S−38.180 Palvelunlaatu Internetissä

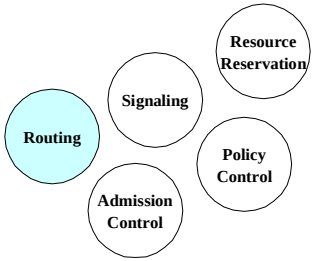
S−38.180 Quality of Service in Internet

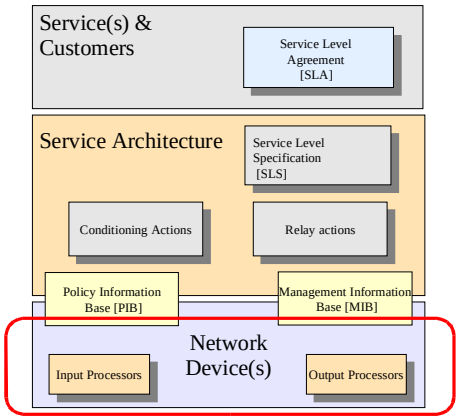
Luento 5: QoS reititys

Lecture 3: QoS routing

Today's Topic

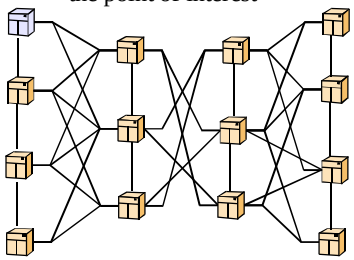
- This lecture is about control plane of Internet routers and especially routing in Control plane

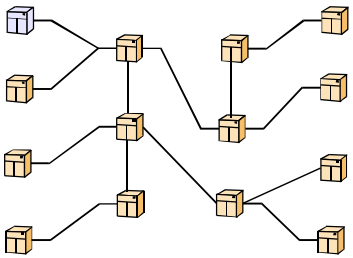




Conventional IP routing

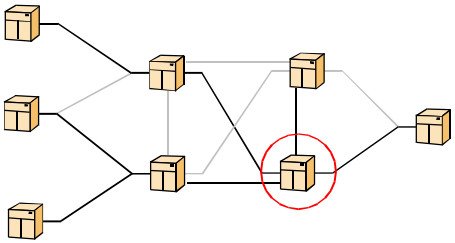
- **Routing** is a matter of finding a path (usually shortest possible) between any two networks in the whole Internet
  - Finding a path means that mess of networks is organised in to **tree** like structure representing neccesary links to reach all possible networks from the point of interest





Conventional IP routing

- Nature of conventional shortest path algorithms cause traffic to be aggregated to lowest cost links
  - Centralises traffic into hot spots in the network
  - Large amount of links are left to idle while few are overloaded



Conventional IP routing

- Construction of routing tables is responsibility of routing protocols
- Routing protocols can be divided based on their usage (scalability):
  - Interior Gateway Protocols: Running inside one autonomous system
    - OSPF, IS−IS, RIP, IGRP ...
  - Exterior Gateway Protocols: Running between autonomous systems
    - BGP, IDPR
- Routing protocols implement neccesary optimization algorithms to find shortest paths between end points:
  - Distance vector (RIP, IGRP, BGP)
  - Link−state (OSPF, IS−IS)

Interior Gateway Protocols

- Possibility to **full knowledge** of domain characterstics
  - Capacities
  - Delays
  - Offered traffic
  - Preferences
- Routing normally based on the shortest path
  - Least amount of hops between two end points

Exterior Gateway Protocol

- Domain characteristics relatively **unknown**
  - Knowledge is based on agreements and policies
  - Real−time data is rarely distributed
  - Reachability information (distance vector features)
  - Support for QoS ???

OSPF

- Operation goes through four phases:
  - **One:** Neighbours are aquired and maintained in adjacency by hello packets
    - Adress and cost information is gathered
    - Heartbeat of particular link (failure detection)
  - **Two:** Link−state advertisement (LSA) packets are formed based on information gathered by hello packets
  - **Three:** LSA packets are flooded into the network and received from the network to construct topology database
  - **Four:** Least cost routes are calculated to every other router in the network

OSPF

- Link−state advertisement packet contains:
  - Header part identifying
    - Advertising router
    - LSA type
      - Certain LSA types may have additional header information
  - LSA information part (depending on LSA type)
    - Link information and metrics
    - Network information and attached routers

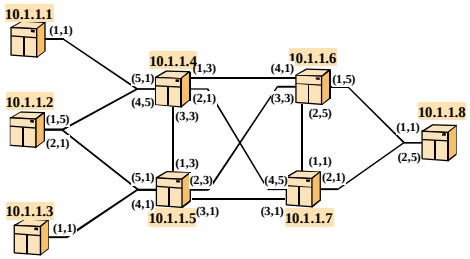
LS Age		Options	LS Type
Link State ID			
Advertising Router			
LS Sequence Number			
LS Checksum		Length	
Router Type	0	# Links	
Link ID			
Link Data			
Link Type	# ToS	Metric	
Link ID			
Link Data			
Link Type	# ToS	Metric	
...			
Link ID			
Link Data			
Link Type	# ToS	Metric	

OSPF

- **Topology database** is initially copied from one of the adjacent neighbours
- Updates to initial database are received and sent by flooding
  - Every adjacent neighbour receives flooded LSAs and process them to topology database.
  - After processing LSAs are repacked and flooded ahead
  - Every router in the net receives a copy of original LSA
- 'Full' knowledge of network devices and links
- Calculation of **routes** is based on Dijkstra algorithm and information in topology database

OSPF

- Metric used in route computation is based on information received in LSAs
  - It set by
    - Network administrator to indicate preference of particular link
    - Automatically as a form of computational intelligence in a router



Routing in general

- **Optimize**
  - Find best possible solution to the problem in hand
    - Minimum cost
    - Shortest path
    - Maximum bandwidth
  - Optimal
  - One solution
  - Full depth search
- **Constrain**
  - Find possible solution to the problem in hand
    - Delay less than X
    - Free capacity larger than Y
  - Usually suboptimal
  - Many possible options
  - Limited search

Routing

- Conventional IP routing is based on connectionless network philosophy
  - Each packet is independent and complete unit
  - Routing is decoupled from the packet streams
  - Pure optimization problem
- Differentiated Services is based on connectionless network philosophy
  - Routing is decoupled from the packet streams
  - Multi variable constraint and optimization problem
- Integrated Services is based on connection oriented network philosophy
  - Path is coupled into the packet streams through state information in the routers
  - Multivariable constraint problem
- Multiprotocol label switching is based on connection oriented philosophy
  - Path is coupled into packet streams through state
  - Multivariable constraint problem

QoS Routing problems

Link constrains:
- Capacity
- Buffer space

Path constrains:
- Delay
- Cost

Unicast QoS routing	
Basic routing problems	**Composite routing problems**
Link optimization routing (bandwidth optimization)	**Link constrained link optimization routing (bandwidth constrained – buffer optimization)**
Link constrained routing (bandwidth constrained)	**Link constrained path optimization routing (bandwidth constrained – least delay)**
	Multilink constrained routing (bandwidth and buffer constrained)
	Link constrained path constrained routing (bandwidth and delay constrained)
Path optimization routing (least cost)	**Path constrained link optimization routing (delay constrained bandwidth optimization)**
Path constrained routing (delay constrained)	**Path constrained path optimization routing (delay constrained least cost)**
	Multipath constrained routing (delay and delay jitter constrained) NP

Routing Strategies

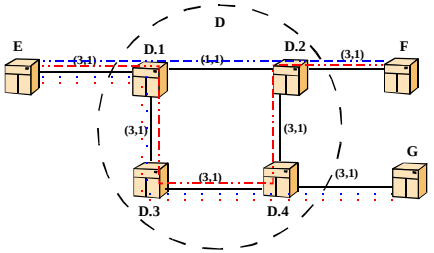
- **Source routing:**
  - Centralized routing decission
    - Source computes route through the network
  - Biggest problems:
    - Knowledge of the global state is only approximate (communication delay)
    - Size of the state base is huge (all links and nodes and their attributes)
- **Distributed routing:**
  - Path computation is distributed to all routers between source and destination (distance vectors)
  - Biggest problems:
    - State change in the network may cause loops which can not be easily solved
    - Construction of distributed heuristics for multiple attributes is not straight forward

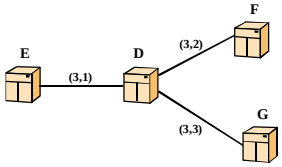
Routing Strategies

- **Hierachical routing:**
  - State base is shrinked with clustering and aggregation
    - Network is partitioned to clusters reflecting areas of common policy
    - State of the clusters is aggregated at the boundaries
  - Approximates distributed source routing
    - Each cluster is individually source routed
- Biggest problems:
  - Aggregation causes imprecision which causes paths to be only semi-optimal
  - Formation of aggregate metrics is not straight forward

Problems with multiple metrics

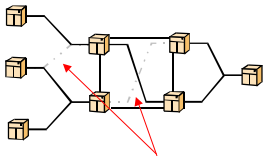
- Metric aggregation:
  - E->G is correct as largest bandwidth path is equal to lowest delay path
  - E->F is incorrect as bandwidth and delay paths are not same
- Path selection:
  - Link which do not qualify by link constraint should be pruned before optimization with path constraint

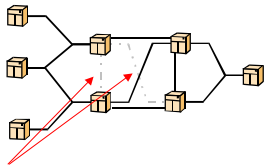




Pruning

- Metric 1: Free capacity greater than X bps
- Metric 2: Delay less than Y ms

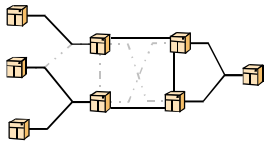


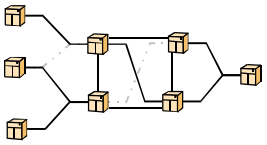


Links which do not have resources to fulfill constraints of the metric are removed (pruned) from the graph

Constraint based routing

- Optimization is used to find path from the reduced topology
  - Cost
  - Delay
- Optimization can be done straight after pruning of first metric
- Lowest delay path is searched
- Requires check whether delay constraint is held





What is the difference

- Pruning constraint 1: Capacity
- Pruning constraint 2: Delay
- Optimization with <delay>

Delay is path constraint which has very little meaning on link by link basis. Therefore it has to be broken down to link constraints.

Easily NP complete problem...

- Pruning constraint 1: Capacity
- Optimization with delay
- Sanity check
  - Delay less than constraint 2

QoS support in OSPF

- Traditional QoS support for OSPF is based on Type of Service paradigm
  - IPv4 TOS makes possible to indicate routing preference
    - Normal service (0000)
    - Minimize monetary cost (0001)
    - Maximize reliability (0010)
    - Maximize throughput (0100)
    - Minimize delay (1000)
  - OSPF TOS has 8 bit numerically encoded QoS support
- IPv4 TOS offers selection of one routing attribute
- OSPF uses separate routing table for every TOS value
- Routing table is calculated from the subset of topology database indicating only links capable of offering service defined by TOS

But nobody uses TOS so there is no actual support for it in the network !!!

Extended QoS Support for OSPF

- Generalisation of QoS concept
  - QoS routing is decoupled from the TOS values of the IP packet
    - Routing decission is done in a **connection oriented way** −> signaling
  - Metrics are selected to reflect dynamic nature of network
    - Link available bandwidth: Current available bandwidth meaning unallocated bandwidth
    - Link propagation delay: Makes possible to differentiate between satellite and terrestial links

This is matters of Integrated Services !!!

Extended QoS Support for OSPF

- Middle way:
  - QoS routing is coupled to the DSCP values of the IP packet
  - Metrics are selected to reflect dynamic nature of network
    - Link available bandwidth: Current available bandwidth meaning subtraction of measured average link utilisation from the link capacity
    - Link propagation delay: Makes possible to differentiate between satellite and terrestial links

This is just a thought how to apply previous to the Differentiated Services !!!