Helsinki University of Technology, Networking Laboratory, N. Beijar
S-38.2121 Routing in Communication Networks

Model solutions for the exam 14.5.2007

Question 1

1. Selitä DAR -reitityksen periaate. Selitä myös yhdysjohtovarausparametrien käyttö DAR:ssa.
   Explain the principle of DAR routing. Explain also the use of trunk-line reservation parameters in DAR.

Model solution and grading

DAR works in a full mesh network. Paths directly from node i to node j and alternate paths of max two hops are allowed. (1p for description of the network)

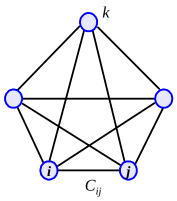
A call from node i to node j is always offered first to the direct link and is carried on it if a circuit is available. Otherwise, the call is offered to the two hop alternate path through node k. (2p for choise of route)

The call succeeds, if r_{ik} and r_{kj} circuits are free. r_{ik} and r_{kj} are the trunk-line reservation parameters. (2p for trunk-line reservation parameters)

If not, the call is blocked and a new k is selected. (1p for choosing k)

Related slides

DAR – Dynamic Alternative Routing (1)



DAR works in a full mesh network

Paths directly from node *i* to node *j* and alternate paths of max two hops are allowed.

r_{ij} - ***link reservation parameter*** of link *i*,*j*.

k(*i*,*j*) - ***current alternate tandem node*** for traffic from node *i* to node *j* on the alternate path

A call from node *i* to node *j* is always offered first to the direct link and is carried on it if a circuit is available. Otherwise, the call is offered to the two hop alternate path through node *k*. The call succeeds, if r_{ik} and r_{kj} circuits are free. If not, the call is blocked and a new *k* is selected,

DAR – Dynamic Alternative Routing (2)

- A call using a two hop alternative path can cause blocking of many subsequent calls if it is allowed to reserve the last circuit.
- Without the link reservation parameter, r_{ij}, the state of the network is unstable (or bistable) – the amount of max through-connected traffic alternates between two levels – the network oscillates.
- E.g. *N* nodes, *N*(*N-1*) links, each have *M* circuits. Each node originates *p* calls.

  If calls use only direct links $\Rightarrow p\,N \leq N\,(N\text{-}1)\,M$
  $\Rightarrow p \leq (N\text{-}1)\,M$

  If all calls use 2 circuits $\Rightarrow$
  Total is $2pN$ circuits $\leq N(N\text{-}1)\,M \Rightarrow p \leq (N\text{-}1)\,M/2$

DAR – Dynamic Alternative Routing (3)

- Even on high capacity links *r* is a small value.
- It is even sufficient that $r \neq 0$ is defined only for the first link on the alternative paths.
- If one call is allowed to try more than one alternative two hop path, the value of *r* must be increased.

Question 2

2. Vertaile IPv4- ja IPv6-pakettien otsikoita. Mitkä ovat tärkeimmät erot? Miten laajennukset on toteutettu IPv6:ssa?
   Compare the headers of IPv4 and IPv6. Which are the main differences? How are extensions implemented in IPv6?

Model solution and grading

The main improvement is the longer 128-bit address, which should solve the shortage of addresses in IPv4. (1p)

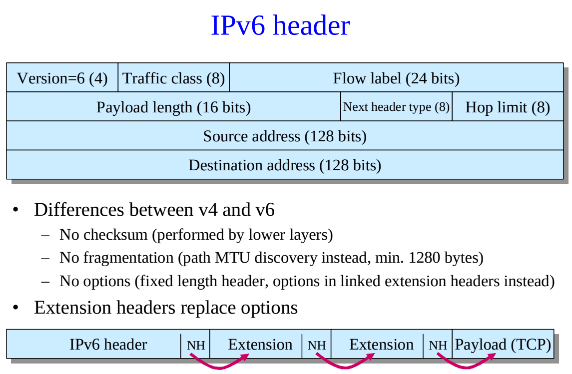
The header has been simplified:
- The checksum (which needed recalculation on each hop) is removed (implemented at lower or higher layers) (1p)
- The fields used for fragmentation have been removed (implemented with extension header) (1p)

Other differences (1p for one of these)
- “Hop limit” replaces “time to live”
- “Traffic class” replaces “type of service”

- Flowlabel used to distinguish packets which are forwarded in the same way

The options of IPv4 has in IPv6 been replaced by a chain of extension headers. This simplifies processing of the packet. Each extension header has a field specifying the type of the next extension header. (2p)

Related slides



Question 3

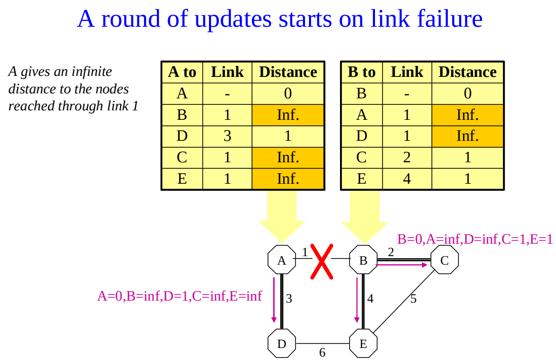
3. Tarkastele esimerkin avulla etäisyysvektoriprotokolla käyttävän verkon toipumista linkin menetyksestä (kaikkien linkkien painot ovat 1).
   Using an example, describe how a network with a distance vector routing protocol recovers from loosing a link. (The link weights are all equal to 1).

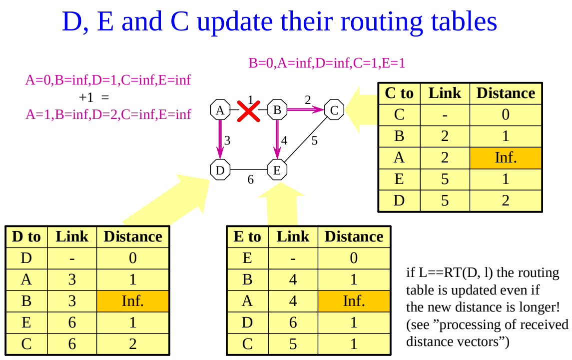
Model solution and grading

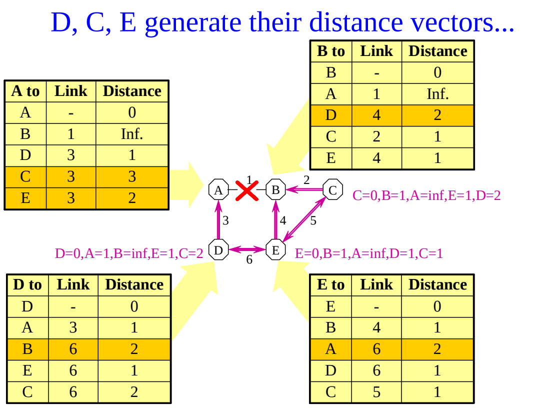
The answer requires an example showing what happens when a link breaks.

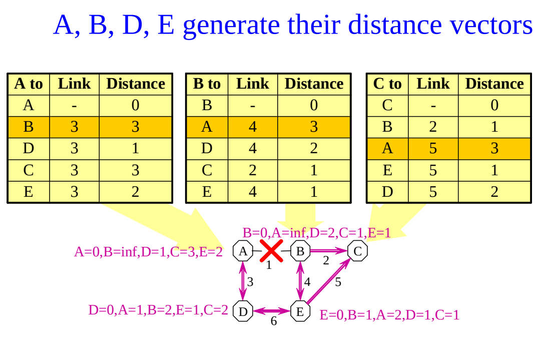
- The neighbors of the link detect the broken link (from lower layer or from timeout of received updates) and set the distance of all destination reached through this link to infinite. On the following update, they send distance vectors with infinite distance. (1p for example, 1p for description)
- According to the reception algorithm, the receiving nodes must update the corresponding entries in their routing table to the received distance (infinite), even though the received distance is higher than the previous one because the update is received over the same link that is used in the routing table. (1p for example, 1p for description)
- After a few rounds of updates the network reaches a stable state again. (1p for example, 1p for description)

Related slides

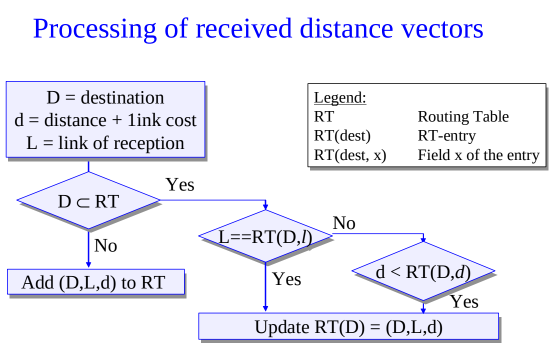








The result is that all nodes are able to communicate with all other nodes again.



Note: this is simplified, shows only the principle!

Common problems

- The question did not require any loops or other problems in the network. However, those answers were accepted if the anwer otherwise fulfilled the requirements.

Question 4

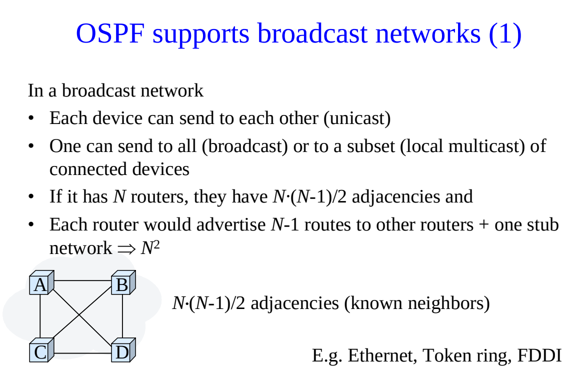
4. Esitä OSPF:n verkko-LSA:n käyttö linkin tilatietokannan koon supistamiskeinona.
   Illustrate the use of OSPF's network-LSA in reducing the size of the link-state database.

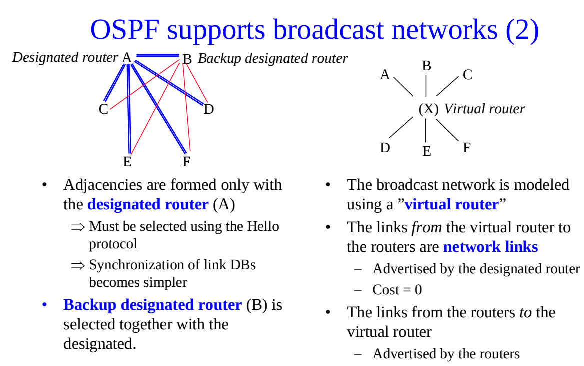
Model solution and grading

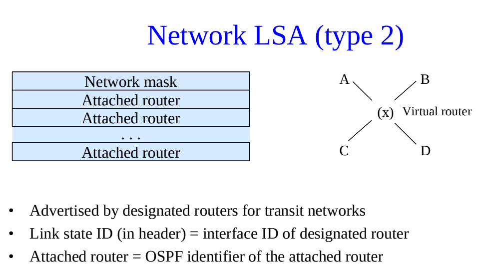
Up to 6p of the following:

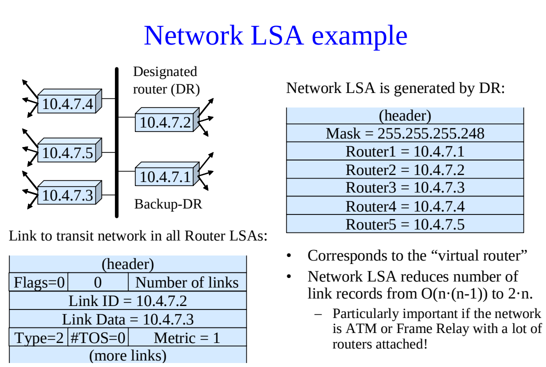
- The network-LSA is used to representation of a broadcast/non-broadcast multiple access network (transit network), such as an Ethernet. (2p)
- The network is abstracted using a virtual router placed in the middle of the network. (1p)
- The network-LSA defines the links from the virtual router to the real routers. (1p)
- This abstraction reduces the number of links from N(N-1) to 2N, i.e. from $O(N^2)$ to O(N). (1p)
- In practice, the network-LSA is advertised by the designated router. (1p)
- The contents of the LSA is a list of the (actual) routers of the network (to which the virtual router is connected). (1p)

Related slides









Common problems

- Some confuse the network-LSA with the area concept

Question 5

5. Selitä esimerkkien avulla Prune, Join ja Assert sanomien tehtävät PIM-DM:ssä.
   Explain with examples the purposes of the Prune, Join and Assert messages of PIM-DM.

Model solution and grading

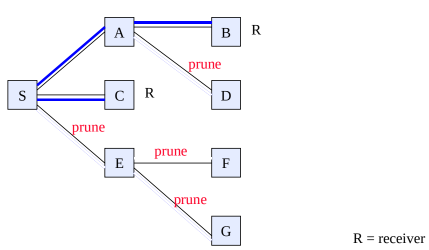
Prune: PIM-DM is based on the flood-and-prune algorithm. The branches of the multicast tree without downstream receivers are pruned. The downstream router then sends a Prune message and the upstream receiver stops sending multicast traffic on the corresponding interface. If all interfaces are pruned, the router sends a Prune message to its upstream router. (2p)

Join: In a broadcast network, several downstream routers may be behind the same interface. If one of them sends a Prune to the upstream router, there may still be other routers that which to receive the multicast traffic. Therefore the upstream router does not prune the interface immediately. Other routers wishing to continue receiving multicast traffic send a Join message to the upstream router, when they have seen a Prune message. Thus, the Join message is used to cancel a prune. (2p)

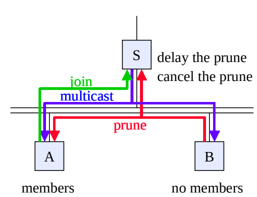
Assert: On a broadcast network, there may be several upstream routers, each forwarding multicast traffic on the network. Thus every multicast packet is duplicated. The upstream routers detect that there is other active upstream routers. They send an Assert message containing their distance to the sender. When the Assert message is received the distances are compared and the router with longer distance to the network stops forwarding multicast traffic to the network. Thus, the Assert messgae is used to select the router with the shortest distance to the sender to be active on the network. (2p)

Related slides

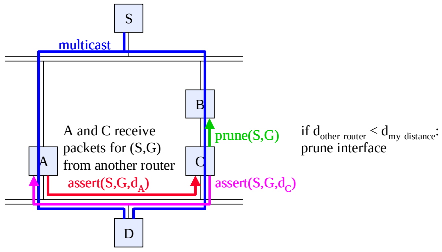
PIM-DM – Pruning



PIM-DM – Pruning on broadcast networks



PIM-DM – Resolving multicasts received on multiple path



Common problems

- In PIM-DM, the Join message is NOT sent by a receiver to join the multicast group. It is used to cancel a prune. (However, in PIM-SM it is used to join the multicast group)

Question 6

6. Selitä topologian aggregoinnin periaate PNNI:n loogisen solmun avulla.
   Explain how topology can be aggregated in PNNI using the concept of a logical node.

Model solution and grading

Using aggregation, the topological information can be reduced, so that the protocol scales to large networks (even including all ATM nodes in the world). The topology is accurately described for the surrounding nodes, and the accuracy decreases for nodes farther away. (1p for understanding the purpose of aggregation)

PNNI builds up the topology of the network recursively from the bottom to the top. The nodes with a common address prefix form a peer group. The peer group is seen as a logical node at the higher hierarchical level. At the lowest level, the nodes are physical nodes (switches). (2 p) (This may be described using a drawing)

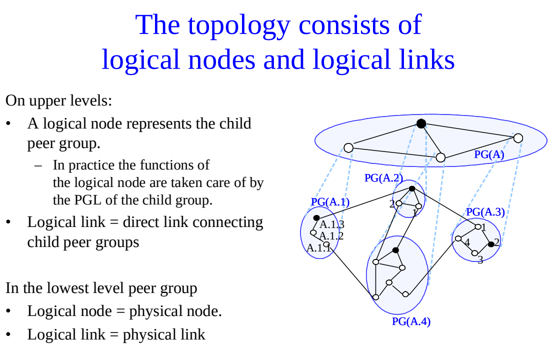
In each peer group (except at the top level), a node is selected as the peer group leader (PGL), which represents the group at the following level. The PGL collects the topology of its peer group, aggregates it and distributes it in the upper-level peer group. Is also distributes topology information from higher levels within its peer group. (1 p)

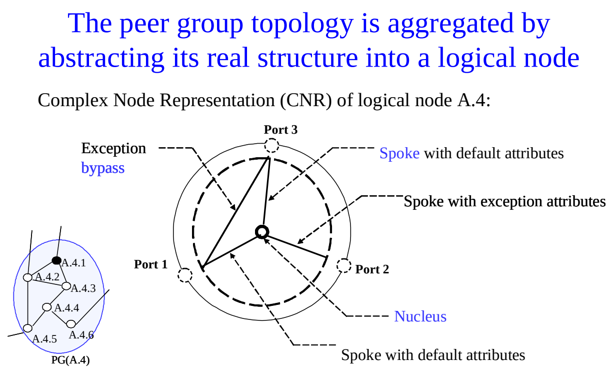
The peer group is described as a logical node using the complex node representation. The inside of the peer group is modeled as a nucleus. Spokes represent link connections from the nucleus to other logical nodes. An exceptional connection between two neighboring logical nodes can be modeled as a bypass. (2 p) (This may be described using a drawing)

Common problems

- The complex node representation was forgotten in most answers. It is however important in the aggregation, since it describes the internal structure of the logical node in a very compact form.

Related slides





General grading principles

Note that this document only describes the grading principles. The model solutions describe the main points that were expected to be included in the answer. It is not a strict requirement list. A good answer must clearly show that the subject is understood.

Generally, small errors in details do not decrease the points. Serious errors showing misunderstanding decrease the points. Some extra information **related to the question** may give small extra points.