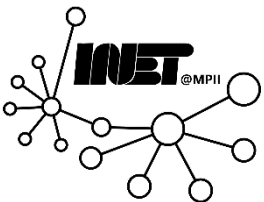# Network Layer
Routing: RIP & OSPF
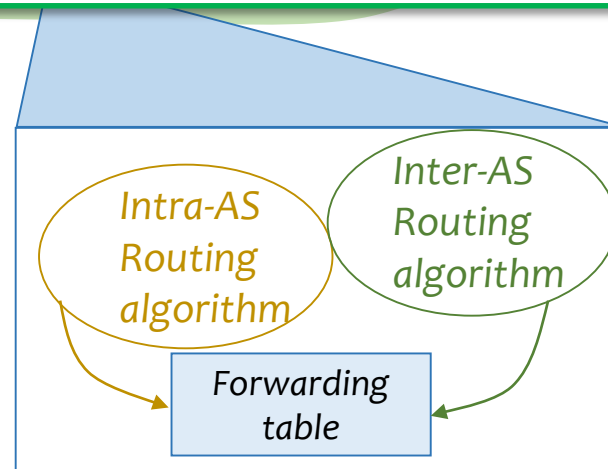
Prof. Anja Feldmann, Ph.D.

Interconnected ASes

Forwarding table is configured by both intra-AS and inter-AS routing algorithm.
- Intra-AS sets entries for *internal* destinations
- Inter-AS & Intra-AS set entries for *external* destinations

Intra-AS
Routing
algorithm

Inter-AS
Routing
algorithm

Forwarding
table

Intra-AS routing

Also known as *Interior Gateway Protocols (IGP)*

Most common Intra-AS routing protocols:

- *Routing Information Protocol (RIP)*
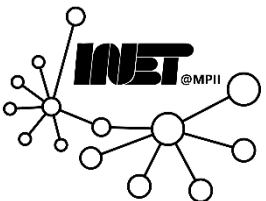- ***Open Shortest Path First (OSPF)***

Intra-AS routing: OSPF

Open Shortest Path First (OSPF)

- *Link state* protocol (based on *Dijkstra*)
- Routers periodically *flood immediate reachability* info to all other routers
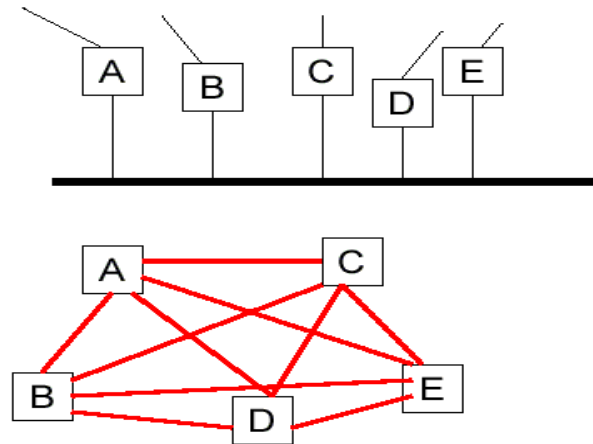- Distance metric: *administrative weight*
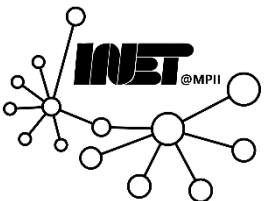
OSPF: Network types

- So far only point-to-point

- Many other technologies

- Specific requirements for OSPF
    - Neighbor relations
    - Synchronization
    - Representation in DB

- Kinds
    - Point-to-point
    - Broadcast
    - Non-broadcast multi-access
    - Point-to-multipoint
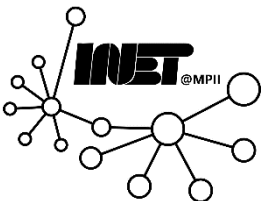
OSPF: Adjacencies on broadcast networks

- If **n** routers are on a broadcast link, **n(n-1)/2** adjacencies can be formed.

OSPF: Adjacencies

- If routers formed pair wise adjacencies:
  - Each would originate *(n-1)+1=n* LSAs for the link.
  - Out of the network, n^2 LSAs would be emanating.

- Routers also send received LSAs to their neighbors
  - *(n-1)* copies of each LSA present on the network
  - Even with multicast: *(n-1)* responses

- Solution: Elect Designated Router (DR)
  - Routers form adjacencies only with DR:
  - Link acts as a (multi-interface) virtual router to the rest of the area

OSPF: Designated router election

- When router joins:
  - Listen to hellos; if DR and BDR advertised, accept them
    - All Hello packets agree on who the DR and BDR are
    - Status quo is not disturbed
- If there is no elected BDR, router with highest priority becomes BDR
- Ties are broken by highest RouterID
  - RouterIDs are unique (IP address of interface)
- If there is no DR, BDR is promoted to DR
- Elect new BDR
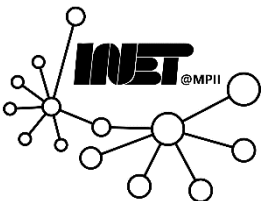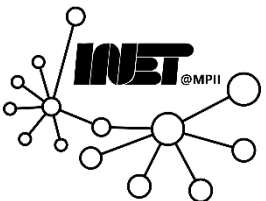
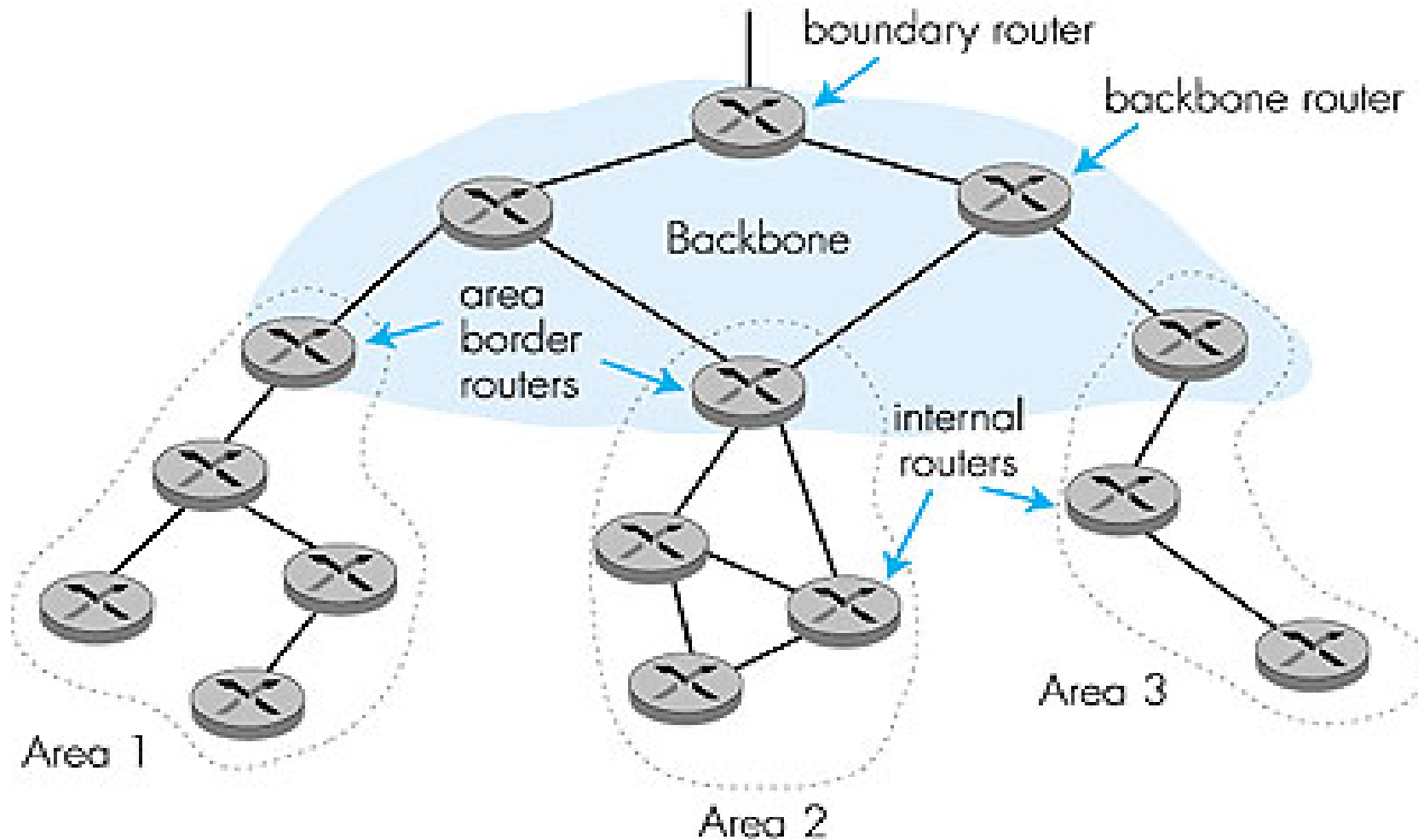# OSPF: Interface state machine
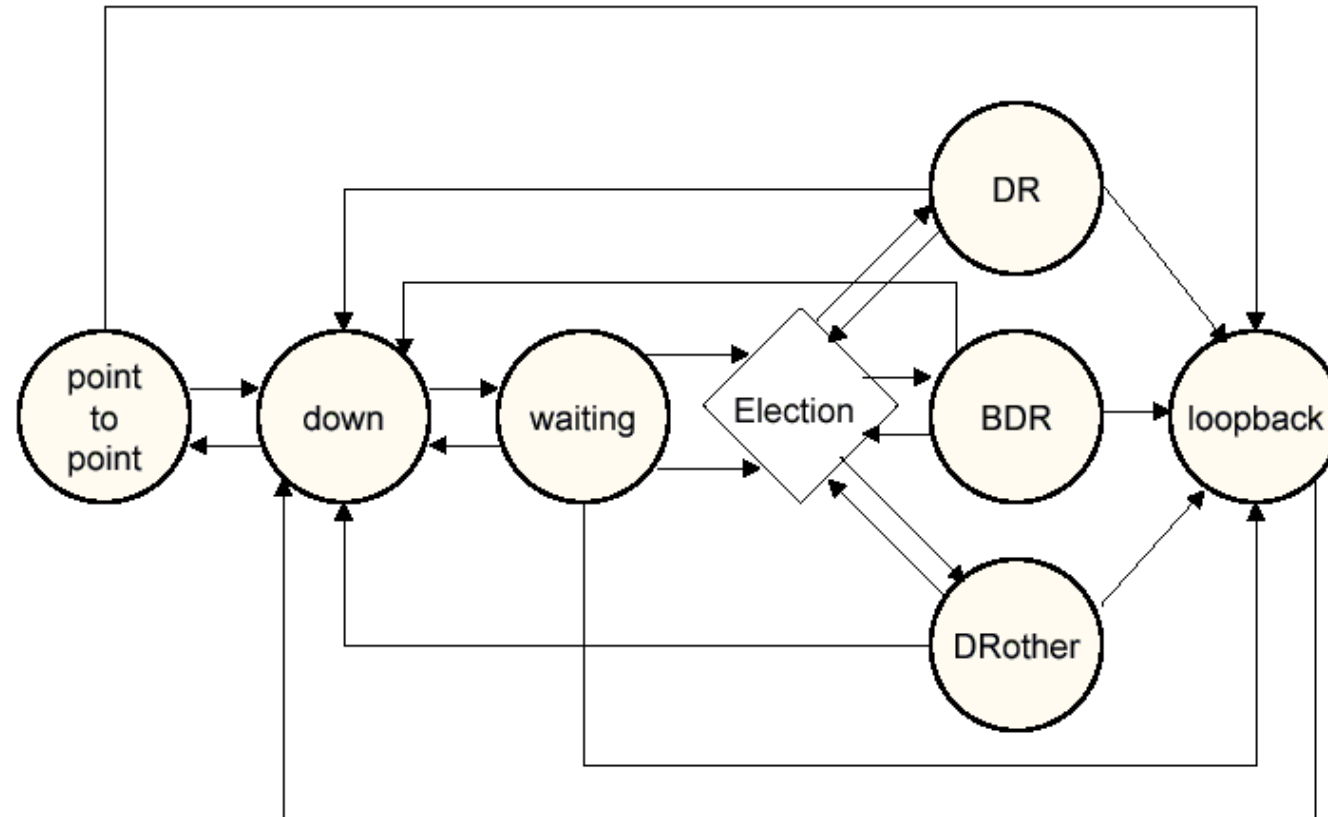
OSPF: Network LSAs

A network LSA represents a *broadcast subnet*

- Router LSAs have links to network LSA
  - Reduction of links

- DR responsible for network LSA
  - Link State ID = IP-address of DR Interface

There are *no Network LSAs* for *stub* networks

Hierarchical OSPF: Quick look

Hierarchical OSPF: Quick look

Two-level hierarchy: *Local* area and *backbone*

- Link-state advertisements only in respective areas.
- Nodes in each area ...
  - Have *detailed* area *topology*
  - *Only* know direction (*shortest path*) to networks in other areas

- **Area Border routers:** *"Summarize"* distances to networks in the area and advertise them to other area border routers.

- **Backbone routers:** Run an OSPF routing algorithm limited to the backbone.

- **Boundary routers:** Connect to other ASes
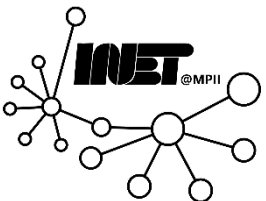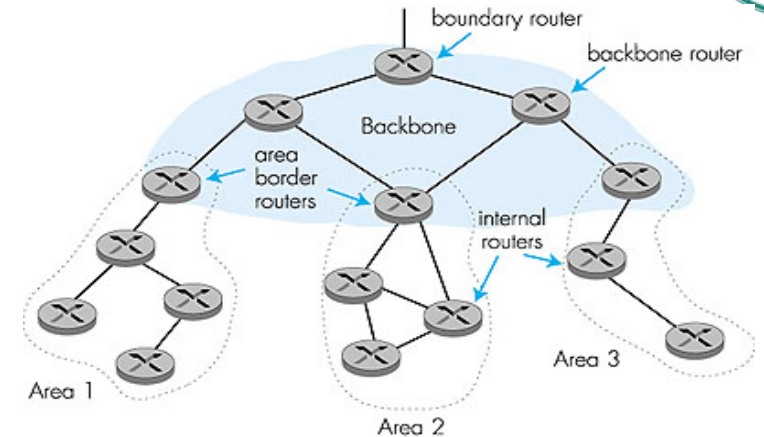
OSPF: Areas

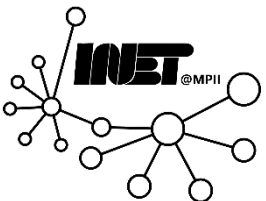An *AS* (or *routing domain*) is divided into *areas*
- Group of routers *"close"* to each other

- Reduce the extent of LSA flooding

- OSPF requires a *backbone area* (*Area 0*)
  - Routing between areas only via backbone area
  - *Strict* area hierarchy (no loops allowed)

- Different LSAs for
  - *Intra-area* traffic
  - *Inter-area* traffic
  - *External* traffic injected from a different AS

OSPF: Area partitions

- Link and router failures can cause areas to be partitioned

- Some partitions are healed automatically

- Some need manual intervention
  - Virtual Links

- Isolated area: Link failure results in no path to the rest of the network
  - Obviously, cannot be healed at all
  - Redundancy is important!

OSPF: LSA types

- *LSA Type 1*: Router LSA

- *LSA Type 2*: Network LSA

- *LSA Type 3*: Summary LSA

- *LSA Type 4*: Summary ASBR LSA

- *LSA Type 5*: Autonomous system external LSA

- *LSA Type 6*: Multicast OSPF LSA

- *LSA Type 7*: Not-so-stubby area LSA

- *LSA Type 8*: External attribute LSA for BGP

OSPF: Advanced features

Security
- All OSPF messages are authenticated (to prevent malicious intrusion)
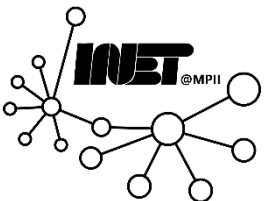
Multiple same-cost paths allowed
- For each link, multiple cost metrics for different *types of service (TOS)* *(e.g., satellite link cost set "low" for best effort; high for real time)*

Integrated *unicast* and *multicast* support
- *Multicast OSPF (MOSPF) uses same topology database as OSPF*

Hierarchical OSPF in large domains

OSPF: Summary

Open Shortest Path First (OSPF)

- *Link state* protocol (based on *Dijkstra*)
- Routers periodically flood immediate reachability info to all other routers
- Distance metric: *administrative weight*

- *Advantage*: fast convergence

- *Disadvantage*: complexity and communication overhead

Intra-AS routing protocols

- ***Intermediate-System-to-Intermediate-System (ISIS)***
  - *ISO 10589; link state*

- ***Interior Gateway Routing Protocol (IGRP)***
  - *Cisco proprietary; distance vector*

- ***Enhanced Interior Gateway Routing Protocol (EIGRP)***
  - *Cisco proprietary; enhanced distance vector*

That's it on RIP and OSPF