Exterior Gateway Protocols: EGP, BGP-4, CIDR

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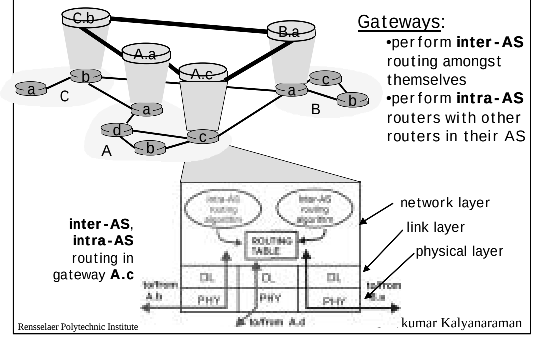
Overview

- ❑ Cores, Peers, and the limit of default routes
- ❑ Autonomous systems & EGP
- ❑ BGP
- ❑ CIDR: reducing router table sizes
- ❑ Refs: Chap 10. Books: “Routing in Internet” by Huitema, “Interconnections” by Perlman, “BGP4” by Stewart

Intra-AS and Inter-AS routing



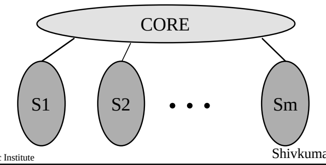
Gateways:
- •perform **inter-AS** routing amongst themselves
- •perform **intra-AS** routers with other routers in their AS

Default Routes: limits

- ❑ Default routes => *partial information*
- ❑ Routers/hosts w/ default routes rely on other routers to complete the picture.
- ❑ In general routing “signposts” should be:
  - ❑ Consistent, I.e., if packet is sent off in one direction then another direction should not be more optimal.
  - ❑ Complete, I.e., should be able to reach all destinations

Core

- ❑ A small set of routers that have consistent & complete information about all destinations.
- ❑ Outlying routers can have partial information provided they point default routes to the core
  - ❑ Partial info allows site administrators to make local routing changes independently.



Peer Backbones

- ❑ Initially NSFNET had only one connection to ARPANET (router in Pittsburg) => only one route between the two.
- ❑ Addition of multiple interconnections => multiple possible routes => need for dynamic routing
- ❑ Single *core* replaced by a network of *peer* backbones => more scalable
  - ❑ Today there are over 30 backbones!
- ❑ Routing protocol at cores/peers: GGP -> EGP-> BGP-4

Autonomous Systems (AS)

- AS = set of routers and networks under the same administration
  - No theoretical limit to the size of the AS
  - All *parts within an AS remain connected.*
    - If two networks rely on core-AS to connect, they don't belong to a single AS
  - AS is identified by a 16-bit AS number
  - At least one border router per AS.
    - This router also collects reachability information ("external routes") and diffuses it internally and vice versa

Autonomous Systems (Continued)

- AS types:
  - Stub AS => only single connection to one other AS => it carries only local traffic.
  - Multihomed AS: Connected to multiple AS, but does not allow transit traffic
  - Transit AS: carries transit traffic under policy restrictions
- Traffic types:
  - *Local* = traffic originating or terminating at AS.
  - *Transit* = non-local traffic

Exterior Gateway Protocol (EGP)

- A mechanism that allows non-core routers to learn routes from core routers so that they can choose optimal backbone routes
- A mechanism for non-core routers to inform core routers about hidden networks
- Autonomous System (AS) has the responsibility of advertising reachability info to other ASs.
  - One+ routers may be designated per AS.
  - Important that reachability info propagates to core routers

EGP weaknesses

- EGP does not interpret the distance metrics in routing update messages => cannot be compute shorter of two routes
- As a result it restricts the topology to a tree structure, with the core as the root
  - Rapid growth => many networks may be temporarily unreachable
  - Only one path to destination => no load sharing

Border Gateway Protocol (BGP)

- Allows multiple cores and arbitrary topologies of AS interconnection.
  - Uses a path-vector concept which enables loop prevention in complex topologies
- In AS-level, shortest path may not be preferred for policy, security, cost reasons.
  - Different routers have different preferences (policy) => as packet goes thru network it will encounter different policies
  - Bellman-Ford/Dijkstra don't work!
  - BGP allows attributes for AS and paths which could include policies (policy-based routing).

BGP (Cont'd)

- When a BGP Speaker A advertises a prefix to its B that it has a path to IP prefix C, B can be certain that A is actively using that AS-path to reach that destination
- BGP uses TCP between 2 peers (reliability)
  - Exchange entire BGP table first (50K+ routes!)
  - Later exchanges only incremental updates
  - Application (BGP)-level keepalive messages
  - Hold-down timer (at least 3 sec) locally config
- Interior and exterior peers: need to exchange reachability information among interior peers before updating intra-AS forwarding table.

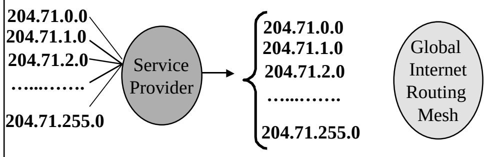
CIDR

- Shortage of class Bs => give out a set of class Cs instead of one class B address
  - Problem: every class C n/w needs a routing entry !
- Solution: *Classless* Inter-domain Routing (CIDR).
  - Also called “supernetting”
  - Key: allocate addresses such that they can be summarized, I.e., contiguously.
    - Share same higher order bits (I.e. prefix)
  - Routing tables and protocols must be capable of carrying a subnet mask. Notation: 128.13.0/23

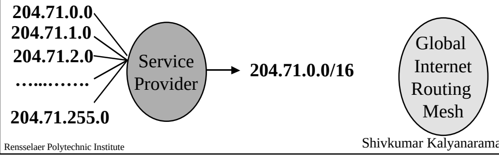
CIDR (Continued)

- Eg: allocate class Cs from 194.0.0.0 thru 195.255.255.255 for hosts in Europe (higher order 7 bits the same).
  - Allows one routing entry for Europe
- Allow other routing entries too. Eg: 194.0.160 + mask of 255.255.240.0
  - When an IP address matches multiple entries (eg 194.0.22.1), choose the one which had the longest mask (“longest-prefix match”)

Inter-domain Routing Without CIDR

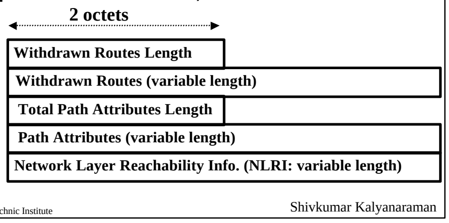


Inter-domain Routing With CIDR



UPDATE message in BGP

- **Primary message between two BGP speakers.**
- **Used to *advertise/withdraw* IP prefixes (NLRI)**
- ***Path attributes* field : unique to BGP**
  - **Apply to all prefixes specified in NLRI field**
  - **Optional vs Well-known; Transitive vs Non-transitive**



Withdrawn Routes Length

Withdrawn Routes (variable length)

Total Path Attributes Length

Path Attributes (variable length)

Network Layer Reachability Info. (NLRI: variable length)

Conceptual *Model of BGP Operation*

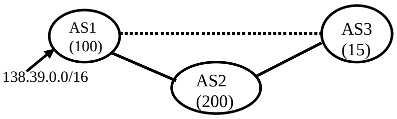
- RIB : Routing Information Base
- Adj-RIB-In: Prefixes learned from neighbors. As many Adj-RIB-In as there are peers
- Loc-RIB: Prefixes selected for local use after analyzing Adj-RIB-Ins. This RIB is advertised internally.
- Adj-RIB-Out : Stores prefixes advertised to a particular neighbor. As many Adj-RIB-Out as there are neighbors

Path Attributes: ORIGIN

- ORIGIN:
  - Describes how a prefix came to BGP at the origin AS
  - Prefixes are learned from a source and “*injected*” into BGP:
    - Directly connected interfaces, manually configured static routes, dynamic IGP or EGP
  - Values:
    - IGP (EGP): Prefix learnt from IGP (EGP)
    - INCOMPLETE: Static routes

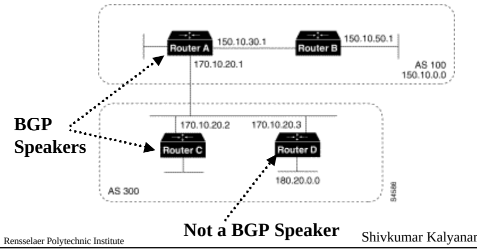
Path Attributes: AS-PATH

- List of **<u>ASs</u>** thru which the prefix announcement has passed. AS on path adds ASN to AS-PATH
- Eg: 138.39.0.0/16 originates at AS1 and is advertised to AS3 via AS2.
- Eg: AS-SEQUENCE: “100 200”
- Used for loop detection and path selection

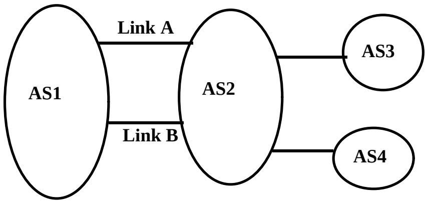


Path Attributes: NEXT-HOP

- Next-hop: node to which packets must be sent for the IP prefixes. May not be same as peer.
- **UPDATE for 180.20.0.0, NEXT-HOP= 170.10.20.3**



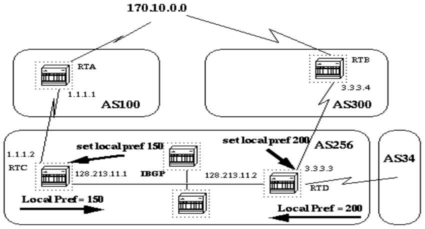
Attributes: MULTI-EXIT Discriminator



- **Also called METRIC or MED Attribute**
- **AS1:multihomed customer. AS2 includes MED to AS1**
- **AS1 chooses which link (NEXTHOP) to use**

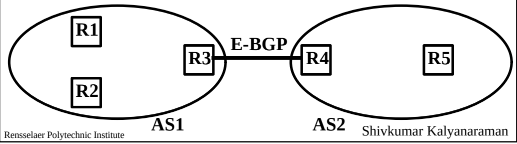
Path Attribute: LOCAL-PREF

- **Locally configured indication about which path is preferred to exit the AS in order to reach a certain network. Default value = 100.**



I-BGP

- So far we have talked about E-BGP. I.e. interaction between R3 and R4
- How do R1, R2, R5 (termination points of internal default routes) learn of external routes ?
  - Need a way to internally distribute routes

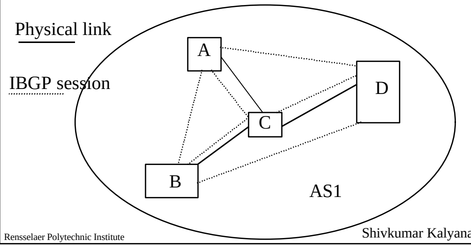


I-BGP

- Why is IGP (OSPF, ISIS) not used ?
  - In large ASs full route table is very large
  - Rate of change of routes is frequent
  - Tremendous amount of control traffic
- I-BGP :
  - Within an AS
  - Same protocol/state machines as EBGP
  - But different rules about advertising prefixes
  - Prefix learned from an I-BGP neighbor cannot be advertised to another I-BGP neighbor to avoid looping => need <u>full IBGP mesh !</u>
    - <u>*AS-PATH cannot be used internally. Why ?*</u>

IBGP vs EBGP

- I-BGP sessions between every pair of routers within an AS: full mesh.
- Independent of physical connectivity.



Other Attributes

- AGGREGATOR
  - If a BGP speaker aggregates on some of the prefixes heard from other neighbors, it may attach the AGGREGATOR attribute specifying the router which performed aggregation
- COMMUNITY STRING
  - The community attribute is a *transitive, optional attribute* in the range 0 to 4,294,967,200.
  - Way to group destinations(NLRIs) or ASs and apply policy routing decisions (accept, prefer, redistribute, etc.) on them.

BGP *Route Selection* Process

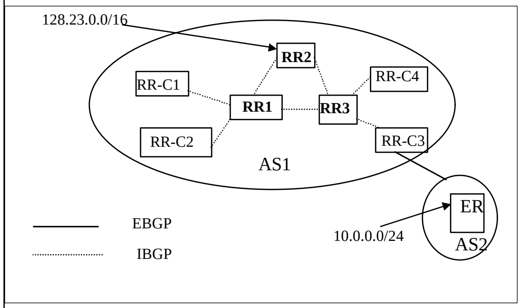
Series of tie-breaker decisions...

- **If NEXTHOP is inaccessible do not consider the route.**
- **Prefer largest LOCAL-PREF**
- **If same LOCAL-PREF prefer the shortest AS-PATH.**
- **If all paths are external prefer the lowest ORIGIN code (IGP<EGP<INCOMPLETE).**
- **If ORIGIN codes are the same prefer the lowest MED.**
- **If MED is same, prefer min-cost NEXT-HOP**
- **If routes learned from EBGP or IBGP, prefer paths learnt from EBGP**
- **Final tie-break: Prefer the route with I-BGP ID (IP address)**

IBGP Scaling: *Route Reflection*

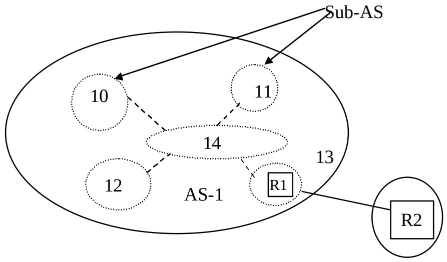
- Add hierarchy to I-BGP
- Route reflector: A router whose BGP implementation supports the re-advertisement of routes between I-BGP neighbors
- Route reflector client: A router which depends on route reflector to re-advertise its routes to entire AS and learn routes from the route reflector

Route Reflection

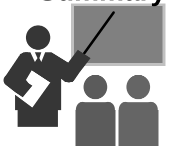


AS Confederations

- Divide and conquer: Divides a large AS into sub-ASs



Summary



- Cores, peers, autonomous systems, EGP
- BGP avoids EGP-induced tree structure and allows policy-based routing, and scaling.
- BGP details: CIDR, Path Attributes, IBGP, scaling, route selection.