TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Computer Science Institute of Systems Architecture, Operating Systems Group

DISTRIBUTED OPERATING SYSTEMS

SCALABILITY AND NAMING

HORST SCHIRMEIER, DISTRIBUTED OPERATING SYSTEMS, SS2024

ORGANISATION

- Lecturer in charge of DOS:
  Dr. Carsten Weinhold, Barkhausen Institute TUD
- Several lectures presented by research-group members
- Mandatory: register for mailing list (see website)
  - must use “tu-dresden.de” mail addresses
- Hybrid format (BBB, recordings, both “best effort”)
  - Lecture: Monday, 11:10
  - Exercise: **Monday 13:00**
    (roughly every 2 weeks, starting 2024-04-15)

EXAMS

- Oral exam covering lectures *and* exercises
- About 1 exam date per month
- Exam appointments:
  - Email to sandy.seifarth-haupold@tu-dresden.de
  - Provide paperwork (forms) at least **2 weeks before exam** otherwise, **automatic cancellation** (and angry secretary) You can cancel until 2 weeks before date; after that, no more cancellation except for sickness.
- Diplom/Master INF study programmes: can be combined with other classes in complex modules

- **Course name** no more precise, rather: “Interesting/advanced Topics in Operating Systems“
  - Scalability
  - Systems security
  - Modeling
- Some overlap with “Distributed Systems” (Dr. Springer / Prof. Wählisch) and some classes by Prof. Fetzer
- In some cases no written material (except slides)

1.0) DOS ORGANISATION
1.1) SCALABILITY IN COMPUTER SYSTEMS
1.2) EXAMPLE: DNS/BIND

HORST SCHIRMEIER, DISTRIBUTED OPERATING SYSTEMS, SS2024

GOAL OF ALL LECTURES ON SCALABILITY

Topics:

- Scalability: terminology, problems, principle approaches
- Case studies, all layers of compute systems

Goal:

- Understand (some of the) important principles how to build scalable systems

TODAY

Outline:

- **Scalability** – and a simple model to reason about one aspect
- **Names** in Distributed Systems:
  purposes of naming, terminology (DNS)
- **Application of scalability** approaches on name resolution

Goal:

- Understand some of the important principles how to build scalable systems (using DNS as example)

TECHNISCHE UNIVERSITÄT DRESDEN

MORE CASE STUDIES LATER IN THE CLASS

- Memory consistency
- Locks and advanced synchronization approaches
- File systems
- Load balancing (MosiX) and HPC (MPI)

GENERAL DEFINITION: SCALABILITY

Scalability:

Scalability is the property of a system to handle a **growing amount of work** by **adding resources** to the system.

(Wikipedia (2019) and many other sources)

SCALABILITY: WEAK ./. STRONG

Ability of a system to use growing resources …

- ***Weak* scalability:**
  to handle growing load, larger problem, …
- ***Strong* scalability:**
  accelerate existing work load, same problem

PROBLEMS

- Performance bottlenecks / Amdahl's Law
- Failures / abuse
- Administration

RESOURCES AND PERFORMANCE

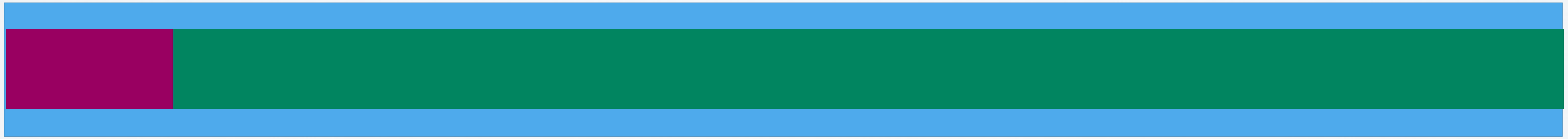
- Processors
- Communication
- Memory (remember basic OS course: “thrashing”)

$$\text{Speedup:} \frac{\text{original execution time}}{\text{enhanced execution time}}$$

SIMPLE MODEL: AMDAHL'S LAW

$$\text{Speedup:} \frac{\text{original execution time}}{\text{enhanced execution time}}$$

Parallel Execution



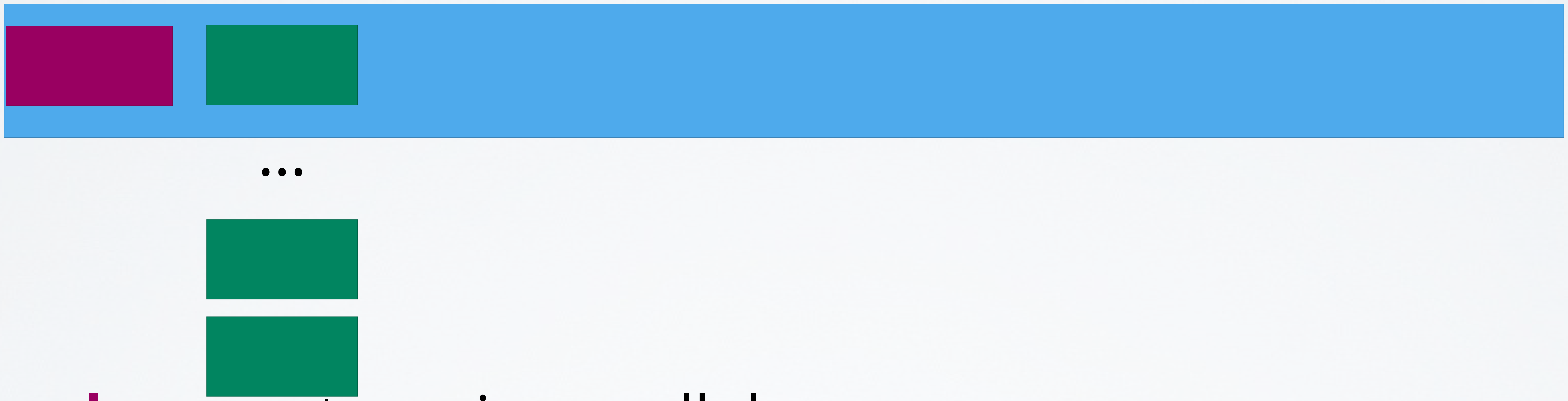
red: cannot run in parallel

green: runs *perfectly* parallel

unlimited processors maximum speedup: **blue**/**red**

AMDAHL'S LAW

Parallel Execution, N processors



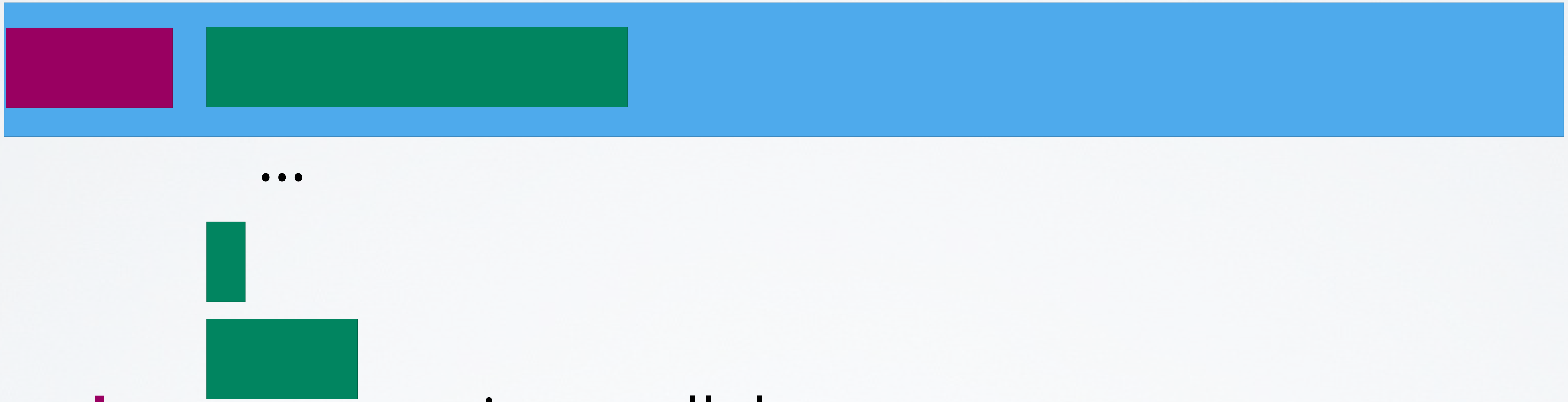
red: cannot run in parallel

green: runs *perfectly* parallel

N processors maximum speedup: **blue**/(**red**+**green**/N)

AMDAHL'S LAW

Parallel Execution, N processors



red: cannot run in parallel

green: runs *perfectly* parallel

maximum speedup: **blue**/(**red**+**green**/N)

AMDAHL'S LAW

$$\text{Speedup:} \frac{\text{original execution time}}{\text{enhanced execution time}}$$

- P: section that can be parallelized
- 1-P: serial section
- N: number of CPUs

$$\text{Speedup}(P,N) = \frac{1}{\left(1 - P + \frac{P}{N}\right)}$$

- if N becomes VERY large, speedup approaches: 1/(1-P)

THE “RPC” PRINCIPLES

- **Partitioning**
  Split systems into parts that can operate independently/parallel to a large extent
- **Replication**
  Provide several copies of components
  - that are kept consistent eventually
  - that can be used in case of failure of copies
- **Locality** (caching)
  Maintain a copy of information that is nearer, cheaper/faster to access than the original

MORE PRINCIPLES

- Identify and address **bottlenecks**
- **Specialize** functionality/interfaces
- Right level of **consistency**
  Caches, replicates, … need not always be fully consistent.
- Lazy information dissemination
- Balance load (make partitioning dynamic)

TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Computer Science Institute of Systems Architecture, Operating Systems Group

1.0) DOS ORGANISATION
1.1) SCALABILITY IN COMPUTER SYSTEMS
1.2) EXAMPLE: DNS/BIND

HORST SCHIRMEIER, DISTRIBUTED OPERATING SYSTEMS, SS2024

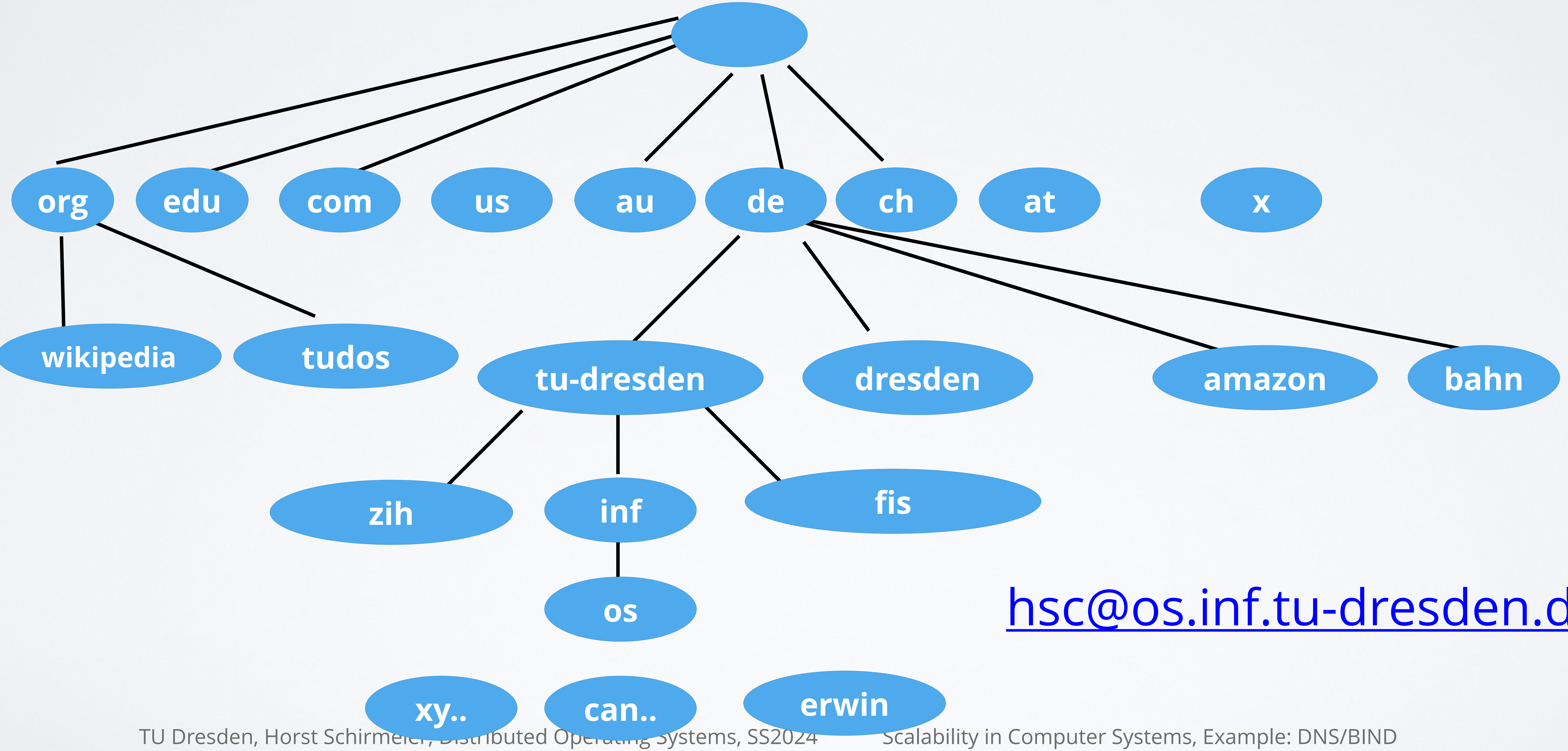
EARLY EMAILS

- UUCP/MMDF:
  - ira!gmdzi!oldenburg!heinrich!user (path to destination)
  - user@ira!heinrich%gmdzi
    (mixing identifiers and path information)

A BIT OF HISTORY

- ARPA-Net at the beginning:
  - a single file: hosts.txt
  - maintained at Network Information Center of SRI (Stanford)
  - accessed via FTP
  - TCP/IP in BSD Unix massively increased ARPA-Net size
    → Chaos, name collisions, consistency, load, …
- **DNS:** Paul Mockapetris et al.

DOMAIN NAME SYSTEM



hsc@os.inf.tu-dresden.de

NAMES, IDENTIFIERS, ADDRESSES

- **Names**
  - symbolic, many names possible for one entity
  - have a **meaning for people**
- **Identifiers**
  - identifies an entity **uniquely**
  - are used by programs
- **Addresses**
  - **locates** an entity
  - changes occasionally (or frequently)

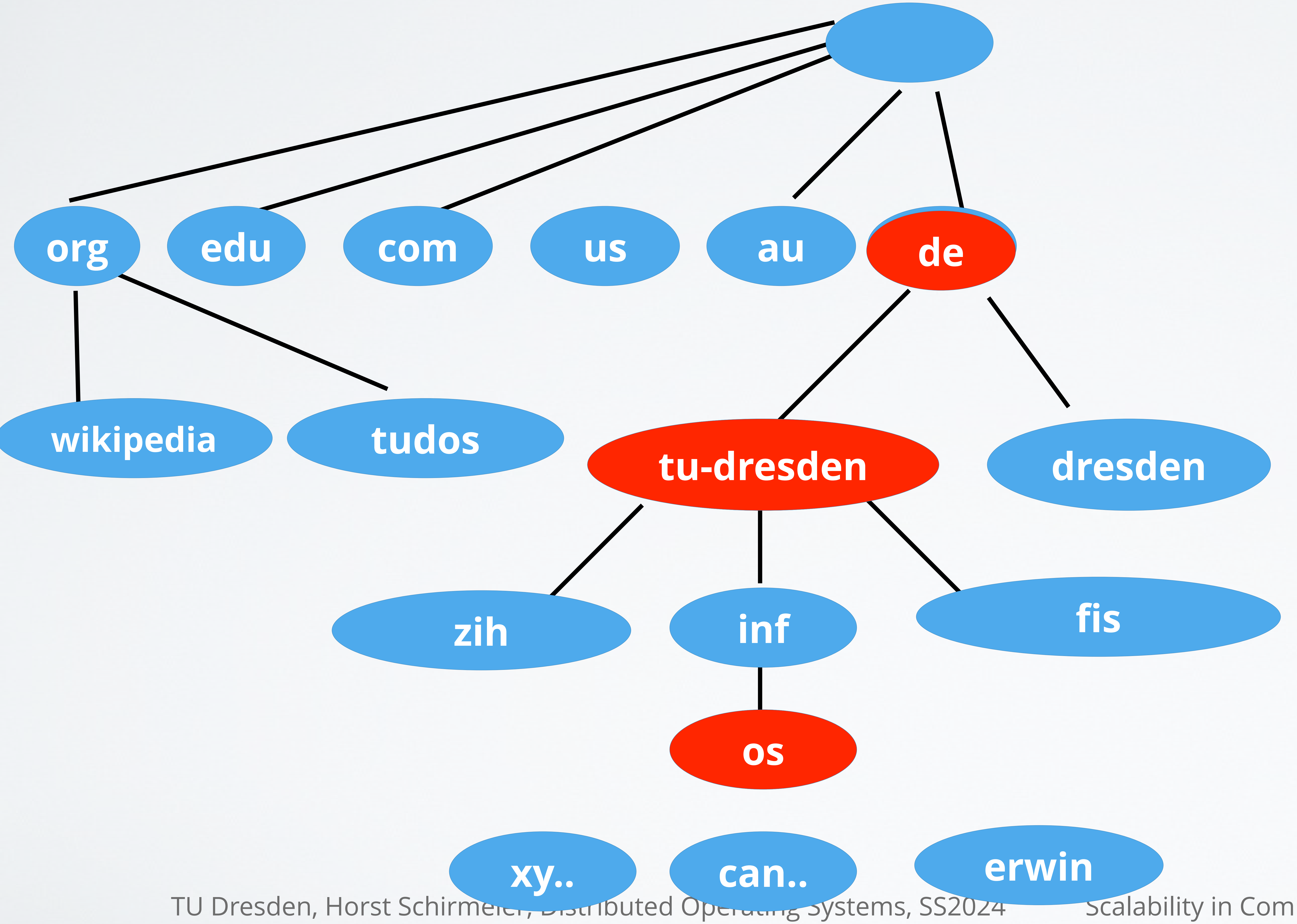
NAME RESOLUTION

- **Name resolution:**
  Map symbolic names to a set of attributes such as: identifiers, addresses, alias names, security properties, encryption keys, …

- Principle interface:
  - **Register** (Context, Name, attributes, …)
  - **Lookup** (Context, Name) → attributes

TECHNISCHE UNIVERSITÄT DRESDEN

DNS DOMAINS



Domain =
subtree in DNS hierarchy:

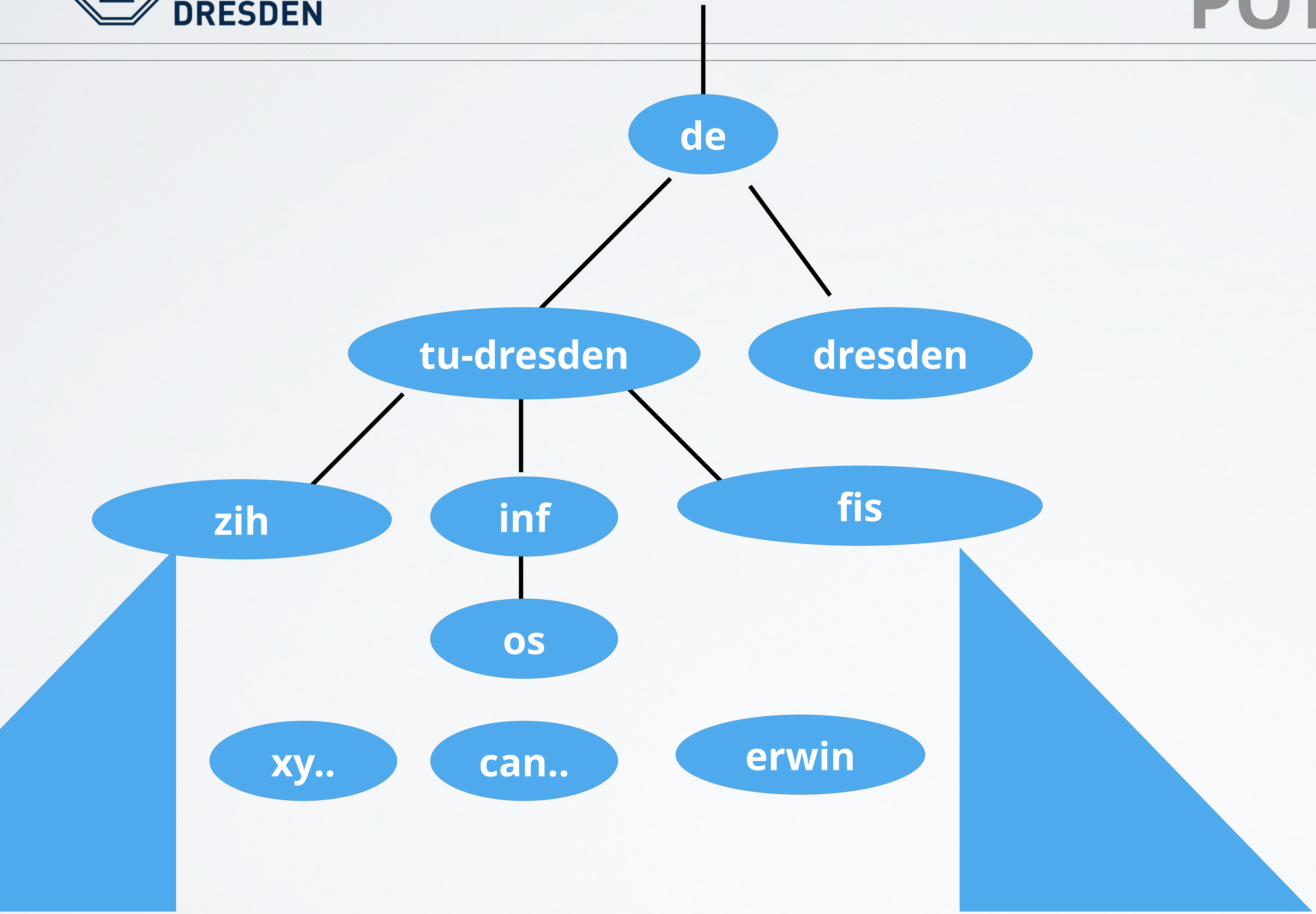
- de
- tu-dresden.de
- os.inf.tu-dresden.de
- tudos.org and os.inf.tu-dresden.de are aliases

TECHNISCHE UNIVERSITÄT DRESDEN

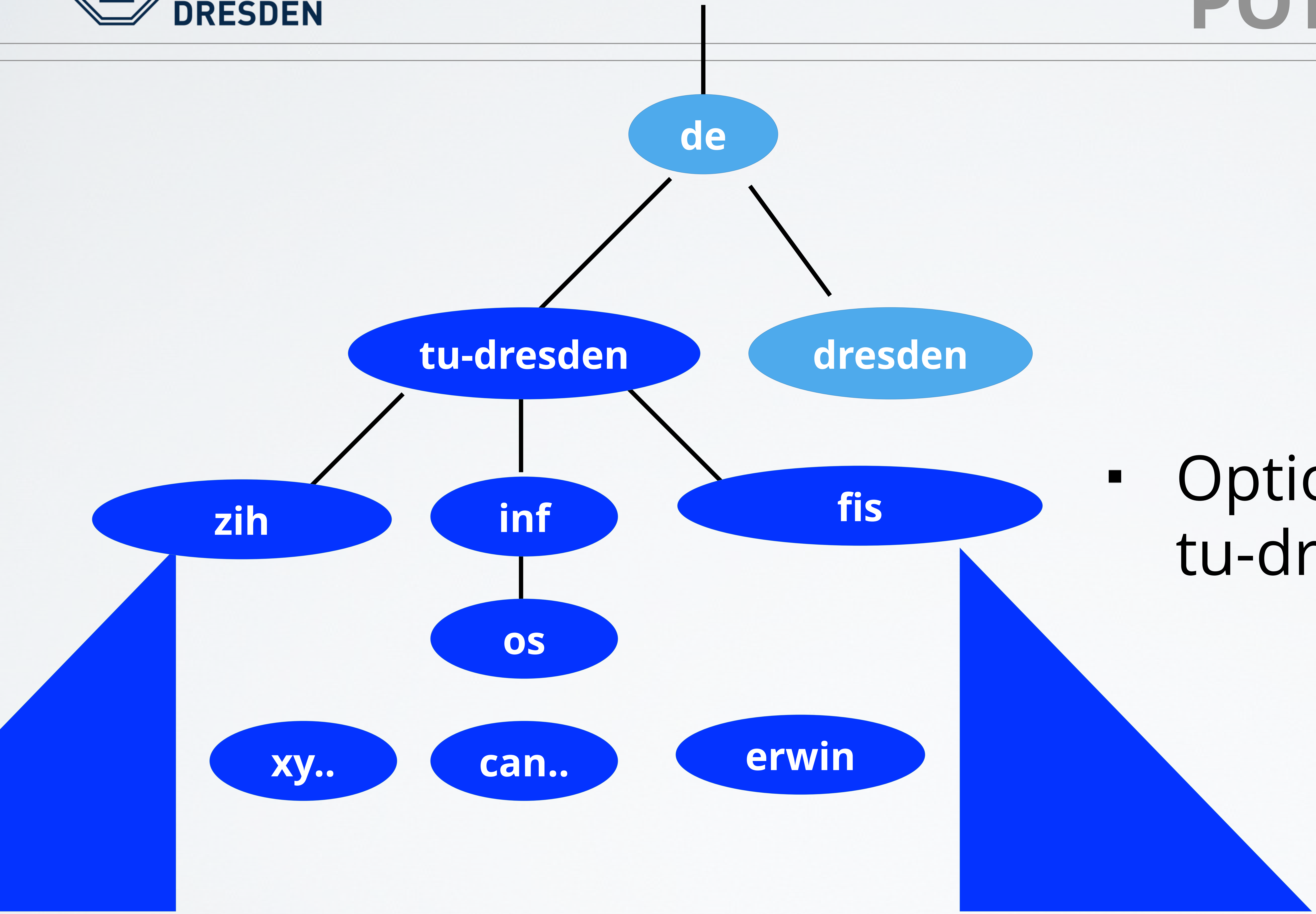
PARTITIONING: ZONE

- **Zone:** Subset of a domain
  over which an **authority** has complete control
  → controlled by a **name server**
- **Subzones** can be delegated to other authorities.
- **Navigation:**
  querying in a set of cooperating name servers

POTENTIAL ZONES

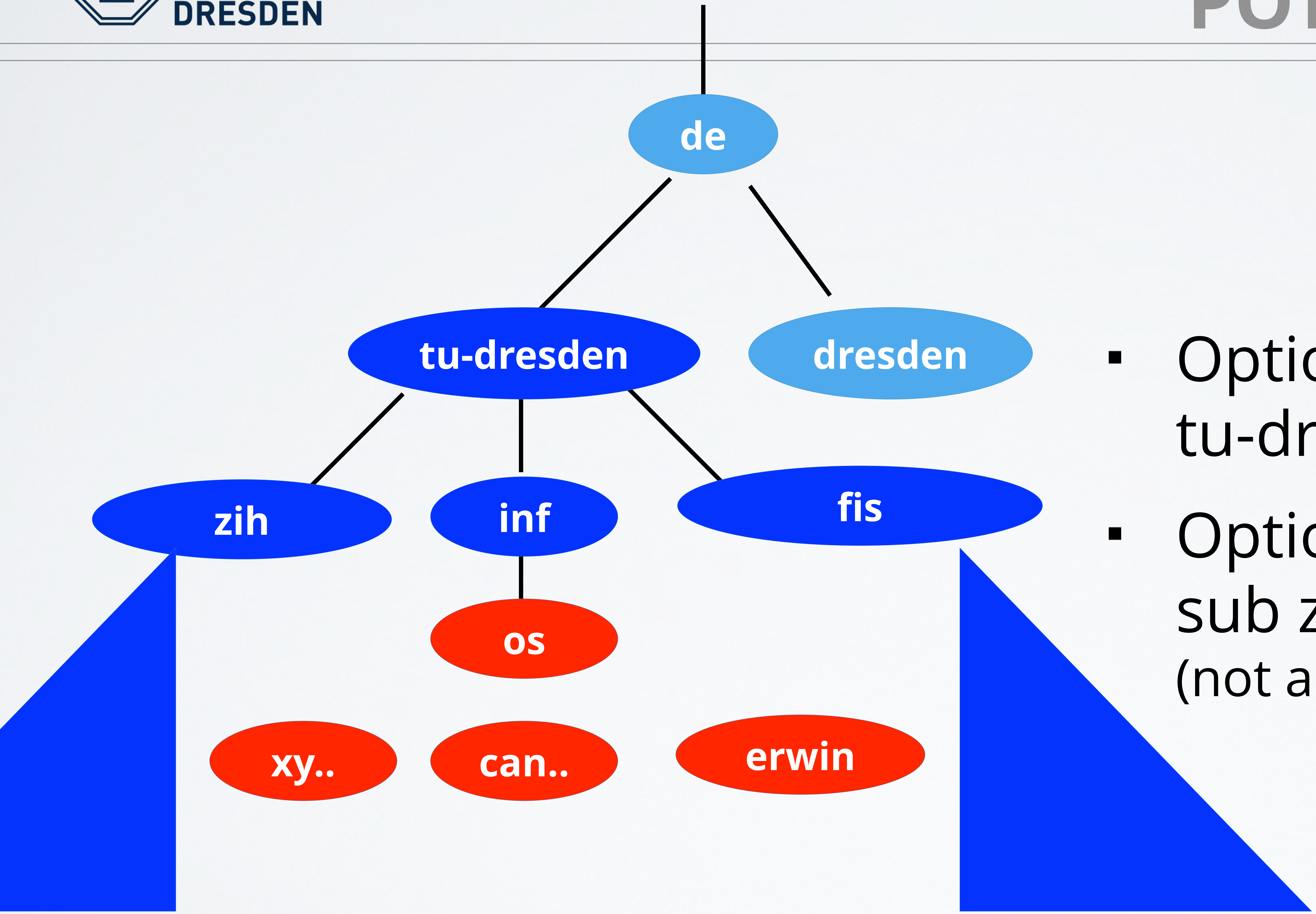


POTENTIAL ZONES



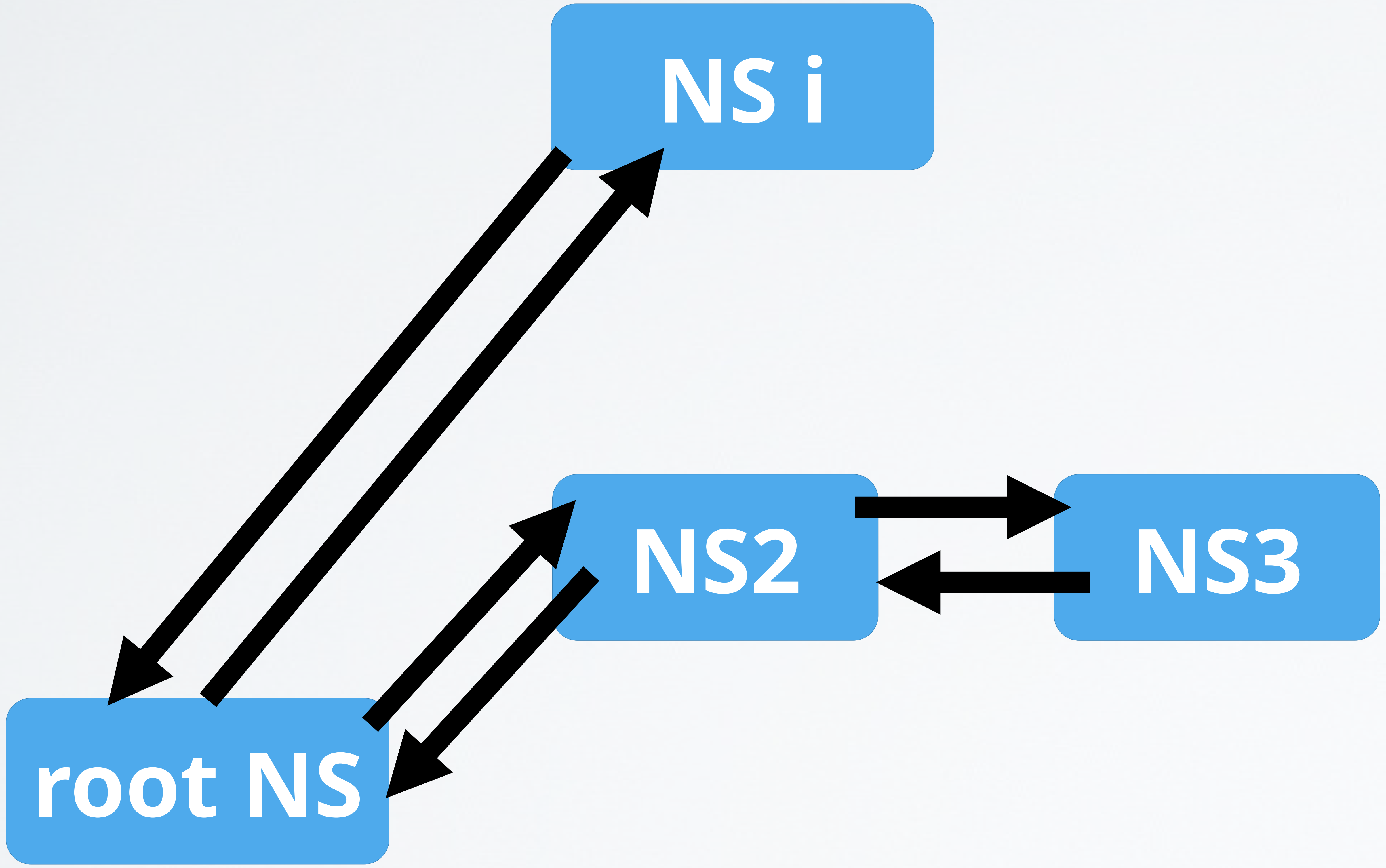
- Option #1: complete tu-dresden domain

POTENTIAL ZONES



- Option #1: complete tu-dresden domain
- Option #2: Opt. #1 with sub zone **os** (not allowed by ZIH anymore)

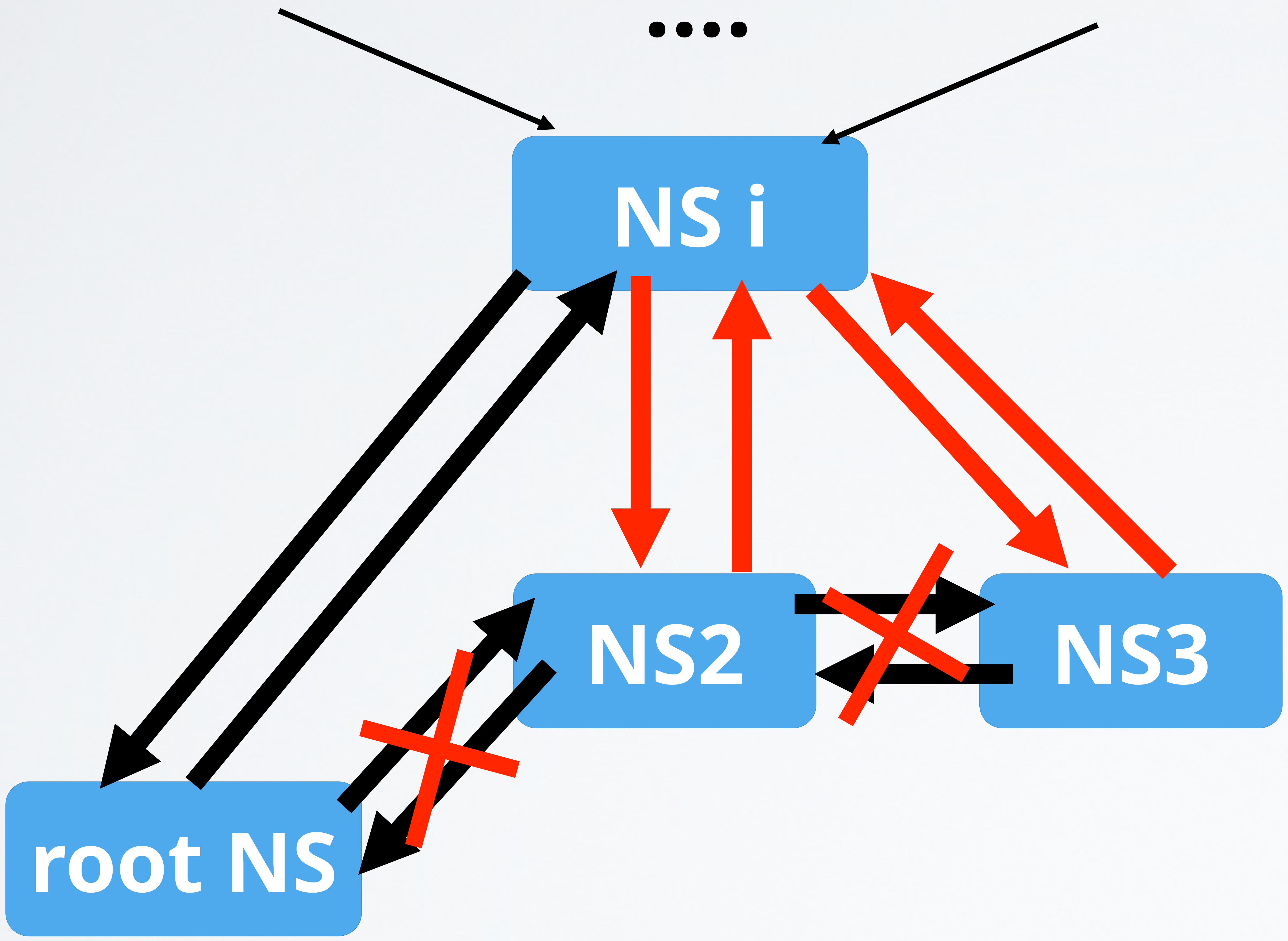
CACHING



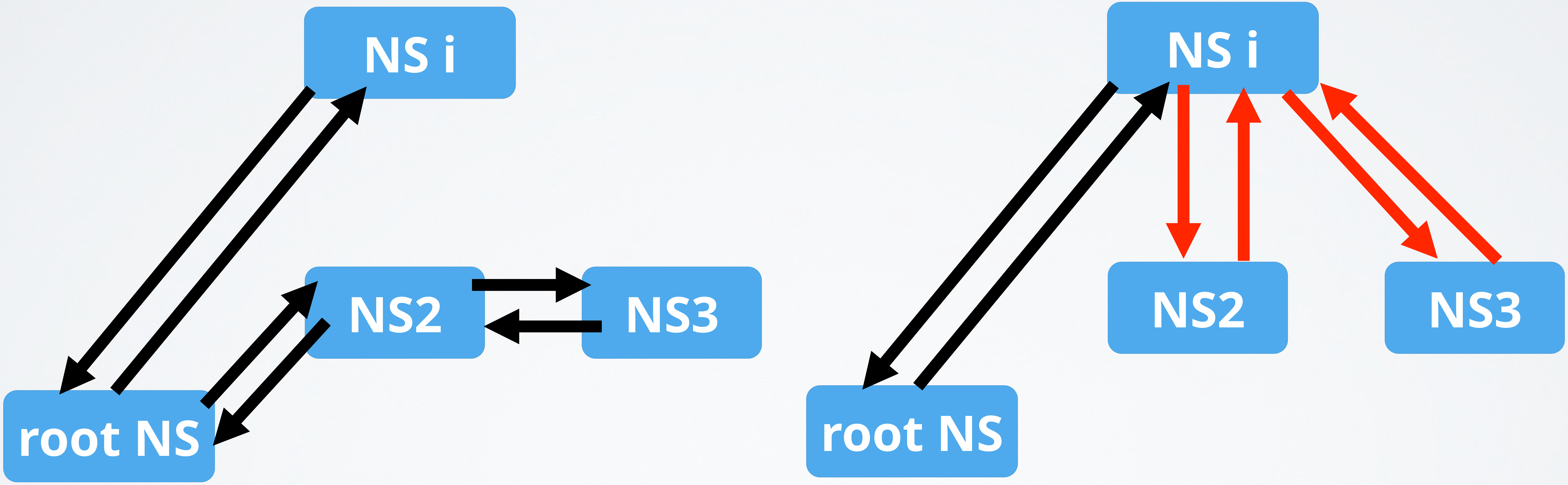
CACHING

- remember intermediate results
- @ root NS makes no sense! (overload)
- **@ NS i !**

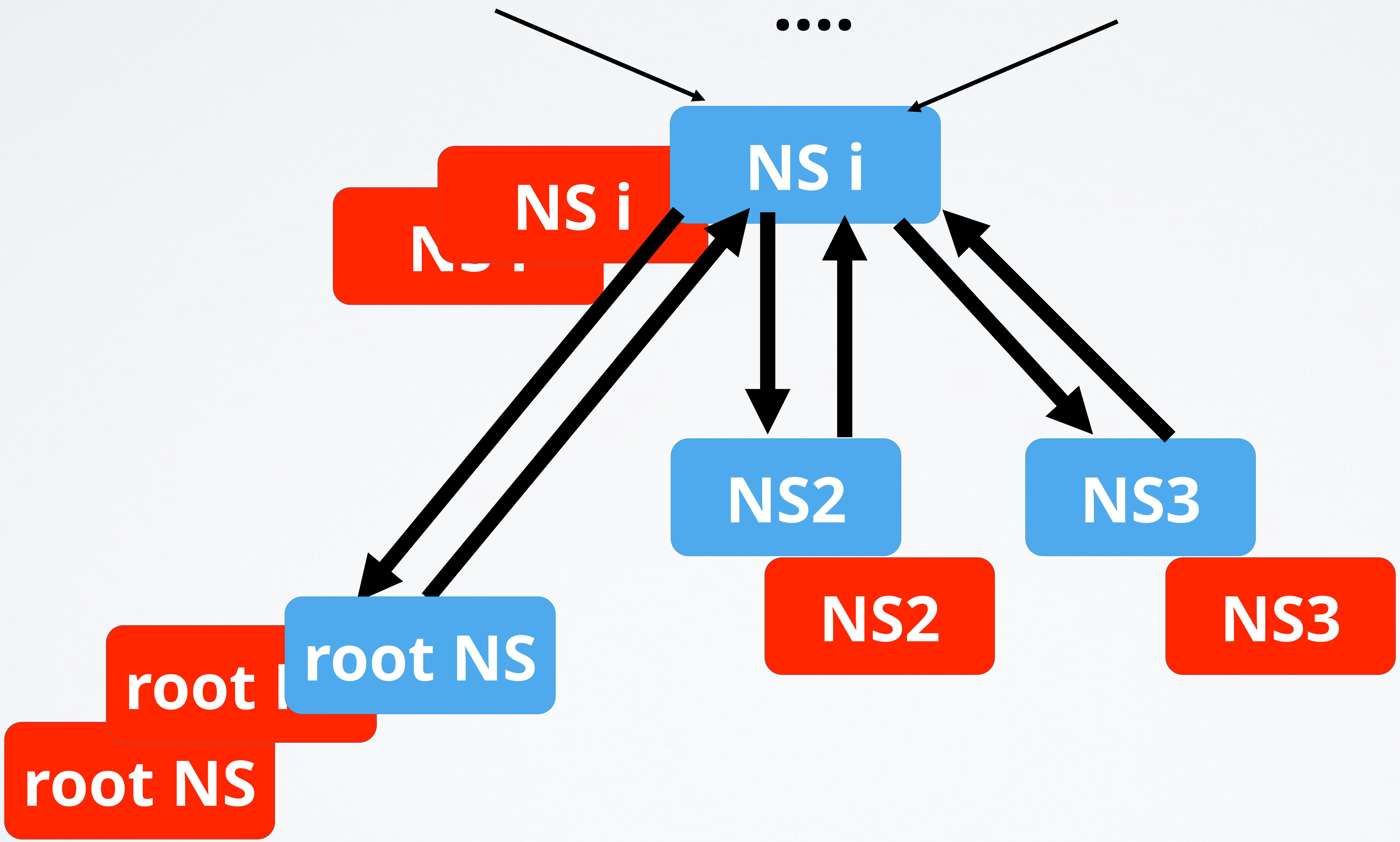
CACHING



RECURSIVE ./. ITERATIVE



REPLICATION



RPC: REPLICATION

- Two **techniques for replication**:
  - Several IPs/names
  - “anycast” (send packet to one of many servers with same IP)
- 13 root name server IPs, ~1700 physical servers via anycast
- Each zone has at least
  one primary and one secondary IP

RESOURCE RECORDS

name =>

Record type	Interpretation	Content
A	address	IPv4 address
AAAA	address	IPv6 address
NS	Name server	DNS name
CNAME	Symbolic link	DNS name of canonicial name
SOA	Start of authority	Zone-specific properties
PTR	IP reverse pointer	DNS name
HINFO	Host info	Text description of host OS
...	...	...

SUMMARY

- Main problems for scalability
- Simple model: Amdahl's law
- Few principle approaches
- DNS as fine example, more to come
  → study DNS it in your first exercise (Apr 15th)

- **Register in mailing list!**
  (with a tu-dresden.de address)

LITERATURE

- Cricket Liu, Paul Albitz: **DNS and BIND**, 5th edition (2006)
  O'Reilly & Associates, Inc. (available online via SLUB)
- Mark Hill, Michael Marty: **Amdahl's Law in the Multicore Era**, 2008
  IEEE (available online via SLUB)
- Couluris, Tollimore, Kindberg: **Distributed systems**