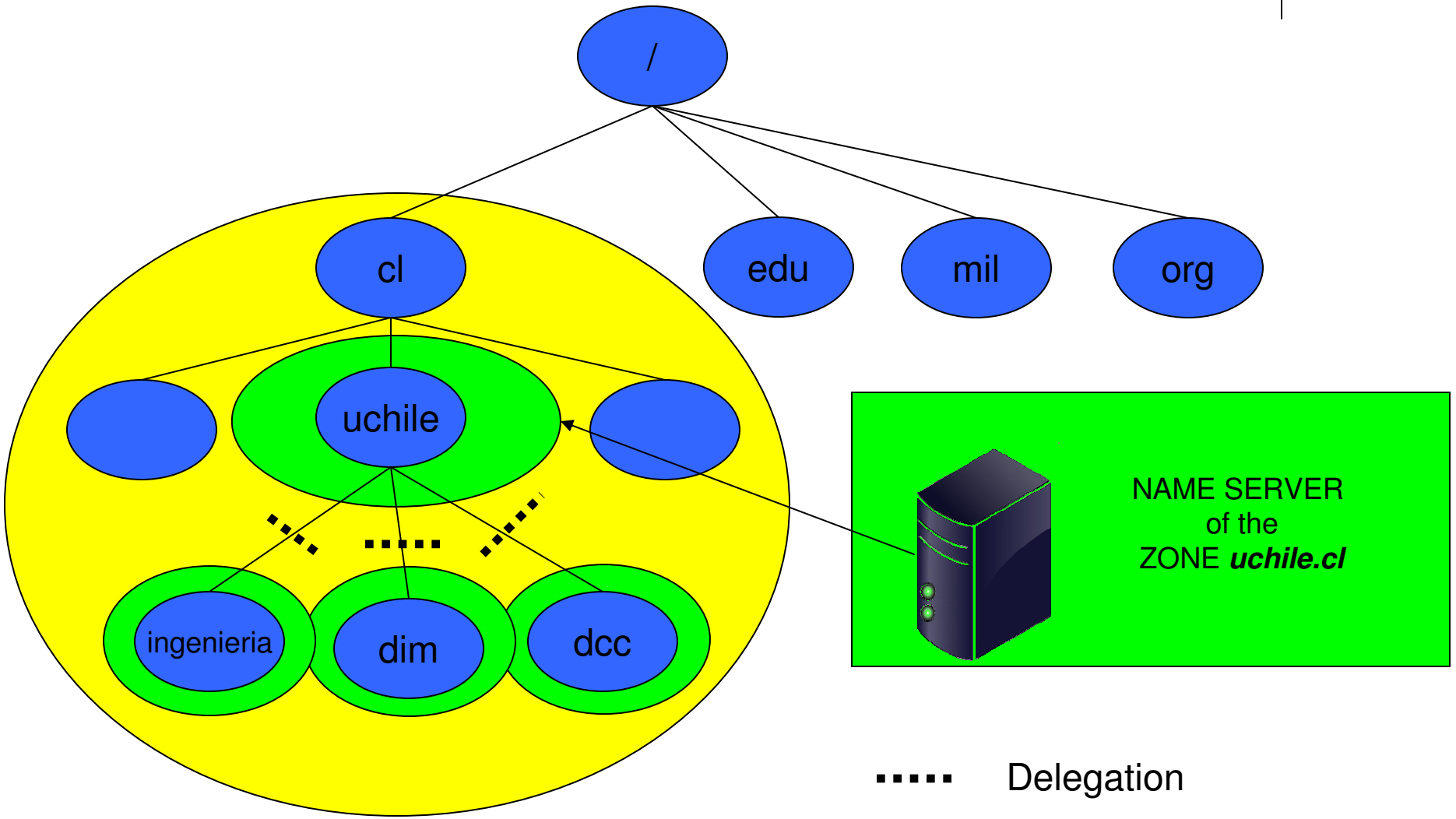


- Domain Name System (DNS)
  - Maps IP adresses to human friendly computer hostnames
    - www.google.com ⇔ 64.233.163.104
  - But also manages other type of information such as the list of mail servers associated to a domain
  - ***Distributed, Replicated, Fault Tolerant***
  - Developped by the IETF (Internet Engineering Task Force) at the beginning of 1980's

DNS
Domain Namespace



DNS
Name servers and Zones



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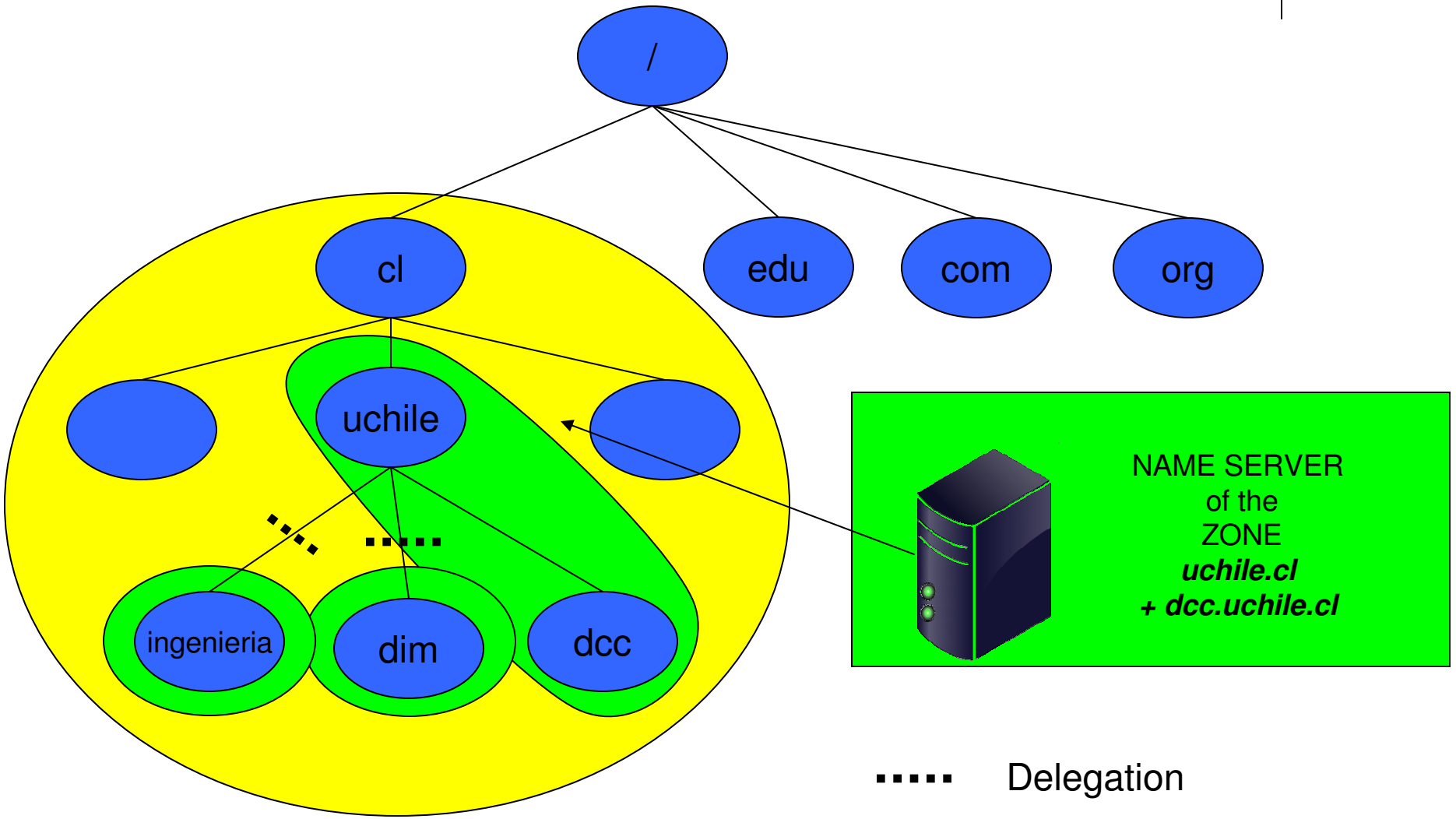
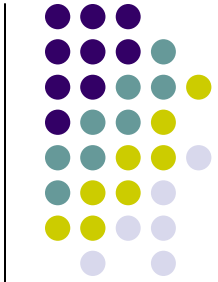


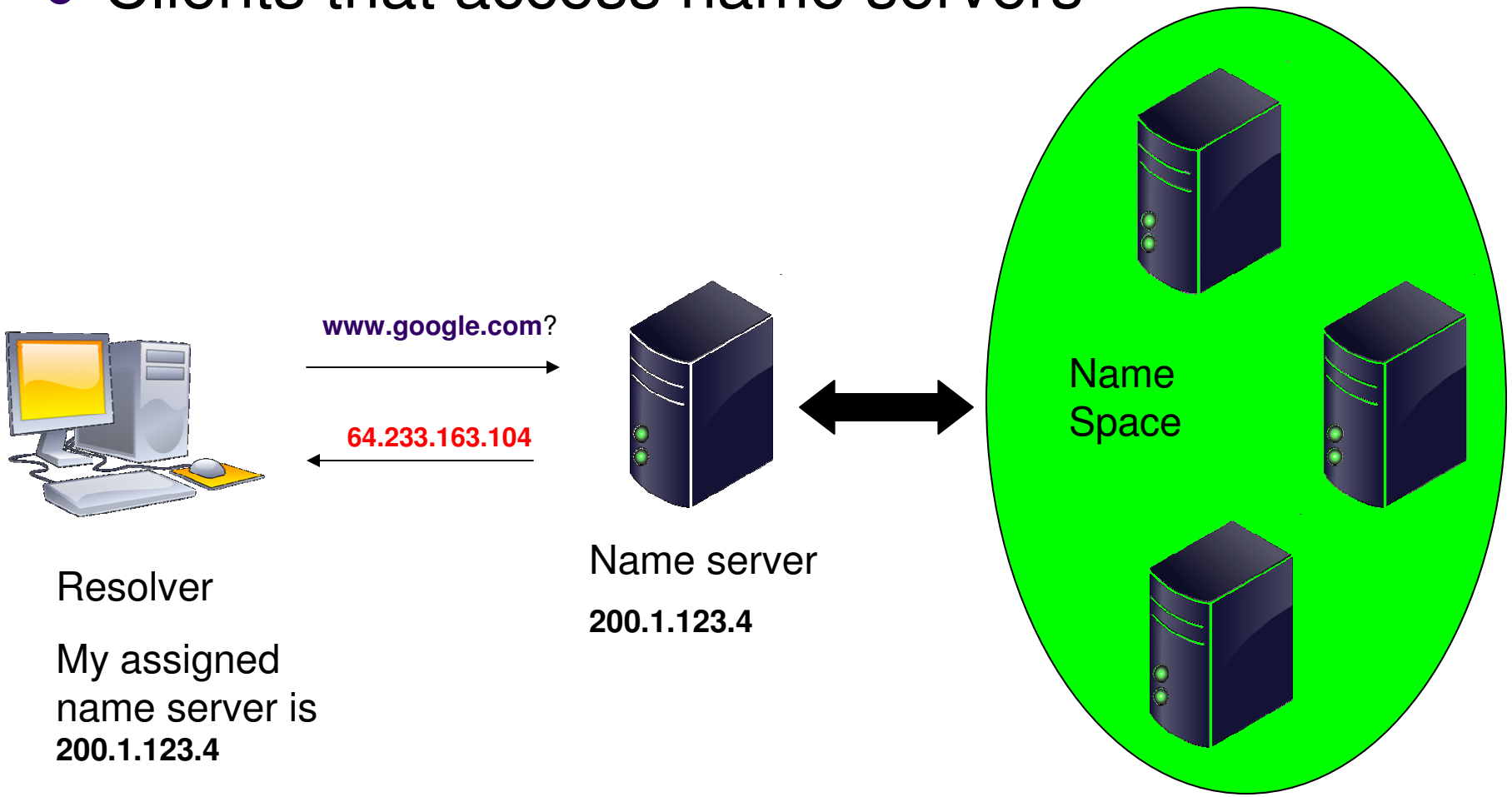
DNS
Type of Resource Records (RR)



A	Host Addresses
PTR	Reverse address name mapping
CNAME	Aliases
MX	Mail exchange for the domain
NS	Authoritative Name Servers

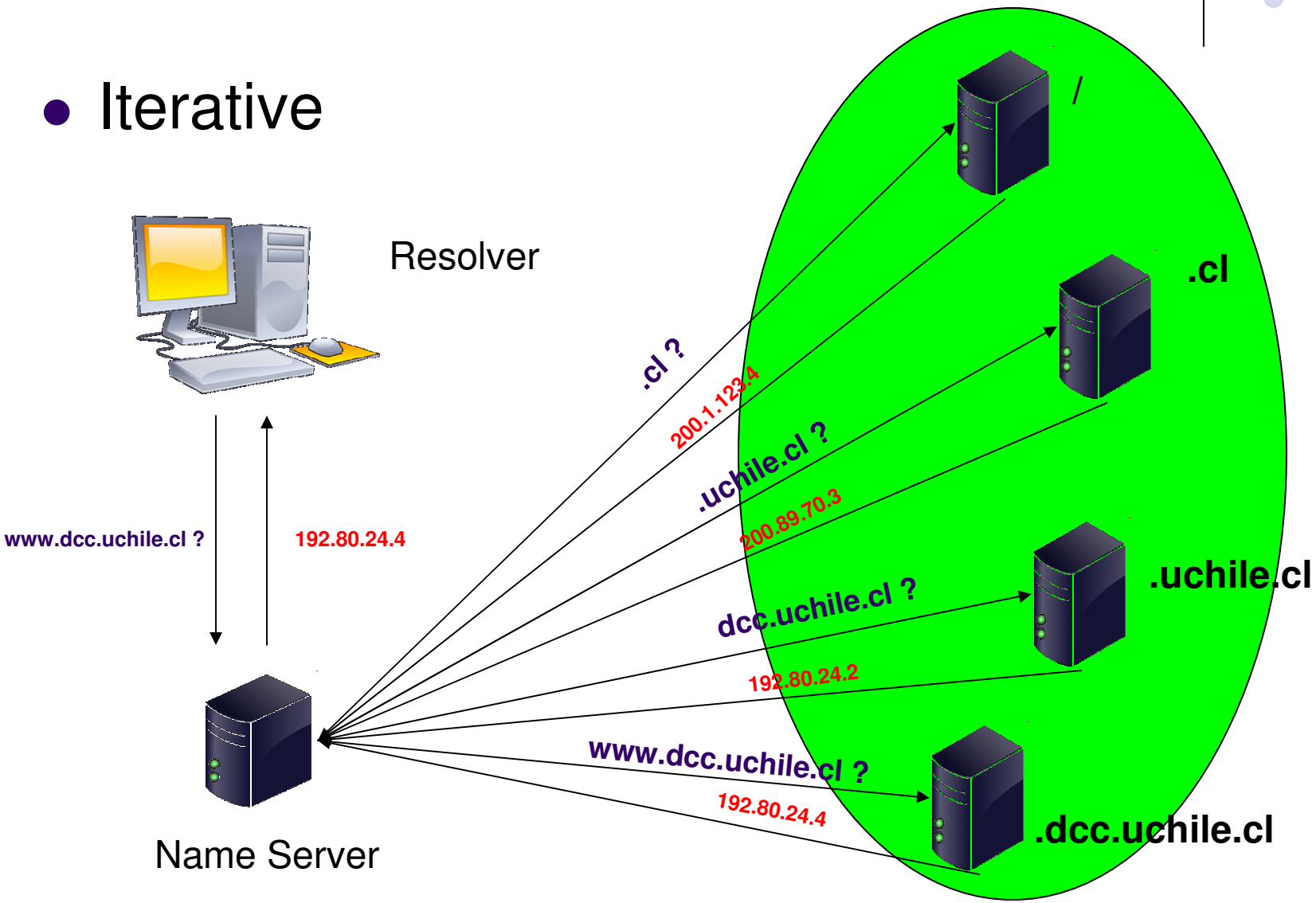
DNS
Resolvers and Name Resolution

- Clients that access name servers



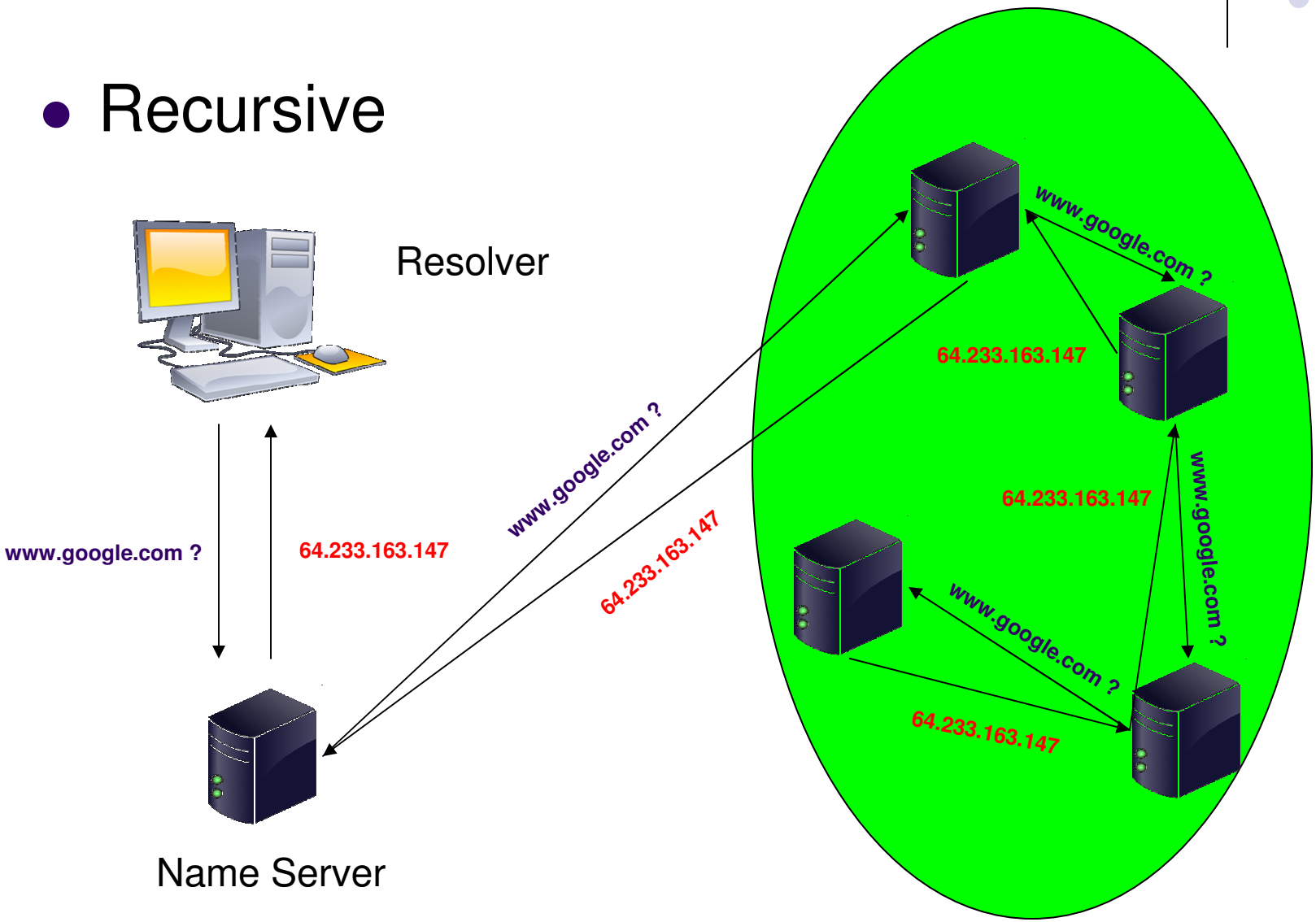
DNS
Resolving Algorithms

- Iterative

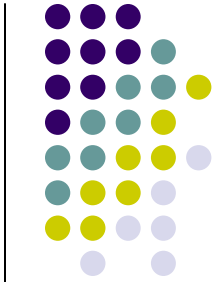


DNS
Resolving Algorithms

- Recursive



DNS Caching



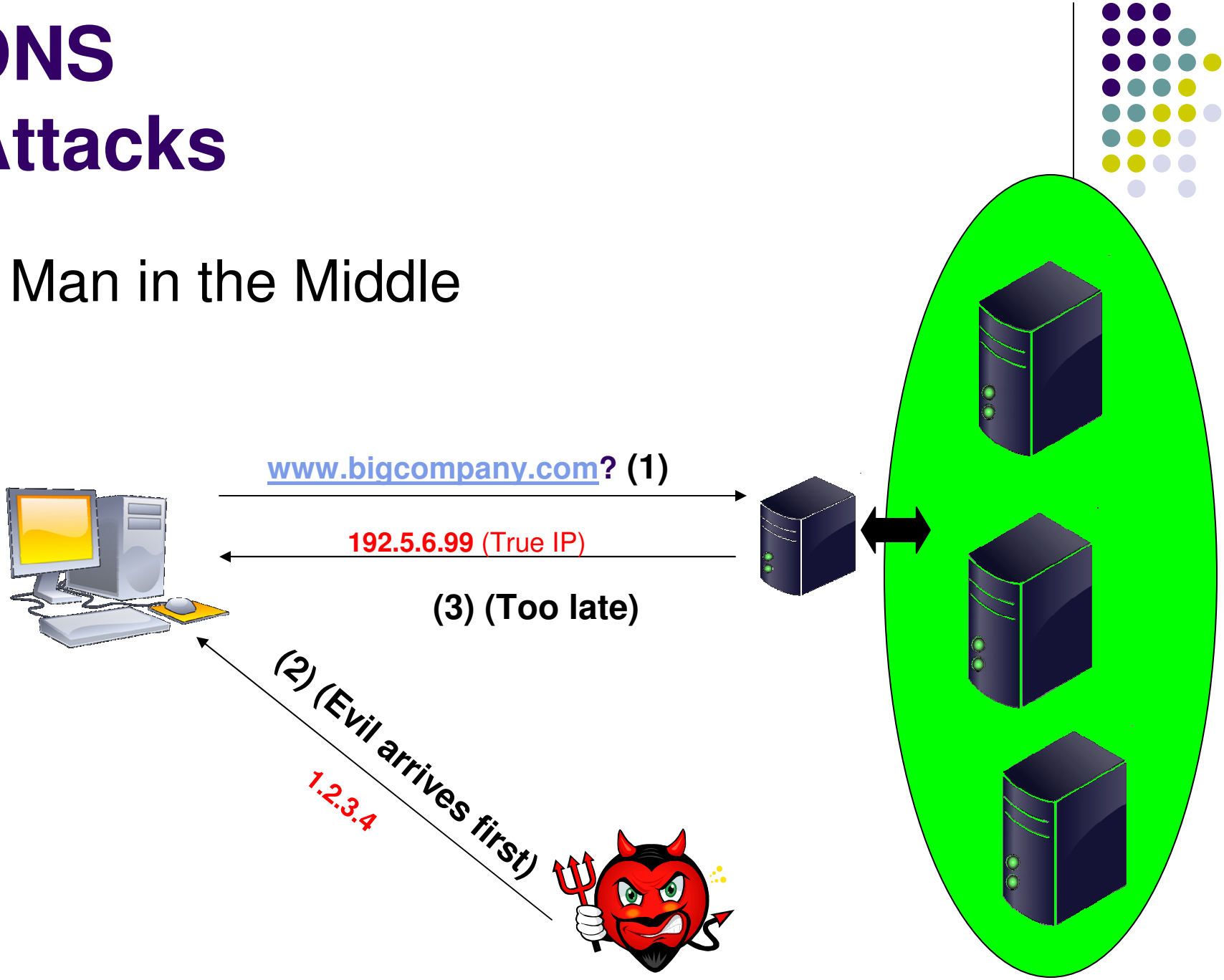
- DNS uses cache to improve performance
  - e.g: In the case of iterative resolving
    - What is the IP for www.dcc.uchile.cl?
    - I know the IP for the name server of the zone ***uchile.cl***.
    - I can ask this server directly without starting from the ***root***.
  - Time To Live (TTL)
    - Tradeoff between ***consistency*** and ***efficiency***

DNS Attacks

- Many attacks on the DNS (references)
  - Man in the Middle
  - Cache poisoning
  - (Distributed) Denial of Service
- Major problem
  - Lack of integrity / authenticity
- Consequences are **HUGE**
  - Phishing
  - Defacements
  - Internet is down

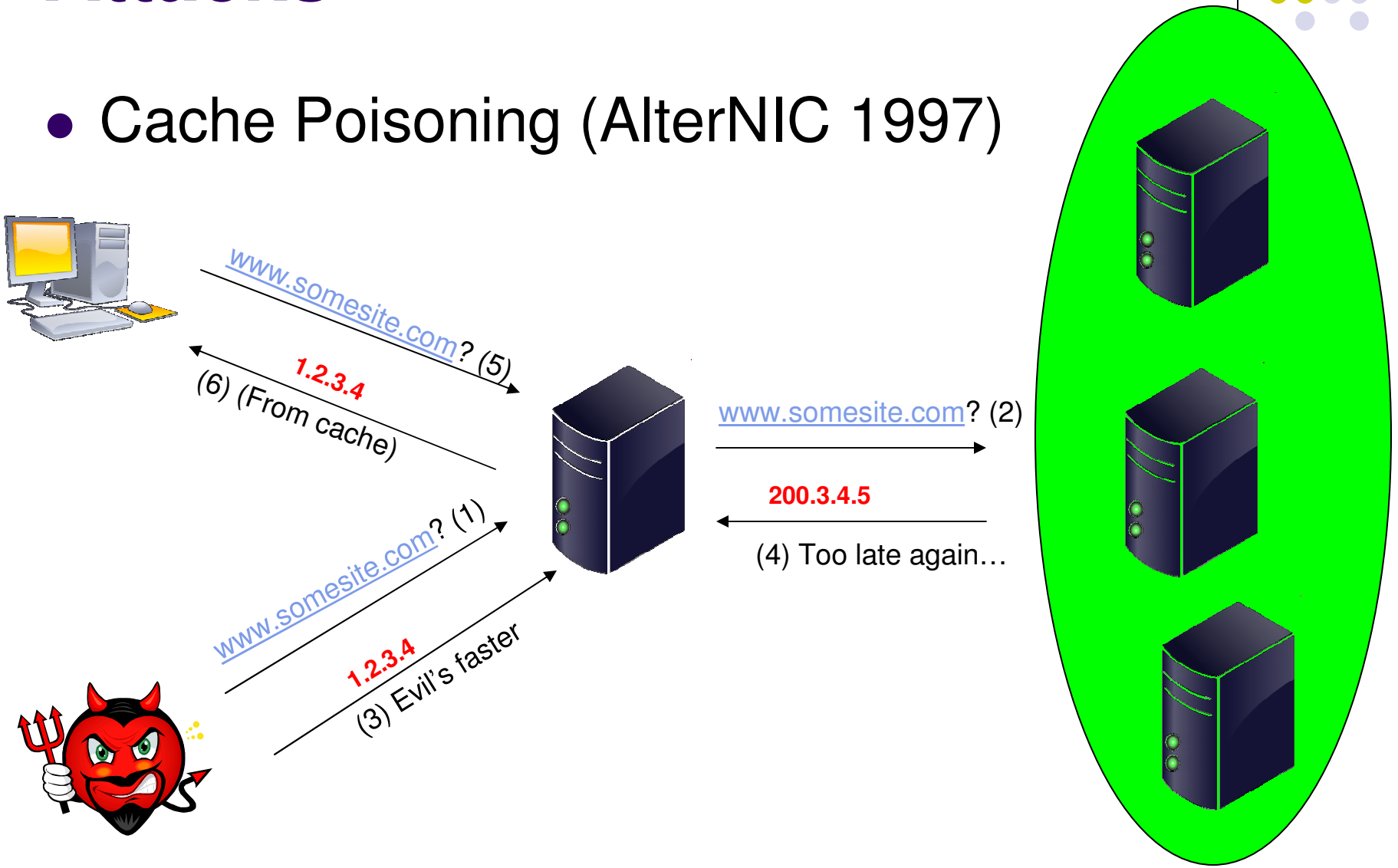
DNS Attacks

- Man in the Middle

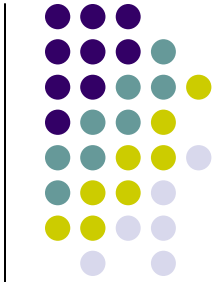


DNS Attacks

- Cache Poisoning (AlterNIC 1997)



DNS Attacks



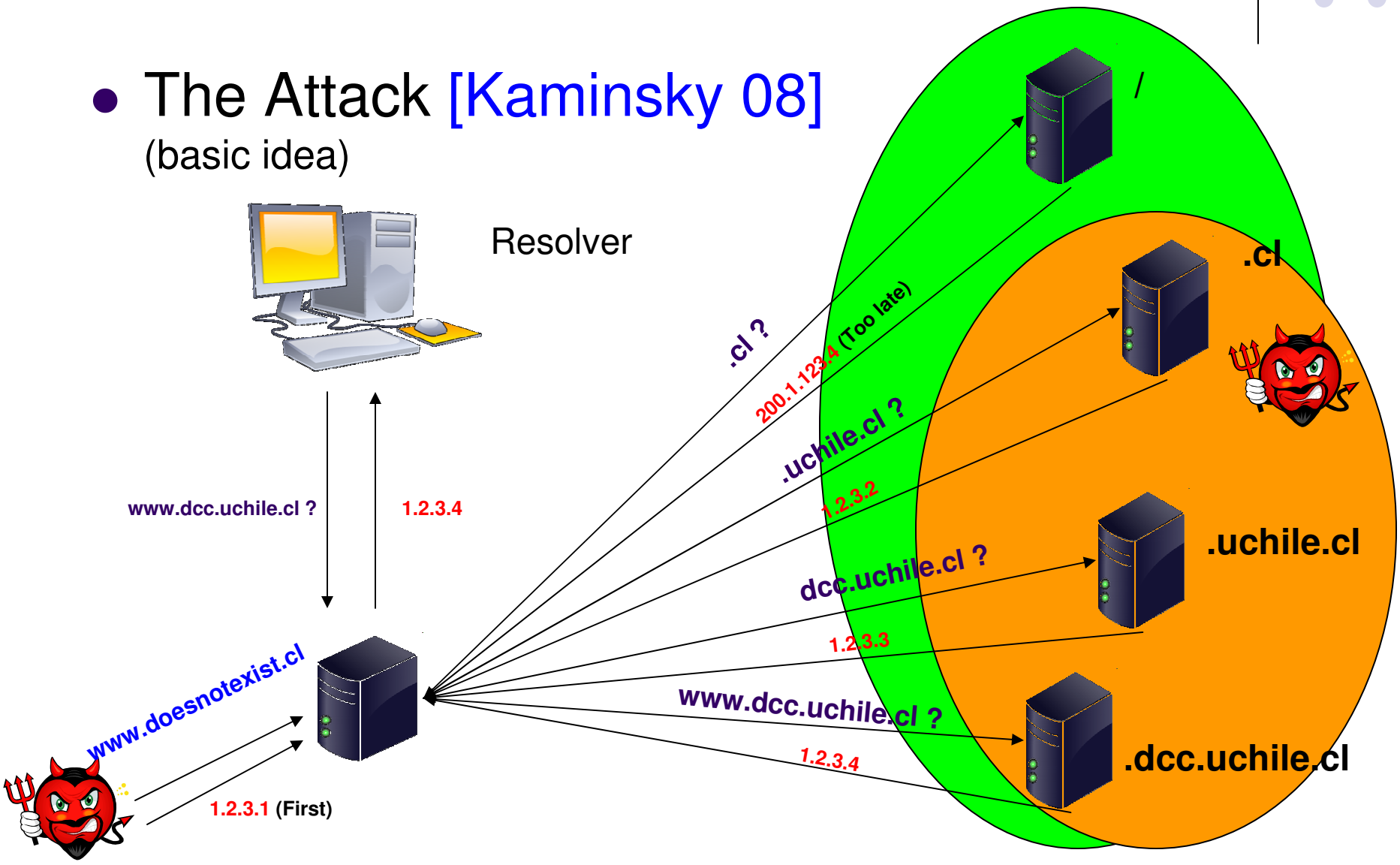
- (Distributed) Denial of Service
  - Such as every internet service, DNS is exposed to (D)DoS
  - However the specificity of the protocol allows ***amplification attacks***
  - (D)DoS is really hard to avoid
    - As we shall see DNSSEC do not pretend to solve this problem and could possibly make it worse…

DNS Attacks

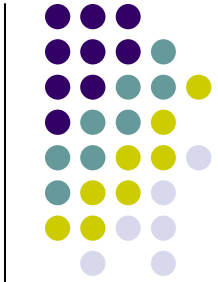
- A new attack [Kaminsky 08]
  - Presented at Black Hat 2008
  - Previous attack only allows to forge only **one (url,ip)** mapping.
  - Kaminsky's attack is far more devastating
    - Allows to control a **whole domain** (.cl)
  - This is scary…
    - Many certificate authorities validate a user's certificate by sending an email… So in this case even SSL is useless!

DNS Attacks

- The Attack [Kaminsky 08]
  (basic idea)

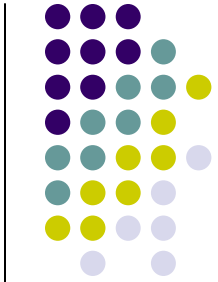


DNSSEC Basics



- What it is for?
  - **Authenticate** data exchanged between the participants of the protocol
- What it is NOT for?
  - Guarantee **privacy** (except for NSEC3)
  - Ensure **availability**

DNSSEC Basics

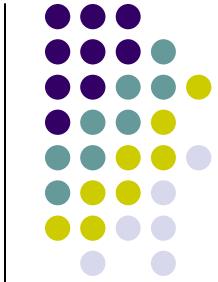


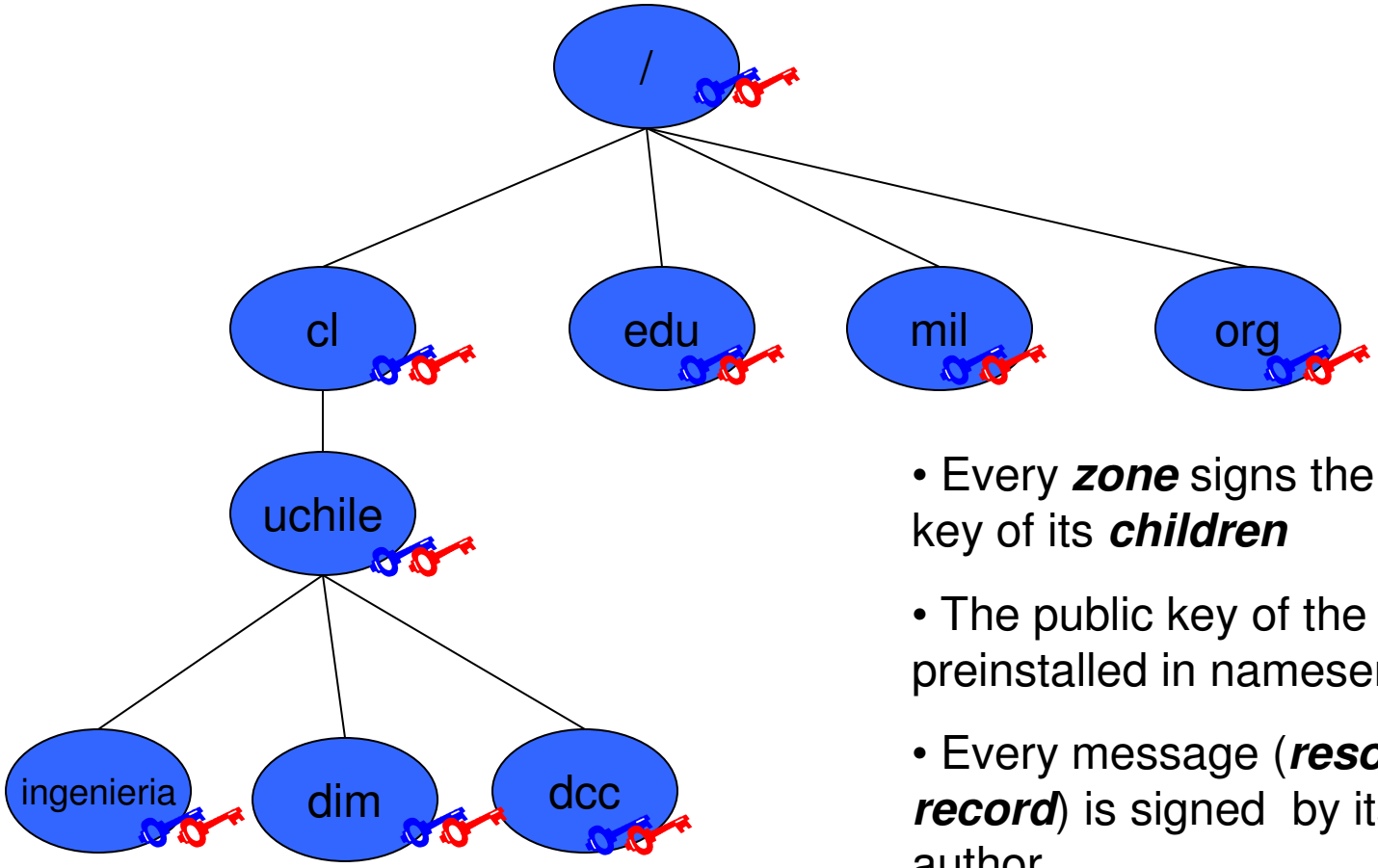
- Core RFCs that describe DNSSEC
  - DNS Security Introduction and Requirements (4033)
  - Resource Records for the DNS Security Extensions (4034)
  - Protocol Modifications for the DNS Security Extensions (4035)

- Another important RFC
  - DNSSEC Operational Practices (4641)

- Web
  - http://www.dnssec.net

DNSSEC Basics

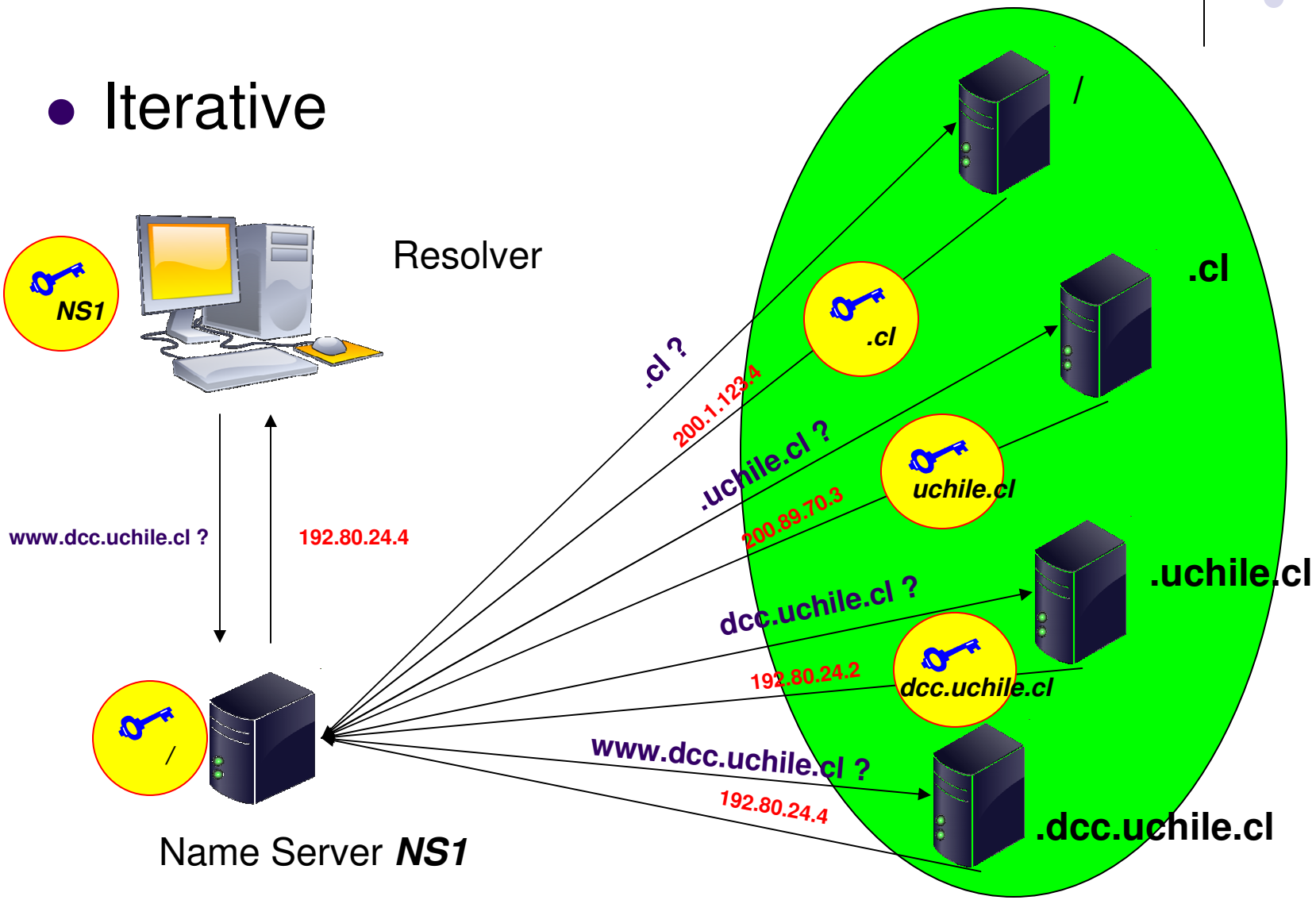




- Every ***zone*** signs the public key of its ***children***
- The public key of the ***root*** is preinstalled in nameserver.
- Every message (***resource record***) is signed by its author.

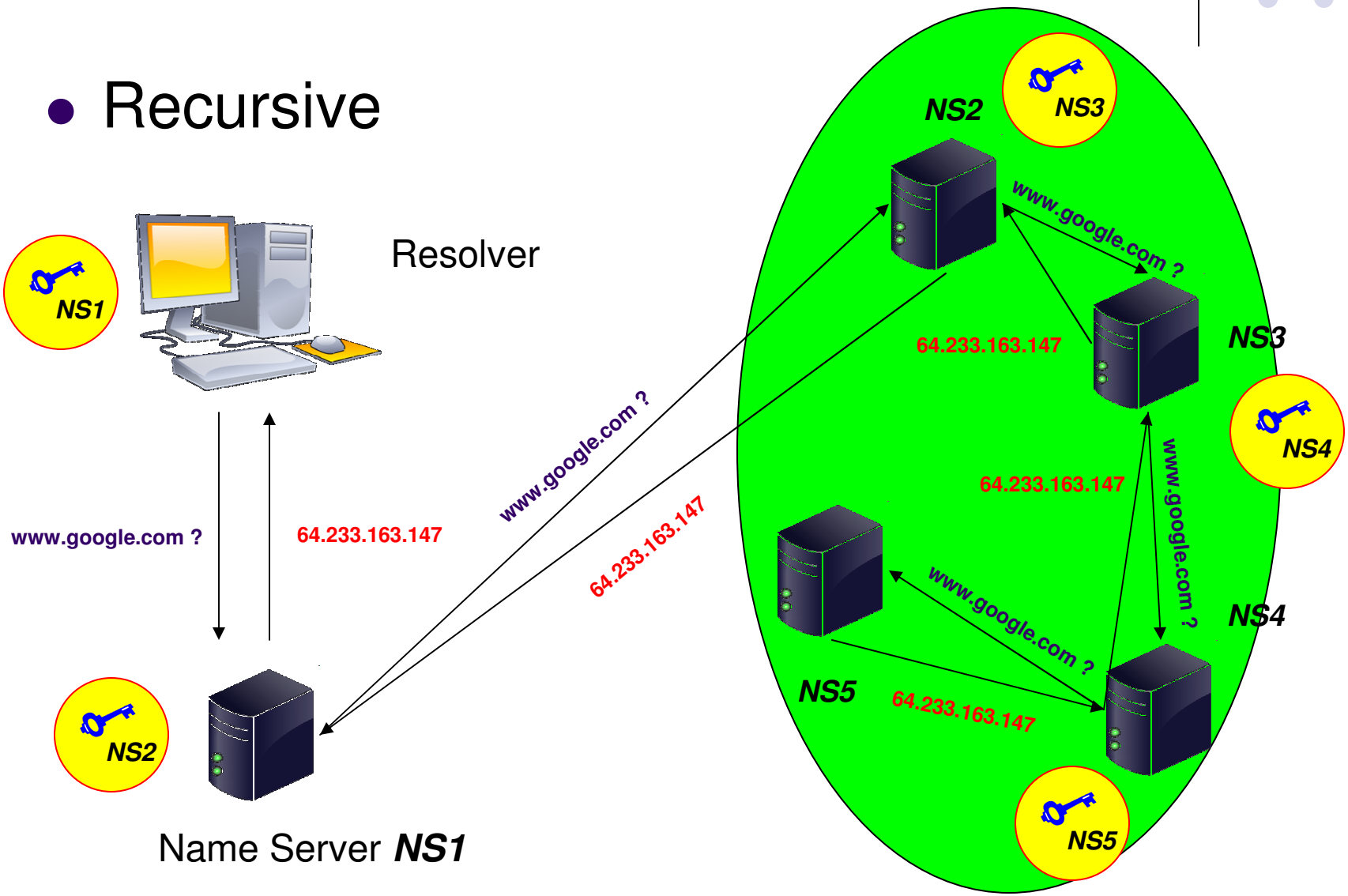
DNSSEC Resolution & Verification

- Iterative



DNSSEC Resolution & Verification

- Recursive

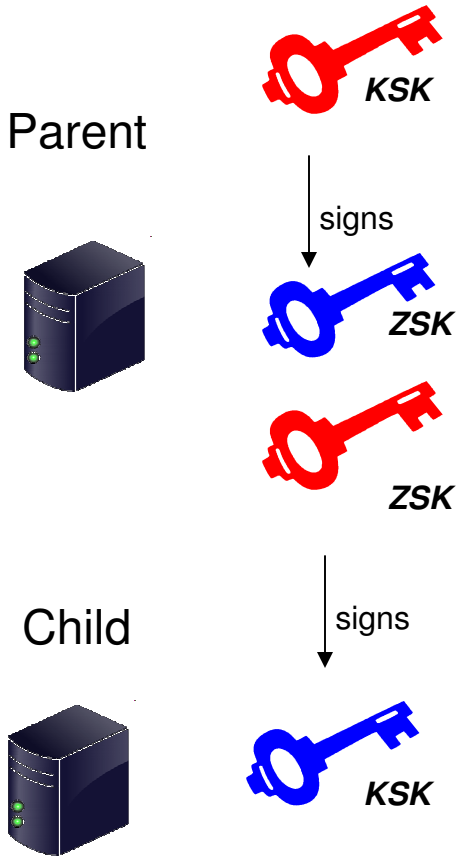


DNSSEC Operational Practices

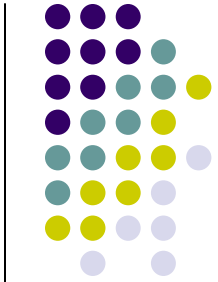
- Time
  - Assumption: ***global clock***.
  - Every signed information has a ***limited lifetime***.
  - This also applies to ***keys***.

DNSSEC Operational Practices

- Two types of Keys
  - Zone Signing Keys (ZSK)
    - Are used to sign all the information of the zone
  - Key Signing Keys (KSK)
    - Are used to sign the ZSK
  - ZSK are used to sign the KSK of the ***child***



DNSSEC Operational Practices



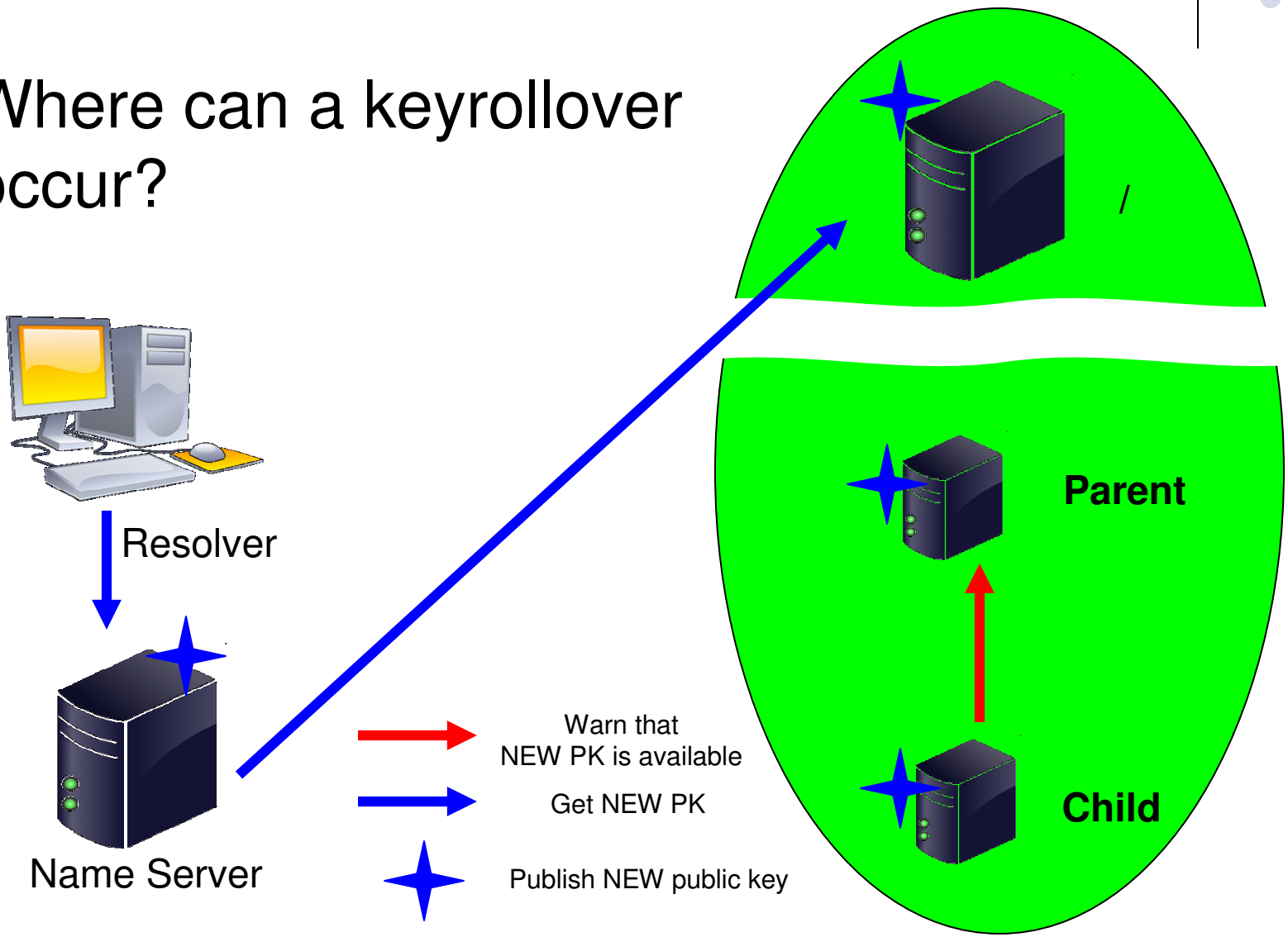
- Motivation of the use of KSK/ZSK
  - No parent/child interaction is required when ZSKs are updated.
  - The KSK can be made stronger.
  - KSK is only used to sign a set of keys. It can be stored in a safer place.
  - KSK have longer effectivity period.

DNSSEC Operational Practices

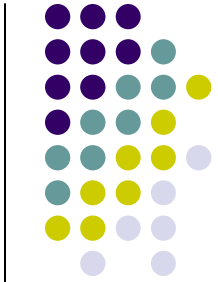
- KEY ROLLOVER
  - It is necesarry to change the keys from time to time
    - As to make cryptanalysis harder
      => Scheduled Rollover
    - Private keys may be stolen or cracked
      => Unscheduled Rollover

DNSSEC Operational Practices

- Where can a keyrollover occur?

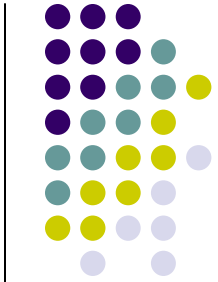


DNSSEC Operational Practices



- Scheduled Key Rollover
  - How do name servers/resolvers know this new public key?
    - Pre-Publish Key Rollover
    - Double Signature Rollover
  - ZSK Rollover
    - No interaction needed
  - KSK Rollover
    - Interaction needed between child and parent

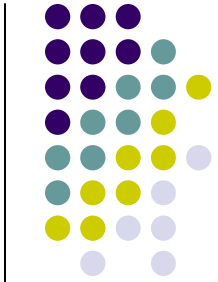
DNSSEC Operational Practices



- ZSK Prepublish Rollover

initial	New DNSKEY	New Signatures	DNSKEY Removal
KSK	KSK	KSK	KSK
ZSK1	ZSK1	ZSK1	
	ZSK2	ZSK2	ZSK2
$\{ZSK1\}_{KSK}$	$\{ZSK1\}_{KSK}$	$\{ZSK1\}_{KSK}$	
	$\{ZSK2\}_{KSK}$	$\{ZSK2\}_{KSK}$	$\{ZSK2\}_{KSK}$
$\{ZONE\_DATA\}_{ZSK1}$	$\{ZONE\_DATA\}_{ZSK1}$	$\{ZONE\_DATA\}_{ZSK2}$	$\{ZONE\_DATA\}_{ZSK2}$

DNSSEC Operational Practices



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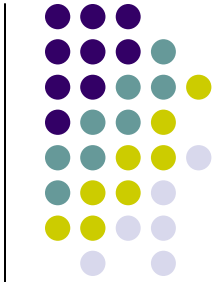

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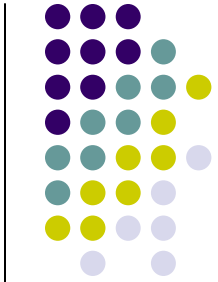

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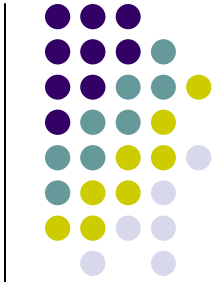

- ZSK Double Signature Rollover

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	ZSK2	ZSK2
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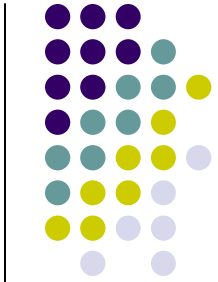

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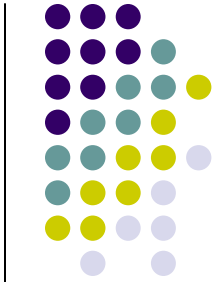

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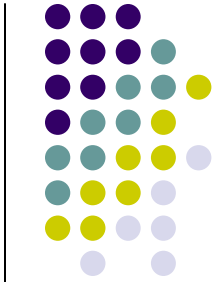
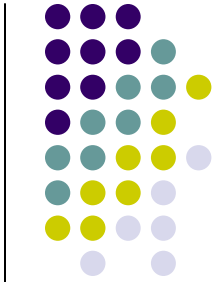
DNSSEC Operational Practices



- Pros and Cons
  - Prepublish Key Rollover
    - + Does not involve signing all the zone data twice.
    - - Process requires 4 steps.
  - Double Signature
    - + Process requires 3 steps.
    - - The number of signatures in the zone doubles. Prohibitive for big zones.

DNSSEC Operational Practices



- KSK Rollover
  - Same idea
    - Now the data to sign are (zone signing) keys
  - However
    - Double Signature Rollover seems better as the data signed is only a set of key
    - The child needs to warn the parent securely that the keys have changed.
      - The way to do this is left to the DNSSEC administrators.

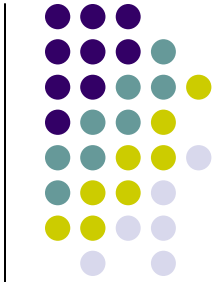
DNSSEC Operational Practices

- Unscheduled Key Rollover

  - **PANIC!**

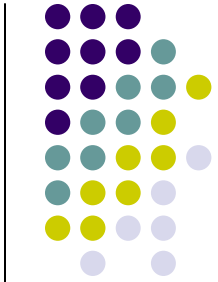
    - *"An authenticated out-of-band and secure notify mechanism to contact parent is needed in this case." (RFC 4641)*

DNSSEC Operational Practices



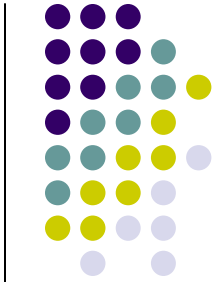
- Unscheduled Key Rollover
  - Keep the chain of trust intact
    - Resign with the compromised key the new set of keys with a very short lifetime, then make a rollover
    - **Problem:** DOMAIN DISPUTE
      - The adversary controls the compromised key, so he can also make a keyrollover…
      - At the end who should we believe?
  - Break the chain of trust
    - Say to the clients that there is a problem
    - Fix the problem
    - Interact with the clients to distribute the new public key
    - **Problem:** DNSSEC is down for a while

NSEC 3



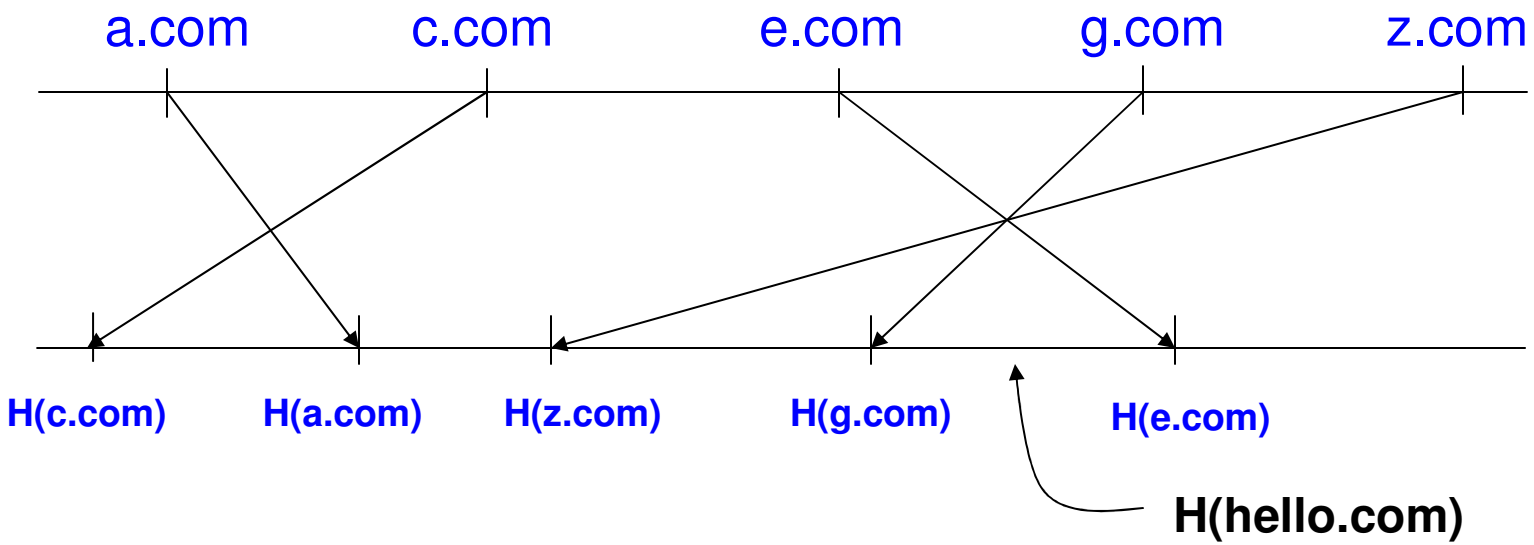
- DNSSEC
  - not only provides an authenticated mapping between IP and domains
  - but also provides proofs of non existence (membership)
    - e.g: Q: www.doesnotexist.com ?
      A: this domain does not exist
- For efficiency
  - As to avoid signing dynamically the response the consecutive pair of domains ordered in alphabetic order are signed. All proofs are ***precomputed***.
  - [a.com, c.com], [c.com, e.com], [e.com,g.com], [g.com,z.com]
  - hello.com does not exist ⇔ g.com < hello.com < z.com

NSEC 3



- Problem: Zone Walking
  - An attacker can collect all the domains of a zone, by asking for domain that lies inside of every succesive intervals.
  - Is that a problem? After all the information is public…
  - Yes but in some case knowing all the domain names for a given level can be a useful information to build an attack for example.

NSEC 3

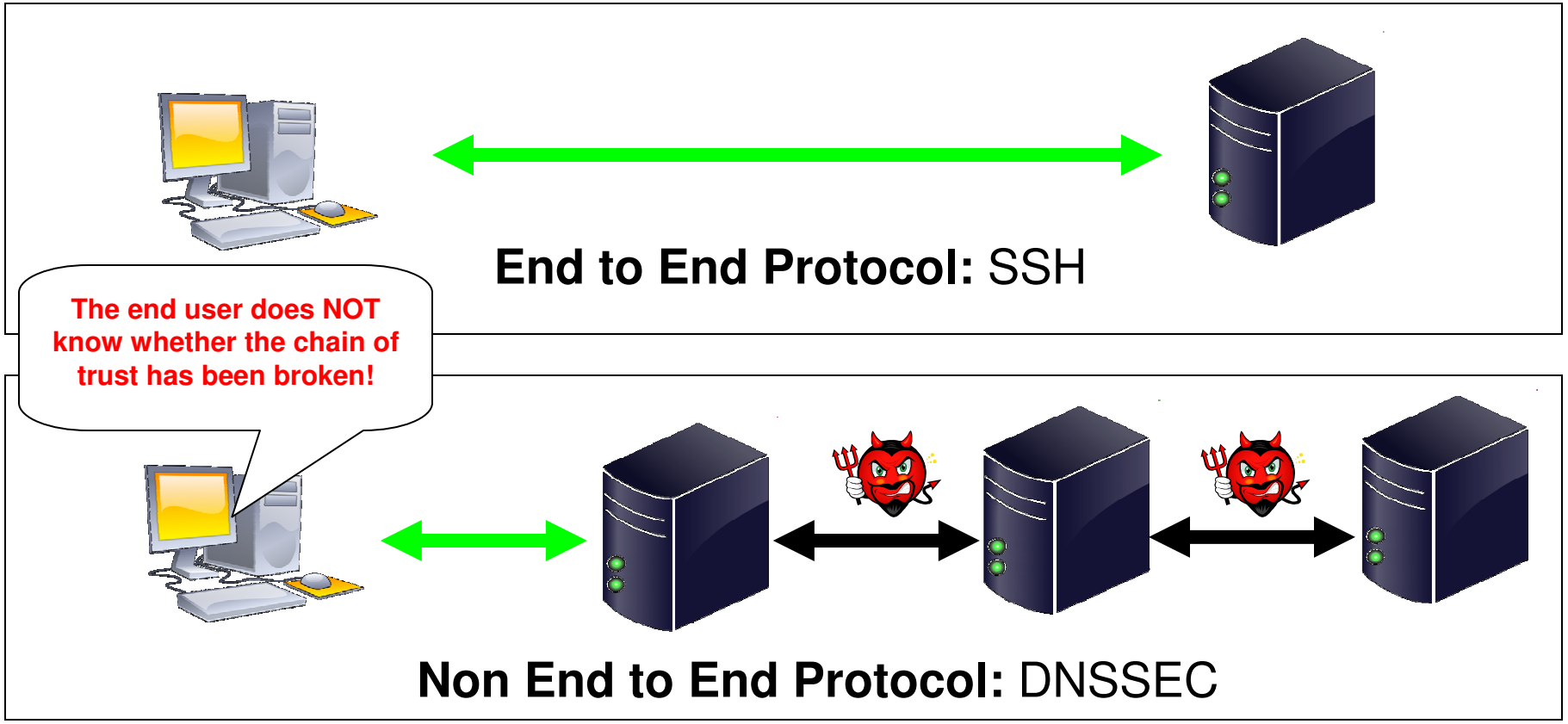
- Solution
  - Applying a hash function H to the domain names as to hide the information of the domain and still be able get nonmembership proofs.
  - 

DNSSEC
Problems and Limitations

- First proposal 1999 (RFC 2535) but still no current implementation at root level 2009
- Only a few of the Top Level Domains (.com, .org, countries…) run DNSSEC
  - Chile is working hard at this moment to implement it!
- Why?
  - Who signs the root?
  - Practical Experiences (Netherlands,…) have been painful
  - DNSSEC is complex
  - People may not see the immediate benefit
  - …

DNSSEC
Problems and Limitations

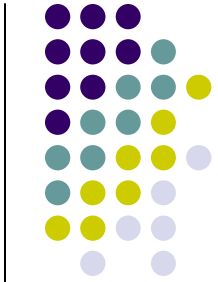
- DNSSEC is a "**Non End to End**" Protocol



DNSSEC
Problems and Limitations

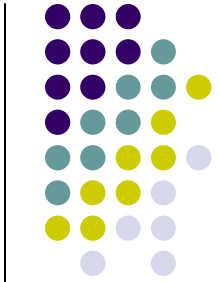
- How to set the public keys life-time?
  - Too big => gives more time to the Adversary
  - Too short => inefficient
    - Need to rollover key very often

DNSSEC
Problems and Limitations



- How to detect (automaticaly) that a private key has been stolen?
  - Users generally don't notice they have been victim of a phishing attack.
  - Defacement
    - When obtained by DNS cache poisoning, the owner of the website is not aware of it.
- ***So in practice can we really detect that a key has been compromised?***

DNSSEC
Problems and Limitations



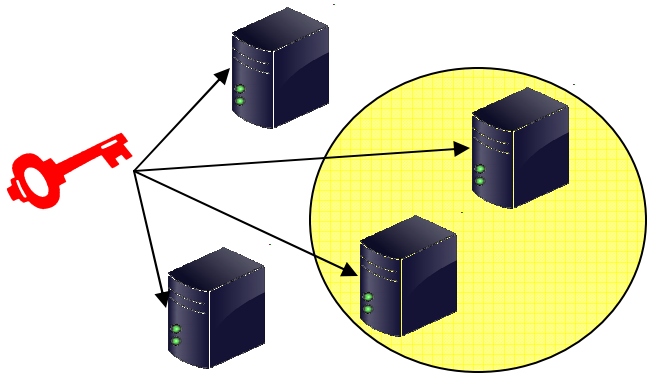
- Key Rollover/Revocation Problem
  - There is no real satisfactory solution for Key Revocation
  - Key Rollver is complex
  - Lack of specification
    - No precise procedure in case of key compromise.
    - How does the child warn its parent?

How to improve the Security of DNS?

- There is no definition for the Adversary
  - What can or cannot do the adversary
    - Steal private keys?
    - Only forge some signatures?
    - Intercept any packet?
    - Control a DNS Name Server?
    - Create a Zone / Domain?
      - Injection attack in Registrars Databases
    - …

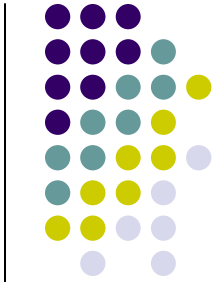
How to improve the Security of DNS?

- Use of Threshold Cryptography [Cachin, Samar 04]
  - What is Threshold Cryptography (very short)?
    - N participants
    - T participants can jointly sign
    - T-1 participant cannot do anything
      - =>Adversary must control T servers to perform an attack



N=4
T=2 participants required to sign

How to improve the Security of DNS?

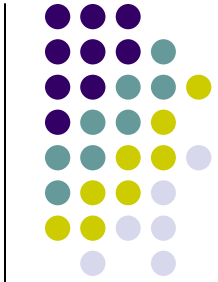


- Use of Threshold Cryptography
  [Cachin, Samar 04]
  - Concrete proposal
    - They use standard RSA signature
    - Need to change the server implementation but not the client
    - Benchmark
  - Stealing private key is harder
    - It can be effective against internal attacks.
  - However
    - If the servers that hold the share have got the same configuration, a same vulnerability can be enough to compromise all the servers.
    - More Complex

How to improve the Security of DNS?

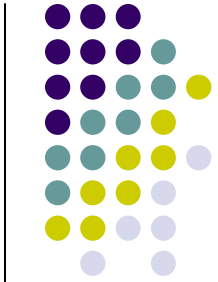
- Identity Based Cryptography [Chan 03]
  - Master Thesis work.
  - Analyzes the possibilty to use IBC to improve the security of DNS instead of using standard public key cryptography.
  - Original approach to solve this problem.

IBC



- Idea
  - A Trusted Authority (TA) generates (SK,PK) and distributes securely the private keys to every participant.
  - Then the TA publishes a public key PK
  - The public key of every participant can be computed from PK and a public information
    - Email, Name, Passport Number, Biometric data

DNS with IBC

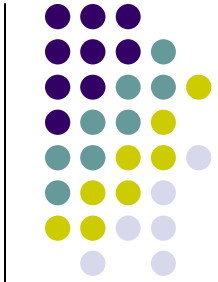


- [Shamir, 84]
  First introduction of the concept.

- [Boneh,Franklin 01]
  First efficient scheme for IBC using bilinear maps.

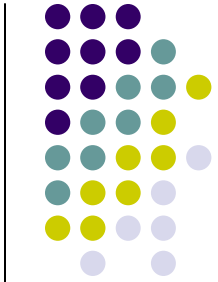
- Many other works, this is a very active field.

IBC



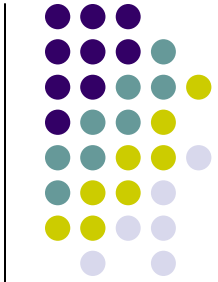
- Advantages
  - No need to store public keys
  - No need to sign/verify public keys
  - No need to manage certificates

DNS with IBC



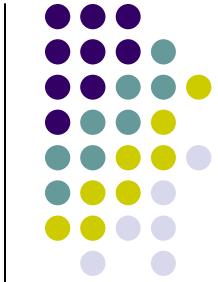
- Problem: Key Escrow
  - The TA knows (generates) all the private keys of users.
  - Is that really a problem?
  - ANSWER
    - **NO:** in our setting, a parent can always create new children with their respective private keys.

DNS with IBC



- Key Rollover
  - Add timestamp to the identity
    - **dcc.uchile.cl || 28-4-2009::29-4-2009**
- Key Revocation
  - Still hard
    - We could use a database of revocated keys but we would loose the good properties of IBC…

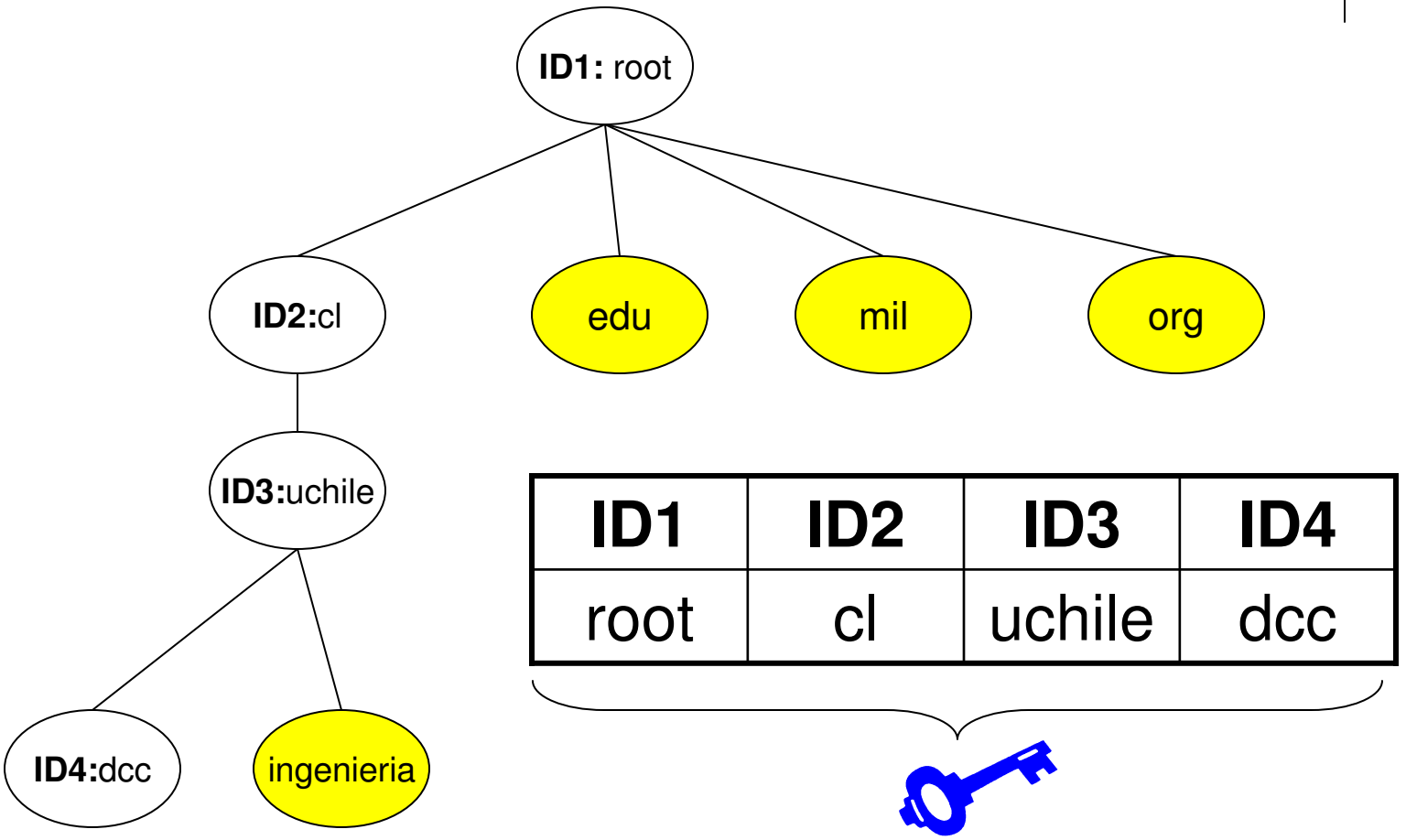
DNS with IBC



- Problem of scalability
  - A single authority has to generate all the private keys. This is not reasonable in the case of DNS.

- Solution
  - Use of Hierchical Identity Based Cryptography
    - The private key generation can be delegated to subauthorities **[Gentry, Silverberg 02]**

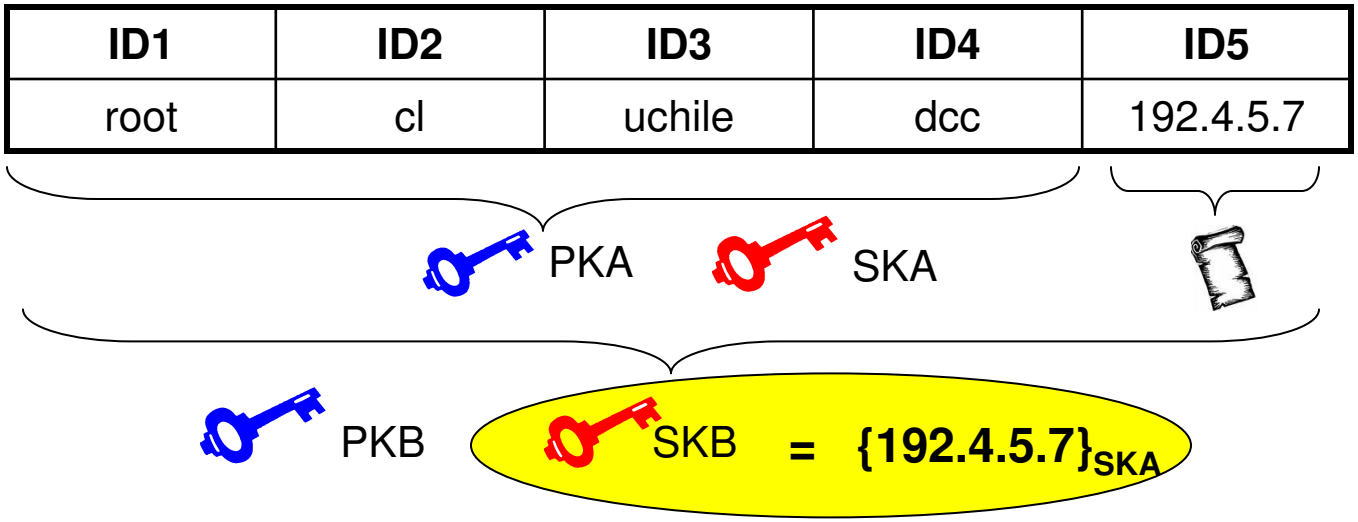
DNS with HIBC



ID1	ID2	ID3	ID4
root	cl	uchile	dcc

DNS with HIBC

- How to sign?



Verification process

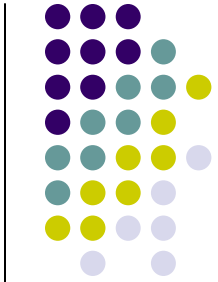
(1) R random

(2) C = Encrypt(PKB,R)

(3) R' = Decrypt(SKB,C)

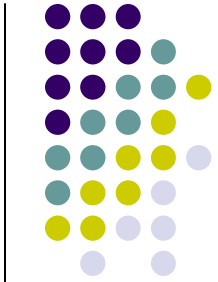
(4) R = R' ?

DNS with HIBC



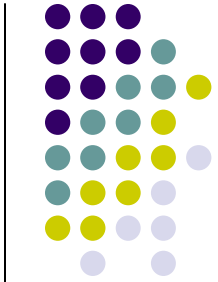
- Efficiency
  - The size of a signature grows ***linearly*** in the ***depth*** of the hierarchy.
  - So we do not win to much (even we may loose) compared to the classical DNSSEC verification procedure.

DNS with HIBC

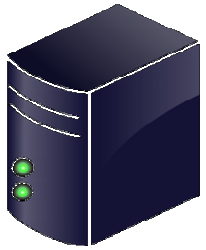


- So at the end, is HIBC useful?
  - HIBC has attractive properties
    - No need to manage public key/certificates
    - Simplifies the scheduled key rollover
  - However some problems remain unsolved
    - Key revocation (unscheduled key rollover)
    - Verification time proportional to the depth of the domain name tree.
    - Not clear that how to adapt the ***Recursive Resolving Algorithm***
    - In practice developping standards for pairings and HIBC takes time.

Conclusion



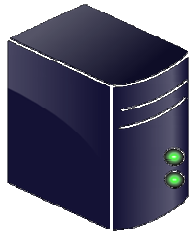
- DNS is essential for Internet
- DNS is not secure and this is a big problem
- DNSSEC adds integrity/authenticity to DNS
- DNSSEC raises some practical problems
  - Key Rollover
  - All or Nothing security / Not Point to Point
  - Administrative problem: who signs the root?
- But DNSSEC is to the date the only concrete proposal to make DNS more secure. Can we do better?

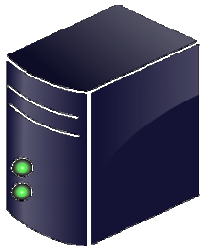


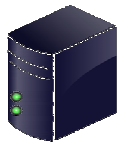











have.you.got.any.question