Internet Routing Overview

AS, IGP, EGP, BGP

Agenda

- **Routing at Large**
- **Types of Autonomous Systems**
- **EGP-2**
- **Introduction BGP**

Routing in Small Networks

- **in small networks**
  - distance vector or link state protocols like RIP or OSPF can be used for dynamic routing
  - it is possible that every router of the network knows about all destinations
    - all destination networks will appear in the routing tables
  - routing decisions are based on technical parameters
    - e.g. hop count, link bandwidth, link delay, interface costs
  - it is sufficient that routing relies only on technical parameters
    - small networks will be administered by a single authority
    - non-technical parameter like traffic contracts have no importance

Routing in Large Networks

- **with increasing network size limitations of these protocols can be recognized**
  - some limitations for example
    - maximum hop count (RIP)
    - time to transmit routing tables (RIP) on low speed links
    - CPU time for SPF calculation (OSPF)
    - memory used for storing routing table (RIP, OSPF)
    - memory used for storing topology database (OSPF)
    - two level hierarchy centered around a core network (OSPF)
    - route fluctuation caused by link instabilities (OSPF)
    - routing based on non-technical criteria like financial contracts or legal rules is not possible

Routing in the Internet

- **limitations prevent using routing protocols like RIP or OSPF for routing in the Internet**
  - note: routing tables of Internet-core routers have about 65.000 net-ID entries
- **routing in the Internet**
  - is based on non-technical criteria like financial contracts or legal rules
  - policy routing
    - e.g. Acceptable Use Policy (AUP) in parts of the Internet
    - e.g. contracts between Internet Service Providers (ISP)
  - we need means to support these issues

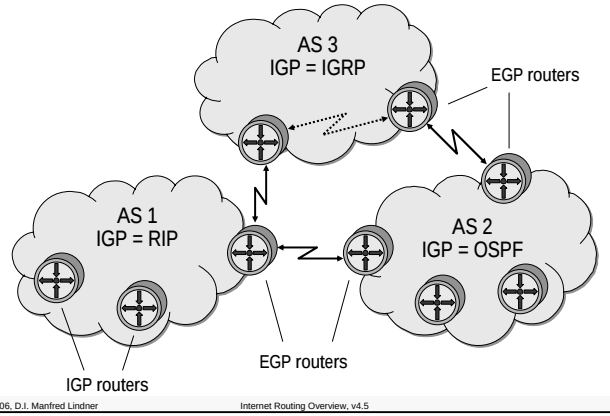
Routing Hierarchy, Autonomous Systems

- **routing hierarchy is necessary for large networks**
  - to control expansion of routing tables
  - to provide a more structured view of the Internet
- **routing hierarchy used in the Internet**
  - based on concept of autonomous system (AS)
- **AS concept allows**
  - segregation of routing domains into separate administration domains
  - note:
    - routing domain is a set of networks and routers having a single routing policy running under a single administration

IGP, EGP

- **within an AS one or more IGP protocols provide interior routing**
  - IGP - Interior Gateway Protocol
  - IGP examples
    - RIP, RIPv2, OSPF, IGRP, eIGRP, Integrated IS-IS
  - IGP router responsible for routing to internal destinations
- **routing information between ASs is exchanged via EGP protocols**
  - EGP - Exterior Gateway Protocols)
  - EGP examples
    - EGP-2, BGP-3, BGP-4
    - EGP router knows how to reach destination networks of other ASs

AS, IGP, EGP



AS Numbers

- **hierarchy based on ASs allows forming of a large internetwork**
  - by dividing it into smaller and more manageable units
  - every unit may have its own set of rules and policies
- **AS are identified by a unique number**
  - can be obtained like IP address from an Internet Registry
    - e.g. RIPE NCC (reséaux IP Européens Network Coordination Center)

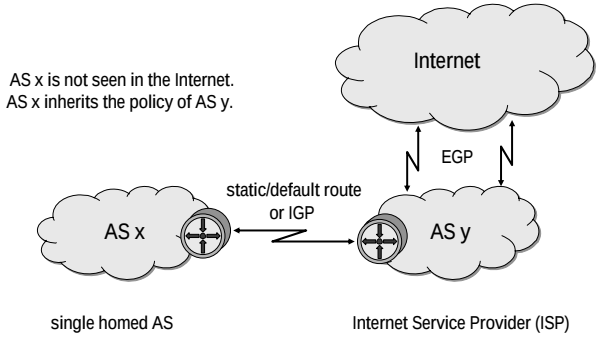
Agenda

- **Routing at Large**
- **Types of Autonomous Systems**
- **EGP-2**
- **Introduction BGP**

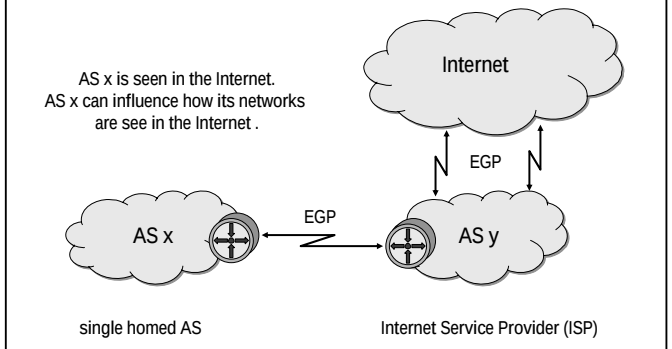
Types of AS

- **single homed (stub) AS**
  - networks outside its domain can be reached via single exit point
- **multi-homed non-transit AS**
  - has more than one exit point to the outside world but cannot be used for transit traffic by other ASs
    - multi-homed to one provider
    - multi-homed to different providers
- **multi-homed transit AS**
  - has more than one exit point to the outside world and can be used for transit traffic by other ASs

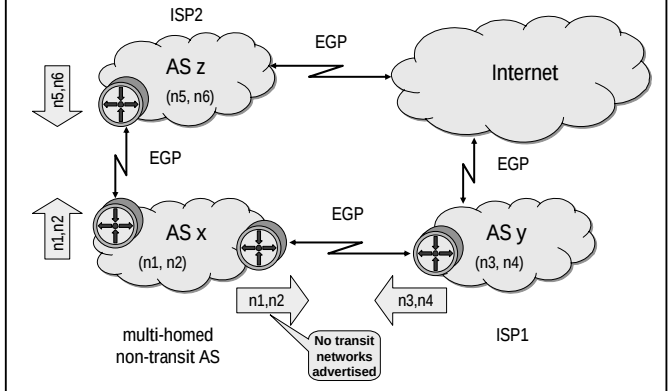
Single-homed AS



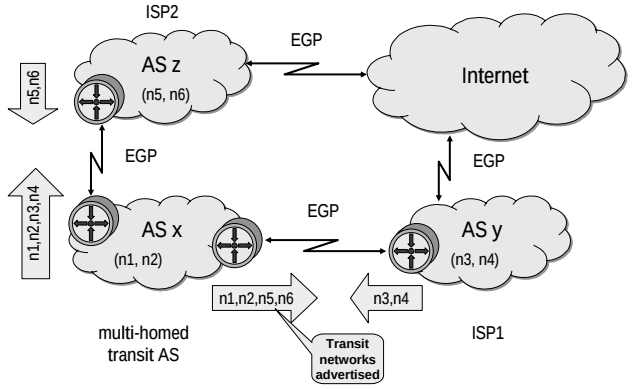
Single-homed AS



Multi-homed Non-transit AS



Multi-homed Transit AS



Agenda

- **Routing at Large**
- **Types of Autonomous Systems**
- **EGP-2**
- **Introduction BGP**

EGP-2 Basics

- **EGP defined in RFC 827 and 904**
  - Internet standard 18, now historic
- **be careful**
  - EGP … family of exterior gateway protocol
  - RFC 827/904 … one implementation of an EGP
  - now we talk about RFC 827 / 904 (EGP-2)
- **EGP-2 session**
  - relationship between two EGP routers connected to the same physical network exchanging network reachability information between two ASs
  - composed of three separate procedures

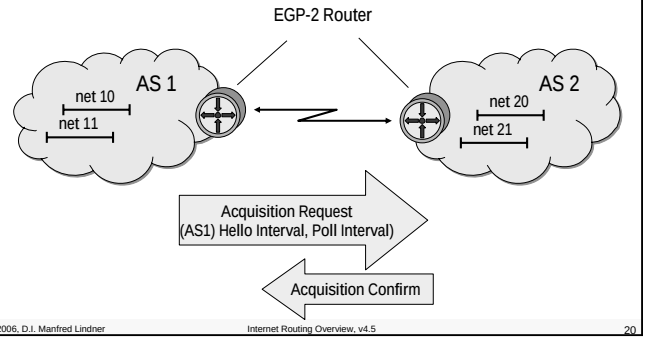
EGP-2 Procedures

- **neighbor acquisition procedure**
  - EGP messages: request, confirm, refusal (session setup)
  - EGP messages: cease, cease acknowledgement (session clear)
  - parameter exchange
    - AS number
    - hello interval (typical value 30 seconds)
    - poll interval (typical value 2 minutes)
- **neighbor reachability procedure**
  - EGP messages: hello, I-H-Y (I Hear You)
  - periodical keepalive

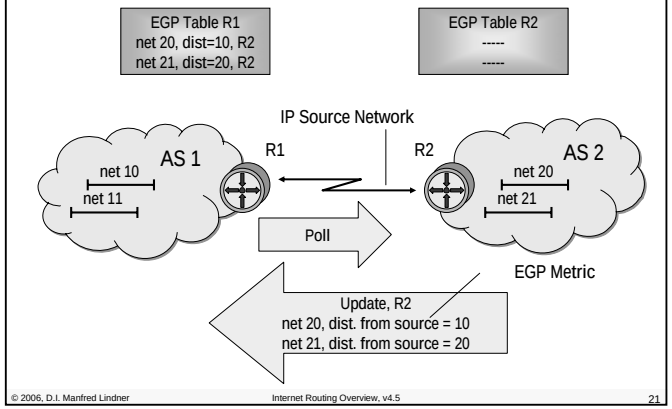
EGP-2 Procedures

- **network reachability procedure**
  - EGP messages: poll, update
  - periodical exchange of complete EGP routing information
  - concept of IP Source Network and redirection
    - AS interior routers can share the same physical network, which is used by EGP routers for their EGP session
  - EGP metric
    - distance from IP Source Network
    - used as indication of reachability
      - 255 means that network is not reachable
    - may be used for indication of preferred route in case of redundancy between two AS´s
      - primary link
      - backup link

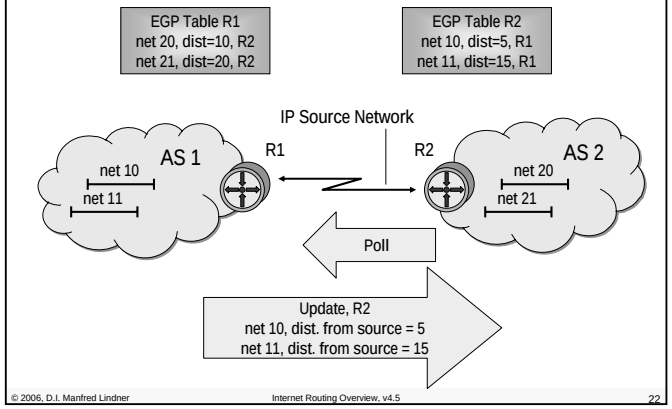
EGP-2 Neighbor Acquisition



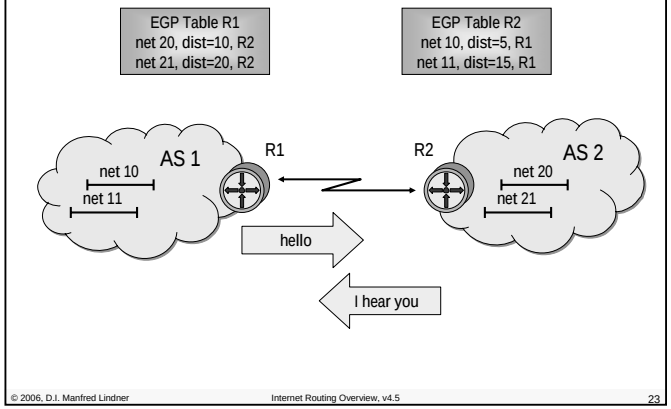
EGP-2 Exchange of Network Reachability



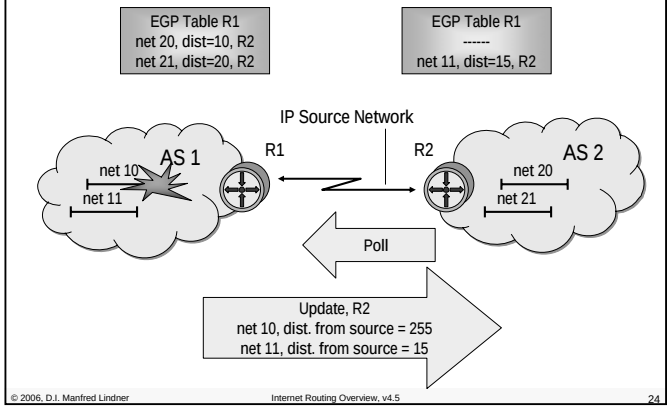
EGP-2 Exchange of Network Reachability



EGP-2 Keepalive



EGP-2 Exchange of Network Reachability



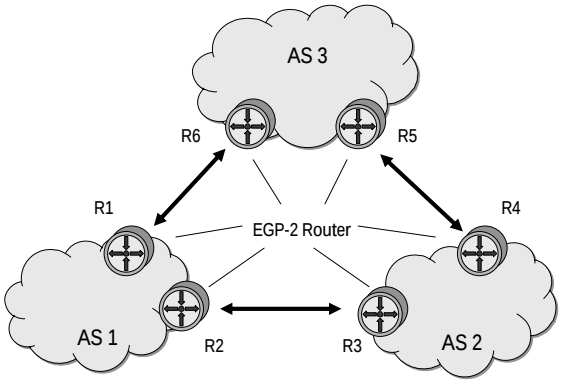
EGP-2 Limitations 1

- **EGP was designed for simple hierarchical topology**
  - stub AS connected to a backbone
    - note: early Internet was organized around a core
  - EGP does not specify how to map an EGP distance to the metric of an interior protocol
    - therefore third party rule
      - only internal networks of an AS should be announced by EGP
    - that is problem if a routing policy should be installed

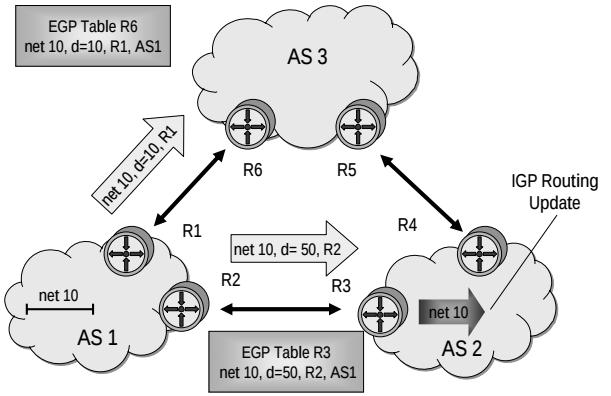
EGP-2 Limitations 2

- **(Cont.)**
  - EGP is more a reachability protocol than a general routing protocol
    - in principle EGP can be used in a more general tree-structured topology (loop-less graph) but routing policy based on distances must be carefully engineered
  - EGP definitely not designed for meshed topology

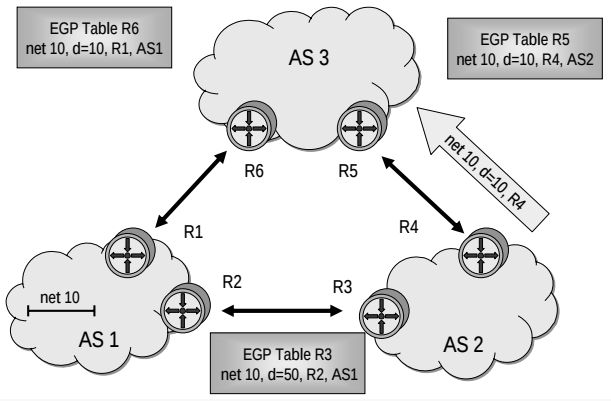
EGP-2 Limitations Example 1



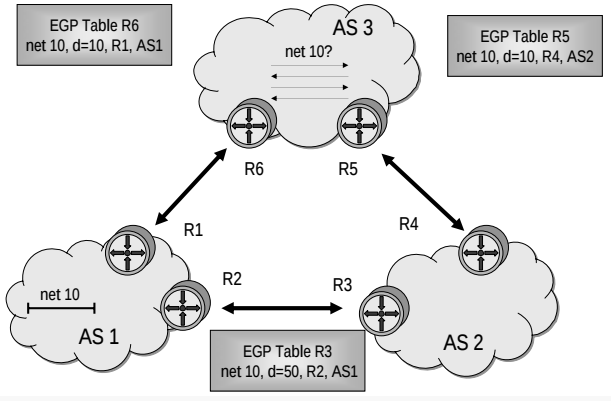
EGP-2 Limitation Example 2



EGP-2 Limitation Example 3



EGP-2 Limitation Example 4



EGP-2 Facts

- **EGP-2 is a historical protocol**
  - should be avoided
  - basis for understanding BGP features
- **Implemented by most vendors, even for NOS**
  - e.g. Novell MPR built-in into NetWare 4.x and 5.x
- **Not designed for meshed networks**
  - no built-in mechanism to avoid routing loops
    - might be handled by careful filtering, but this is clearly not scalable

Agenda

- **Routing at Large**
- **Types of Autonomous Systems**
- **EGP-2**
- **Introduction BGP**

BGP-4

- **Border Gateway Protocol (BGP)**
  - is the Exterior Gateway Protocol used in the Internet nowadays
  - was developed to overcome limitations of EGP-2
  - RFC 1267 (BGP-3) older version
    - classful routing only
  - RFC 1771 (BGP-4) current version, DS
    - classless routing
  - is based on relationship between neighboring BGP-routers
    - peer to peer
    - called BGP session or BGP connection

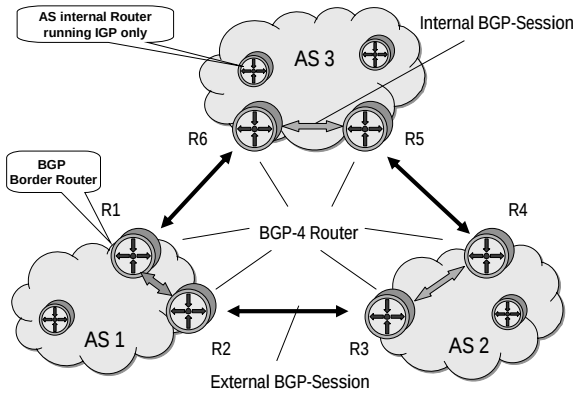
BGP-4 Concepts 1

- **Border Gateway Protocol (cont.)**
  - primary function
    - exchange of network reachability information with other autonomous systems via external BGP sessions
    - but also within an autonomous system between BGP border routers via internal BGP sessions
  - BGP session runs on top of TCP
    - reliable transport connection
    - well known port 179
    - TCP takes care of fragmentation, sequencing, acknowledgement and retransmission
    - hence these procedures need not be done by the BGP protocol itself

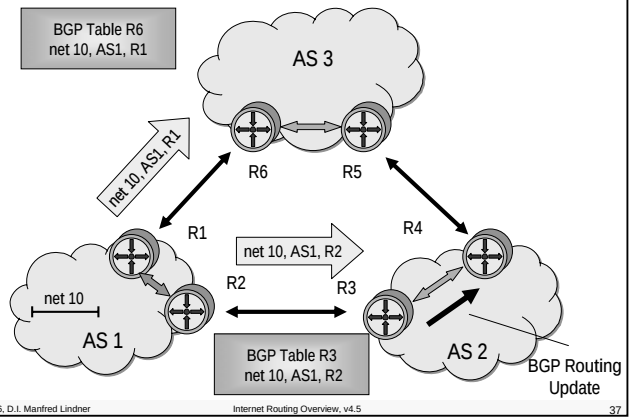
BGP-4 Concepts 2

- **basic ideas**
  - reachability information exchanged between BGP routers carries a sequence of AS numbers
    - indicates the path of ASs a route has traversed
  - path vector protocol
  - this allows BGP to construct a graph of autonomous systems
    - loop prevention
    - no restriction on the underlying topology
  - the best path
    - minimum number of AS hops
  - incremental update
    - after first full exchange of reachability information between BGP routers only changes are reported

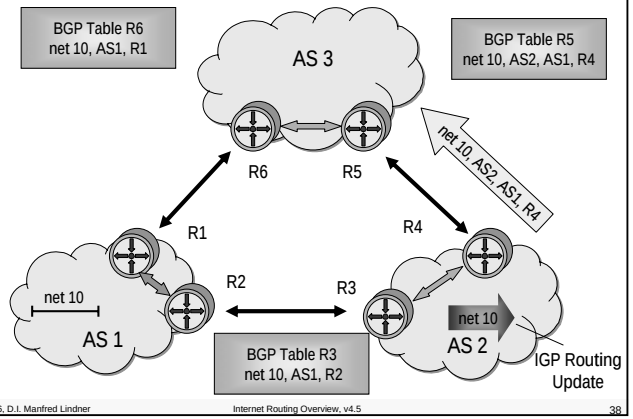
BGP-4 Basic Example (1)



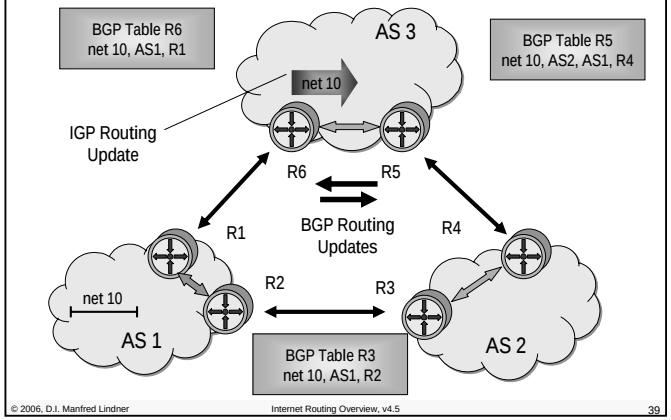
Basic Example (2)



Basic Example (3)



Basic Example (4)



BGP-4 Concepts 3

- **basic ideas (cont.)**
  - description of reachability information by attributes
    - for BGP routing
    - for establishing of routing policy between AS´s
  - BGP-4 advertises so called BGP routes
    - a BGP route is unit of information that pairs a destination with the path attributes to that destination
  - IP prefix and mask notation
    - supports VLSM
    - supports aggregation (CIDR) and supernetting
  - routes can be filtered using attributes, attributes can be manipulated

    --> routing policy can be established