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Algorithms for Radio Networks

Routing in MANET: Link Reversal, OLSR, ZRP

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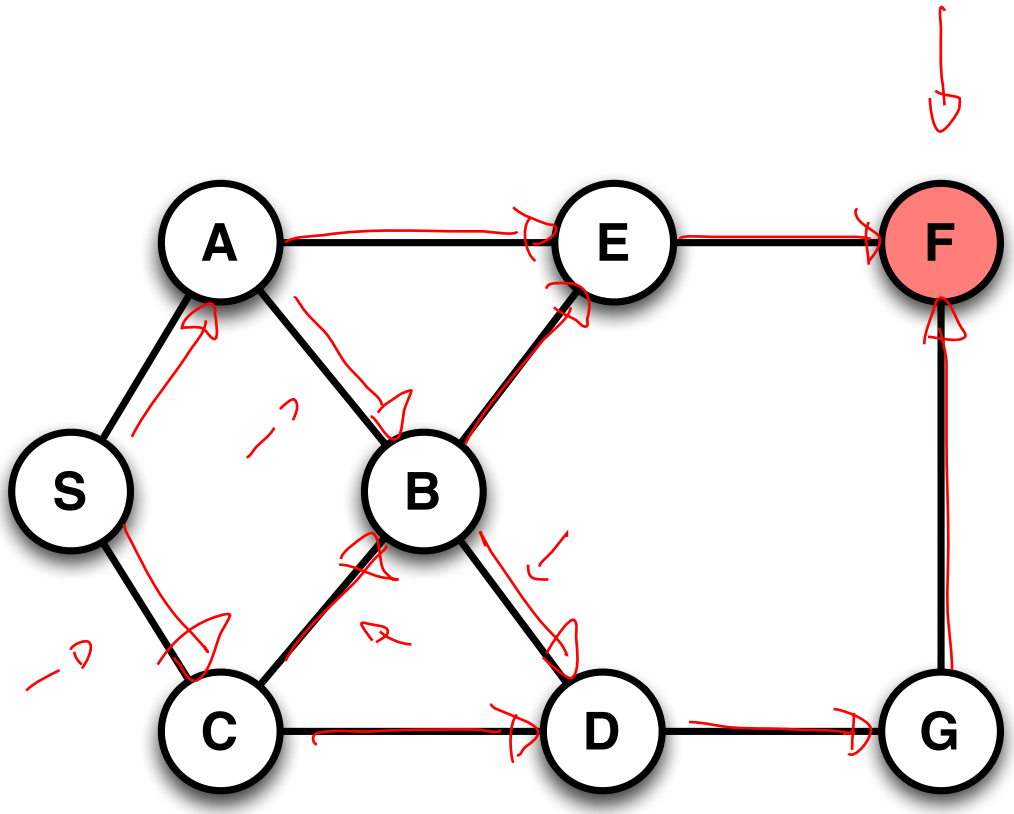
Link Reversal

- **Gafni, Bertsekas,**
  - *Distributed Algorithms for Generating Loop-Free Routes in Networks with Frequently Changing Topology*, IEEE Transactions on Communications, Vol. 29, No. 1 pp. 11-18, IEEE, January 1981
- **Routing protocol**
  - with special repair mechanism

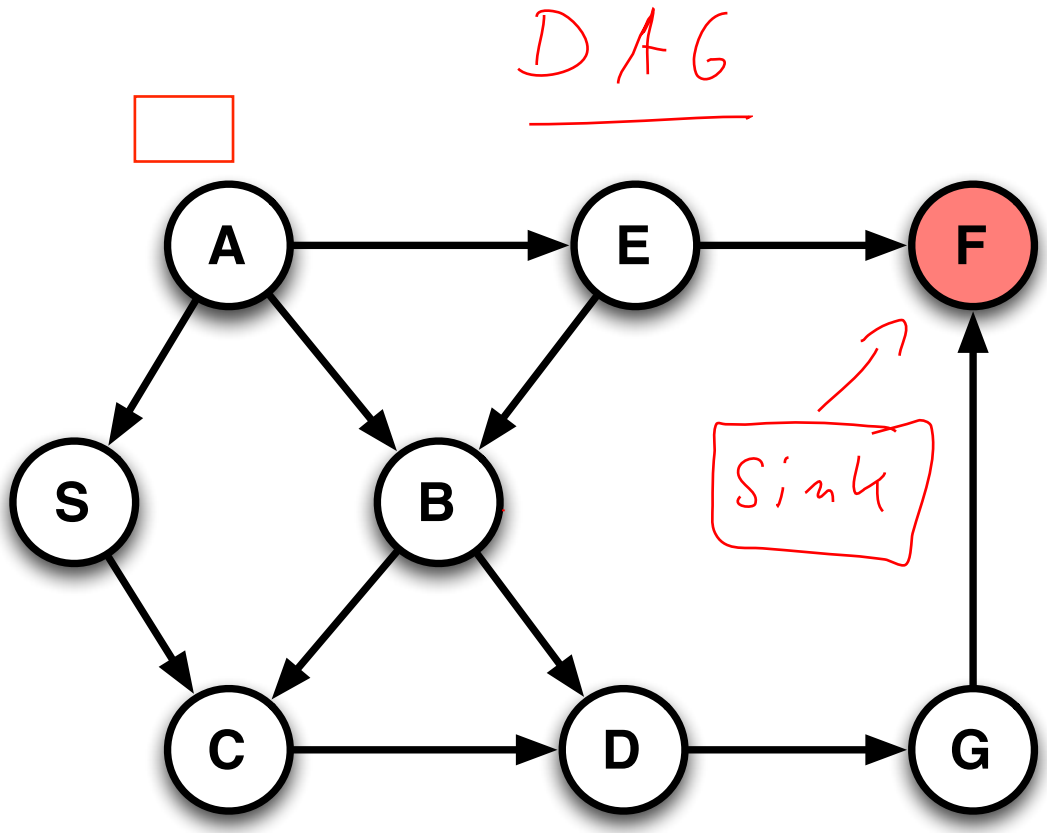
Link Reversal

- **For each target node a direction for each edge is defined**
  - all edges point towards the target
  - e.g. by flooding and topological sorting
- **Routing**
  - Pick any outgoing edge and send packet



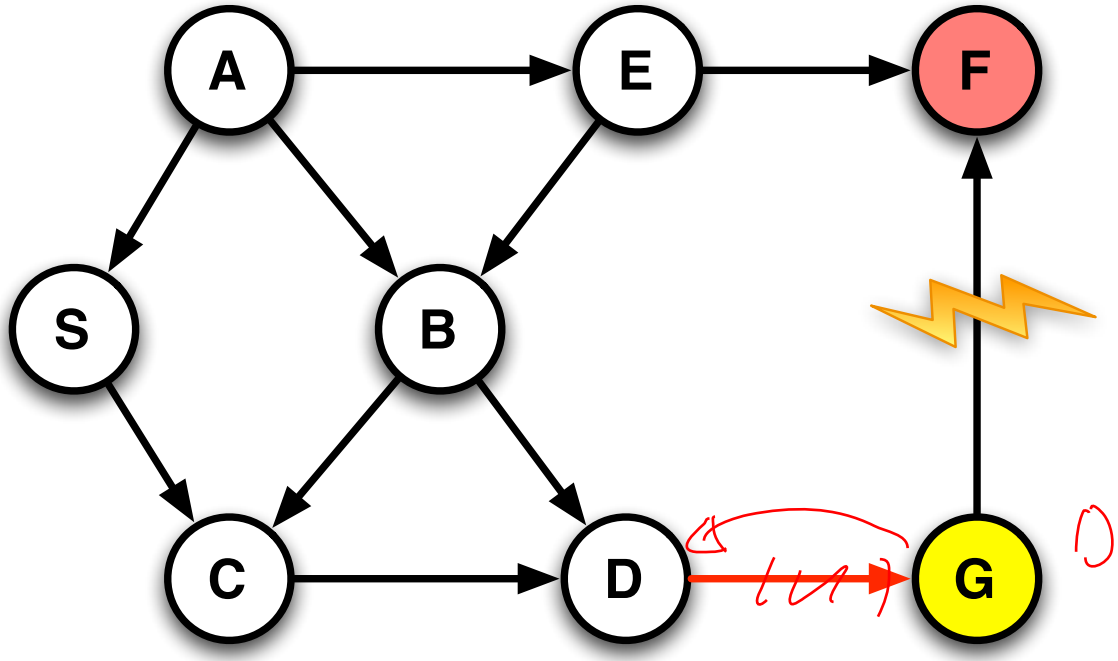
Link Reversal

- **Directed acyclic graph (DAG) for each target**
  - is preserved also in the case of failing edges
- **Connections are symmetrical**
  - direction are only virtual

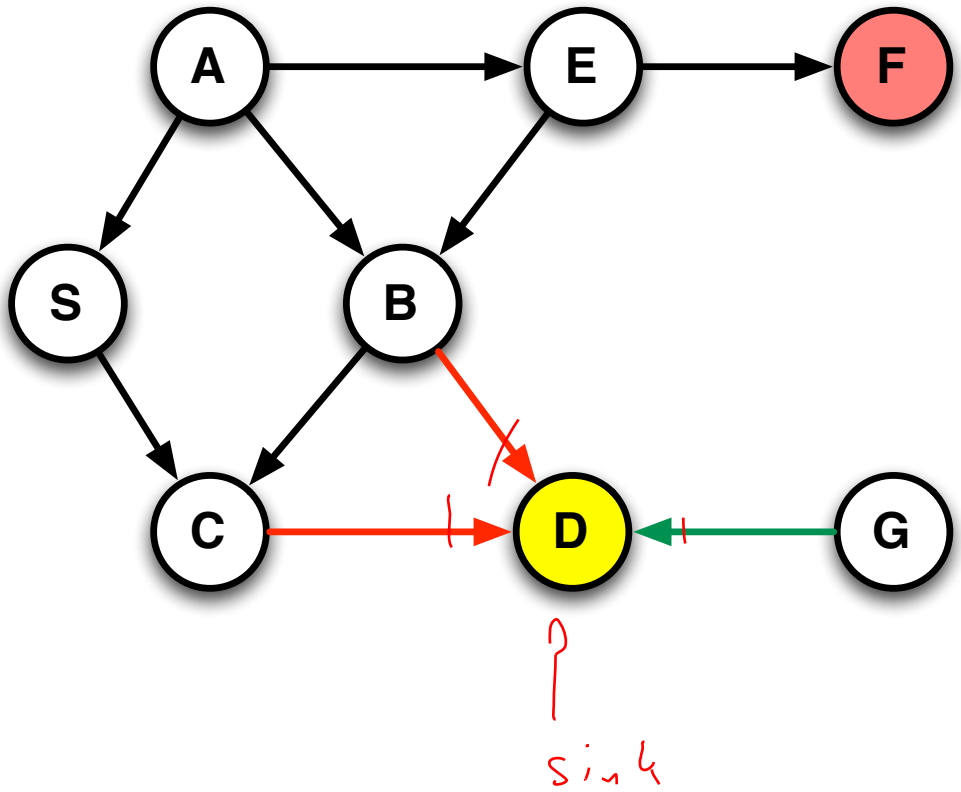


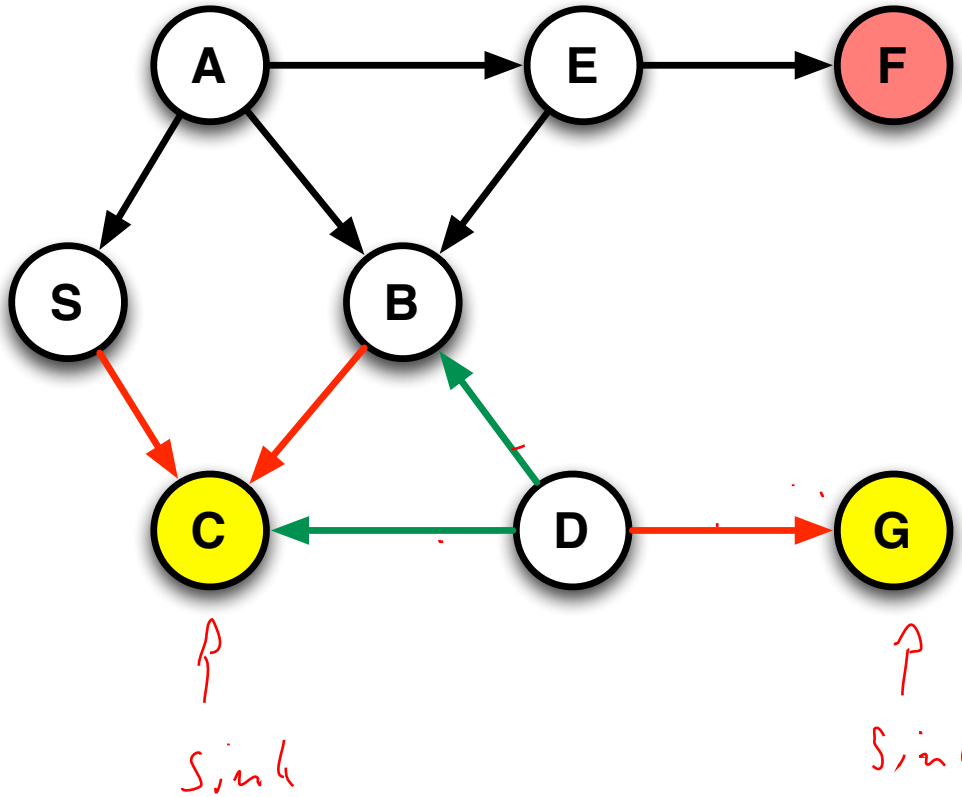
Link Reversal

- **Link F-G is lost**
- **Repair**
  - All nodes without outging edges change the orientation of all incoming edges

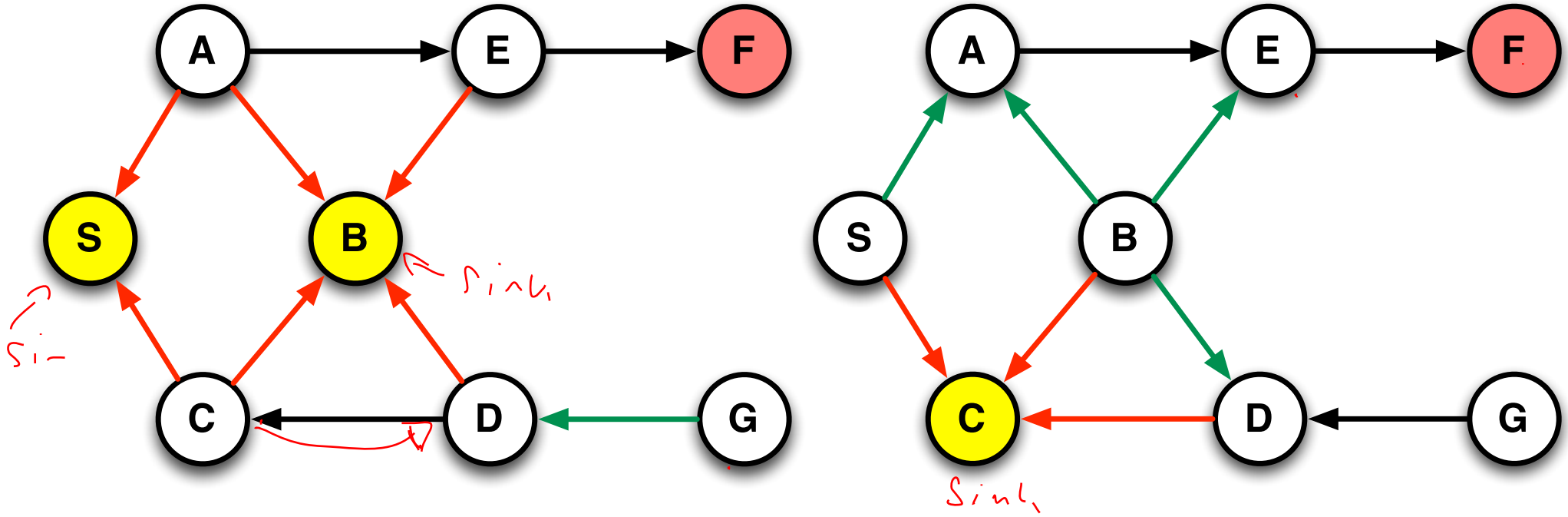


Link Reversal

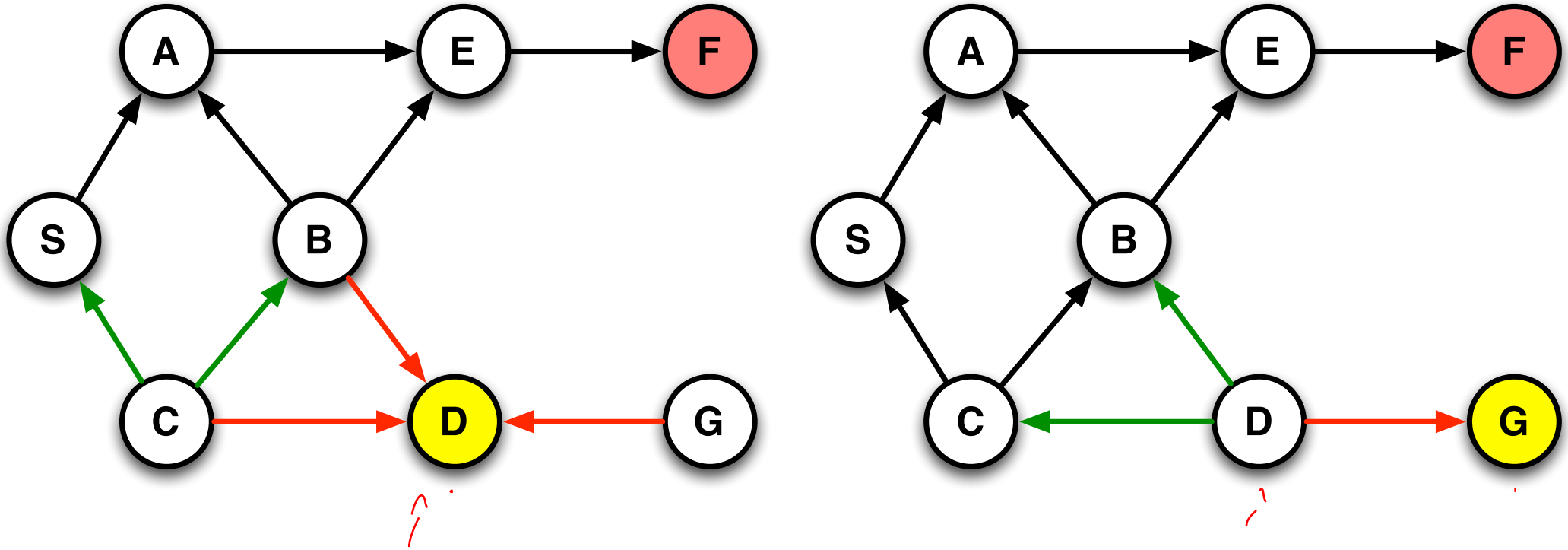




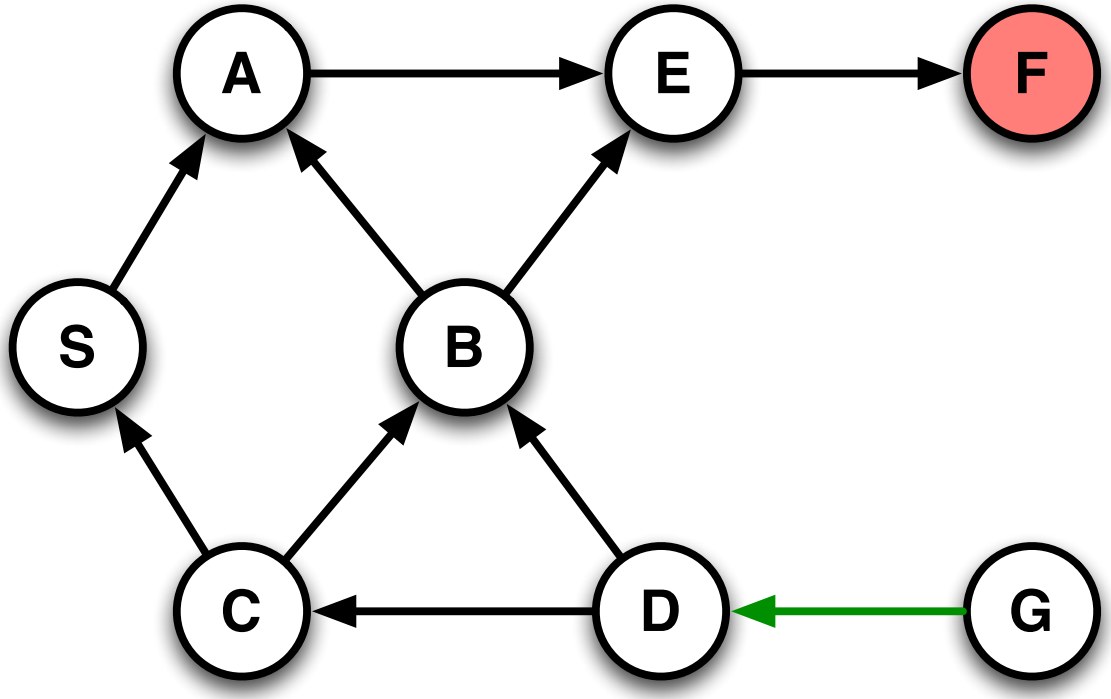
Link Reversal



Link Reversal



Link Reversal



2. → does it converge?

1. → Is it correct aftr converges

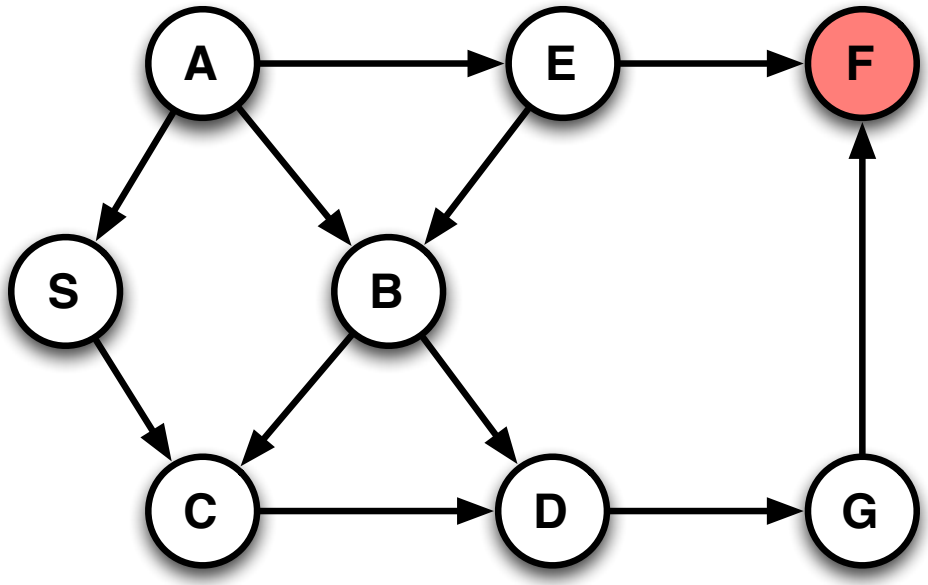
Link Reversal

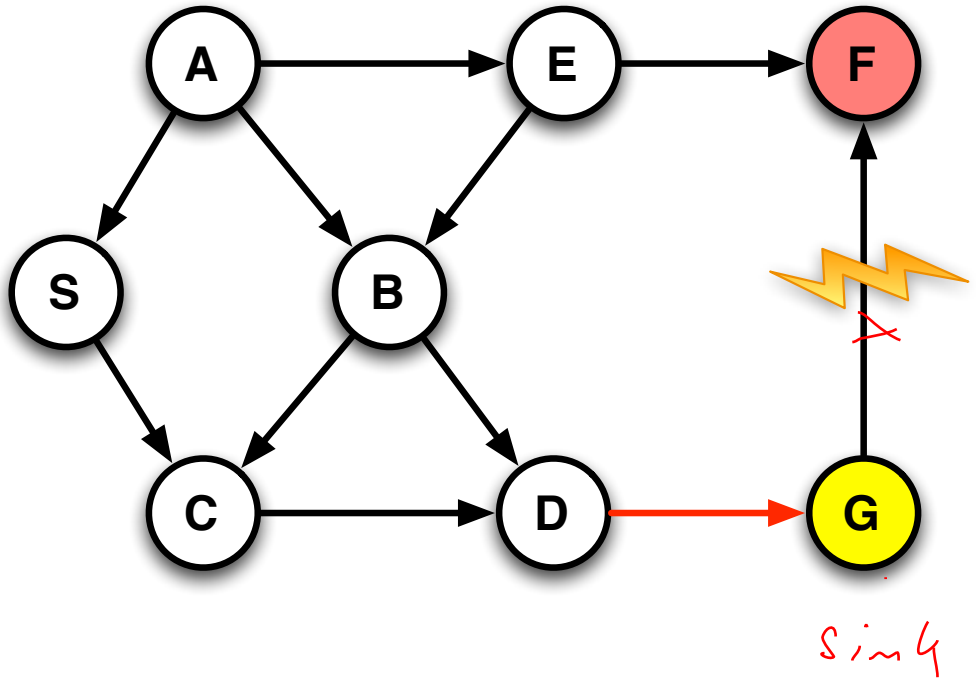
- **Motivation**
  - Link reversal should cause only local changes
  - Not necessarily the case
- **Repair is initiated,**
  - when the first packet is sent
- **Method known as a full reversal**

Partial Reversal

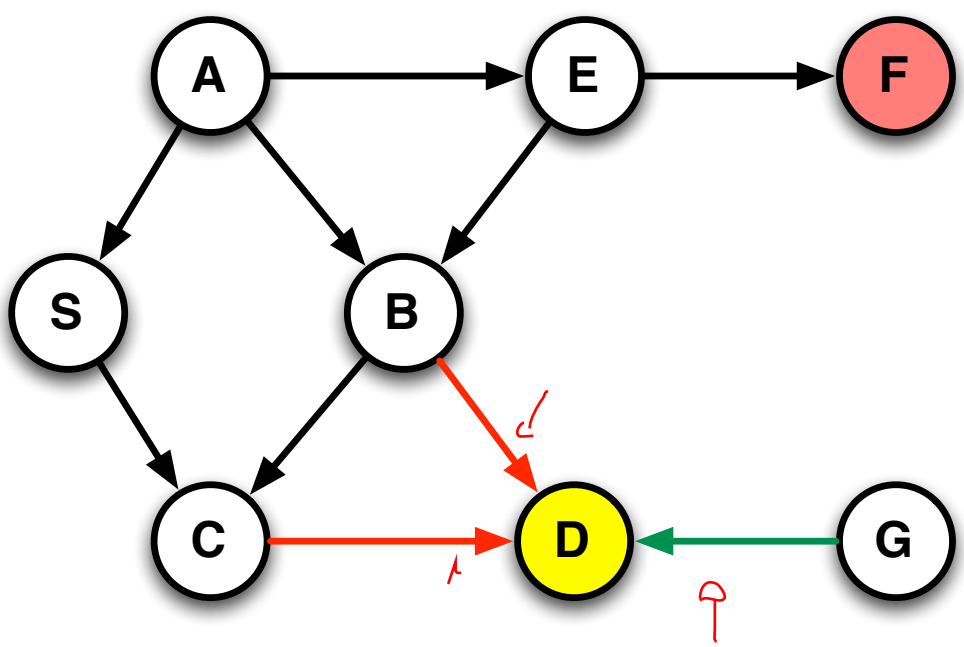
- **Partial reversal**
  - Only the edges are reversed which have not been reversed before
  - If all edges have been already reversed, then reverse all edges again

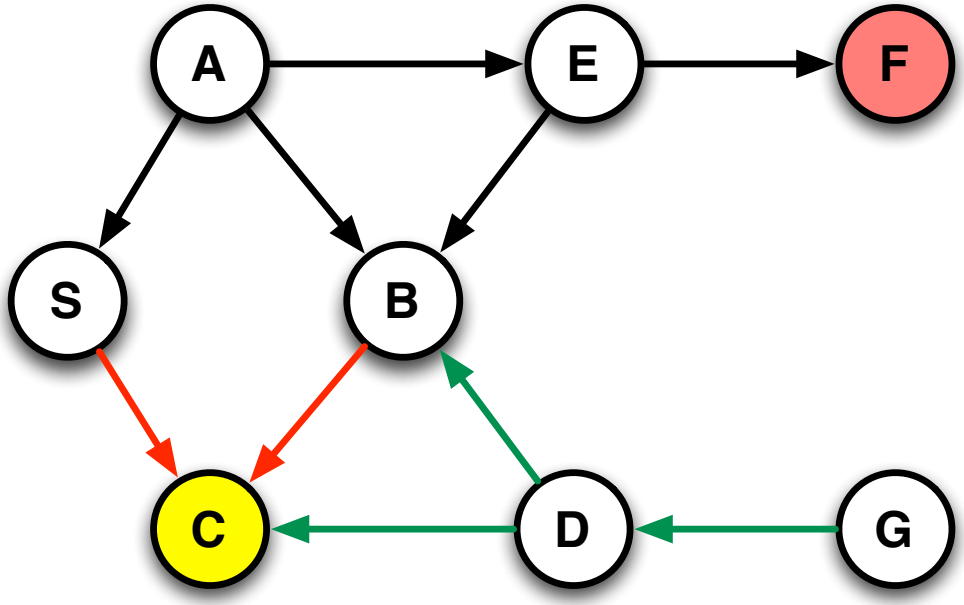
Partial Reversal





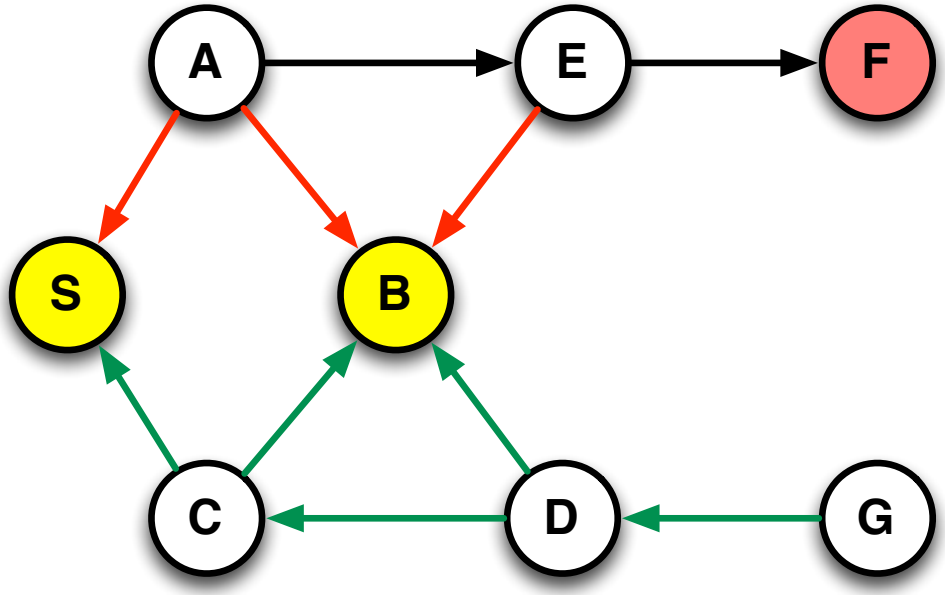
Partial Reversal

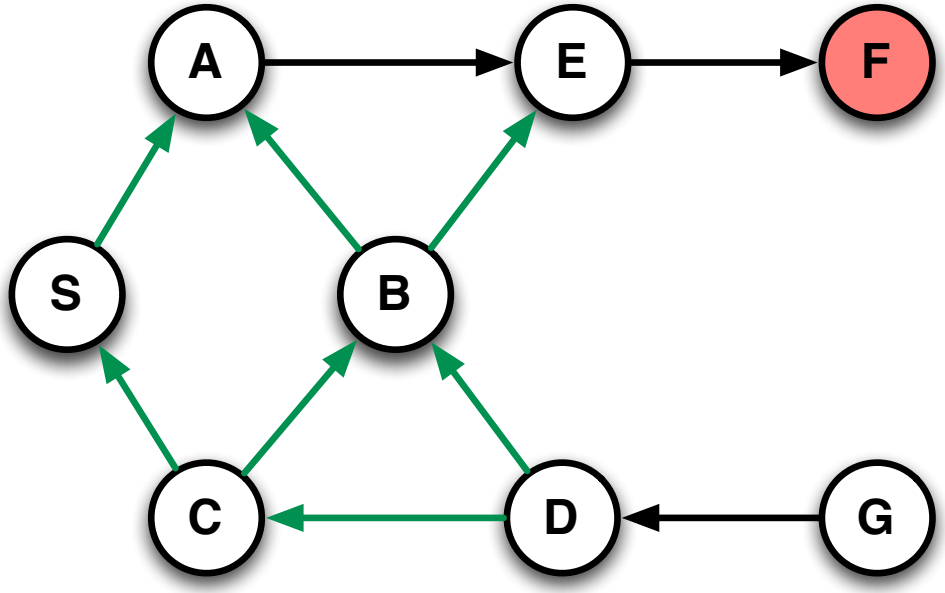




Partial Reversal

1. Is it correct?
2. Does it converge?

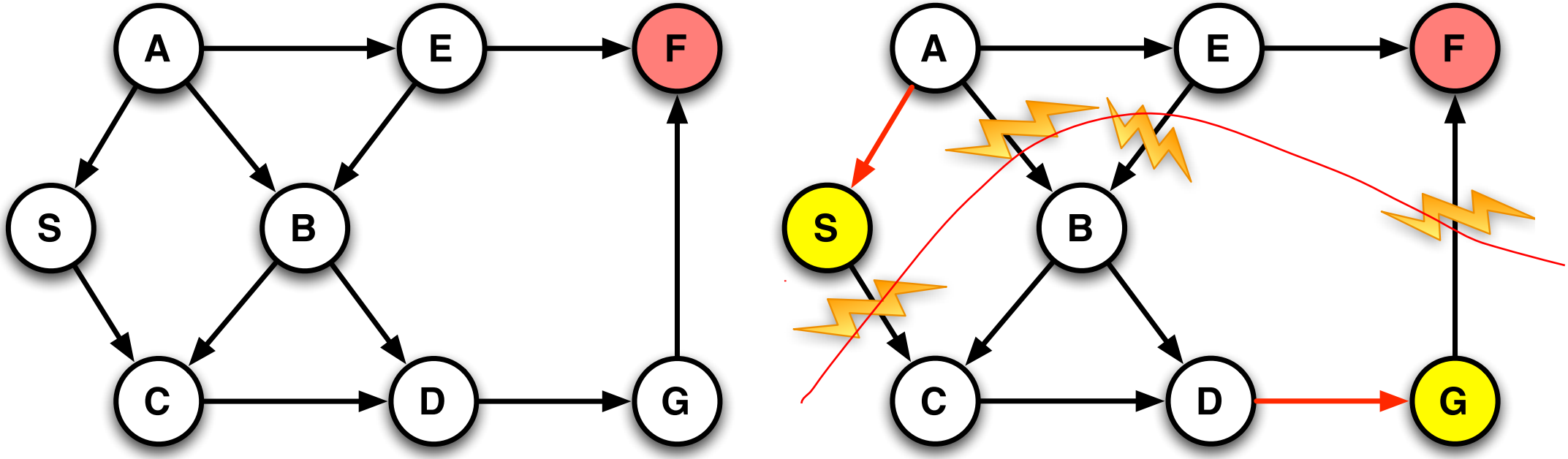




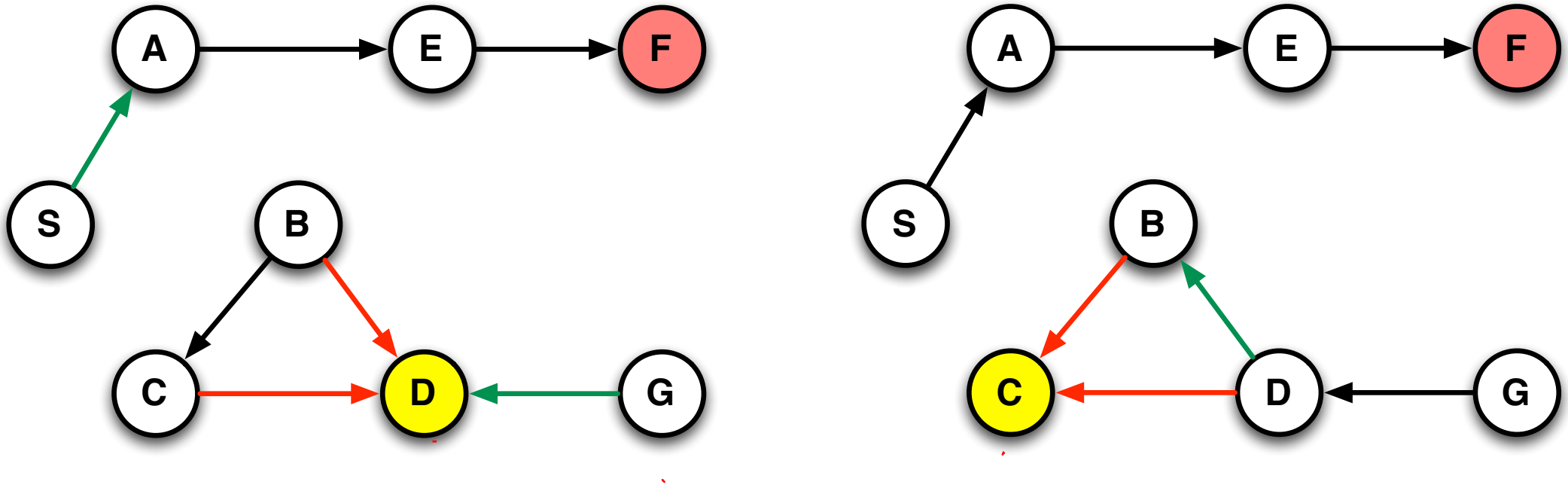
Link Reversal

- **Advantages**
  - Link reversal intends local repair
  - Several substitute routes (potentially) available
- **Disadvantages**
  - Connection errors must be detected
    - Hello messages cause additional traffic
  - If network is partitioned, the repair mechanism does not terminate

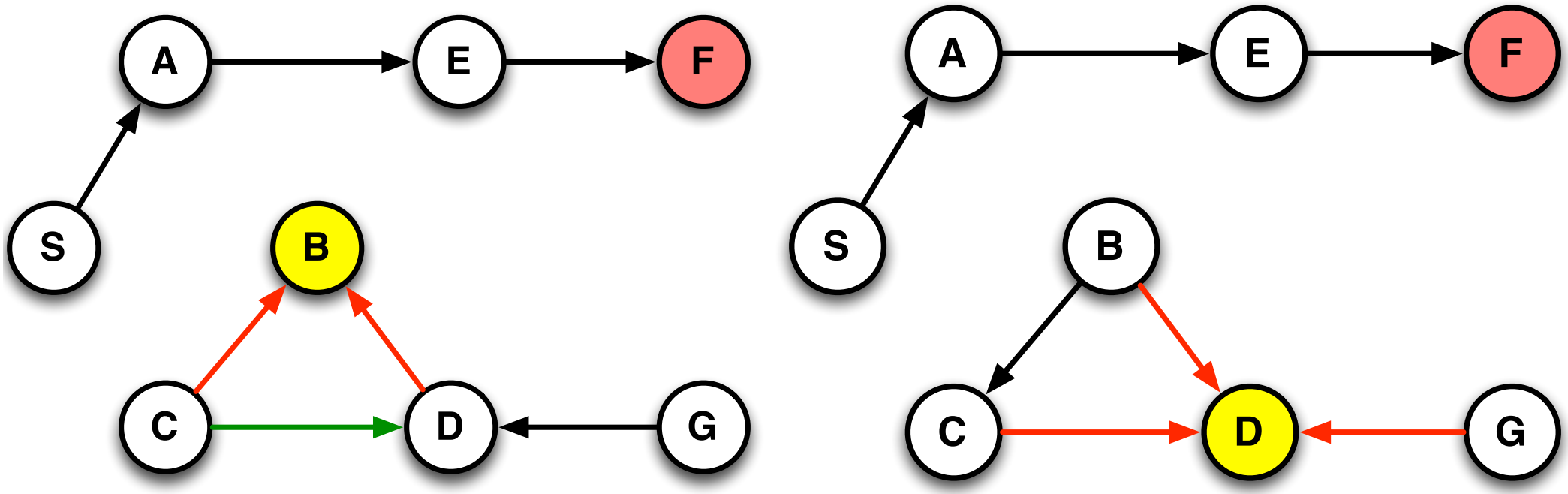
Link Reversal if Network is Partitioned



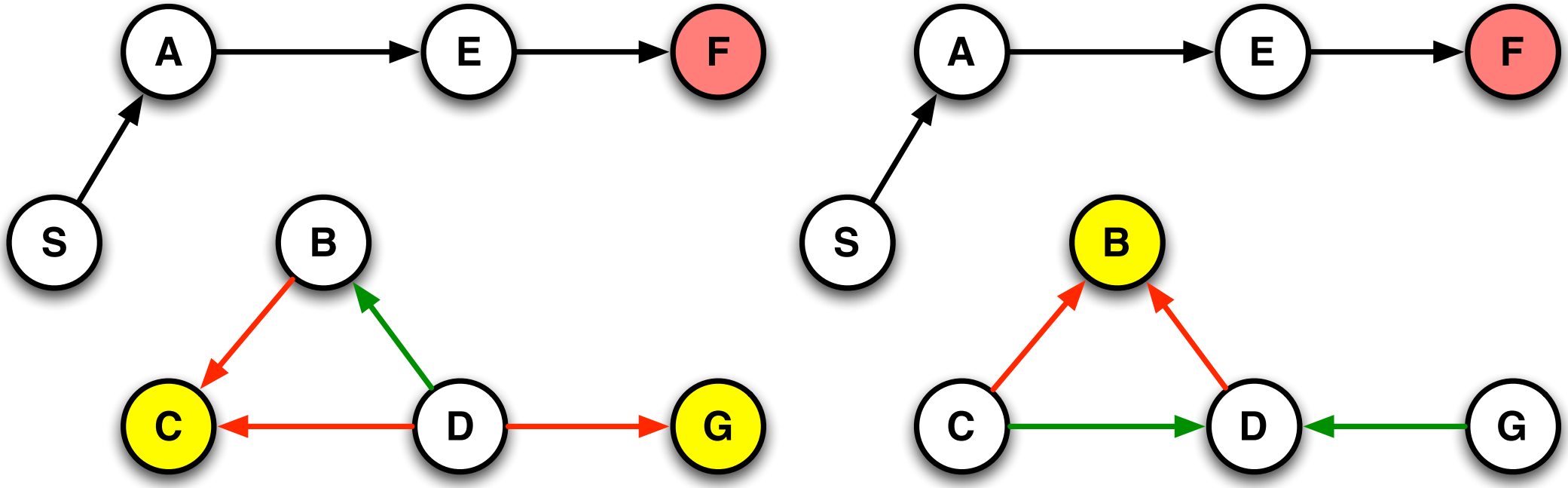
Link Reversal if Network is Partitioned



Link Reversal if Network is Partitioned



Link Reversal if Network is Partitioned



TORA

- **Separate network does not terminate with link reversals**
- **Mechanism for recognizing partitioning**
  - TORA (Temporally-Ordered Routing Algorithm (TORA)
    - Park, Corson, Highly Adaptive Distributed Routing Algorithm for Mobile Wireless Networks, Infocom 1997
  - Analysis of link reversal provides this information

Link Reversal

- **Reactive protocol**
  - Repair only when data packet is not delivered
- **Proactive protocol**
  - Hello packets check all connections
- **Link reversal can be both proactive and reactive**

Routing in MANETs

- **Routing**
  - Determination of message paths
  - Transport of data
- **Protocol types**
  - proactive
    - Routing tables with updates
  - reactive
    - repair of message paths only when necessary
  - hybrid
    - combination of proactive and reactive

Routing Protocols

- **Proactive**
  - Routes are **demand independent**
  - Standard Link-State und Distance-Vector Protocols
    - Destination Sequenced Distance Vector (**DSDV**)
    - Optimized Link State Routing (**OLSR**)
- **Reactive**
  - Route are determined when needed
    - Dynamic Source Routing (**DSR**)
    - Ad hoc On-demand Distance Vector (**AODV**)
    - Dynamic MANET On-demand Routing Protocol
    - Temporally Ordered Routing Algorithm (**TORA**)
- **Hybrid**
  - combination of reactive und proactive
    - Zone Routing Protocol (**ZRP**)
    - Greedy Perimeter Stateless Routing (**GPSR**)

Optimized Link State Routing

- **Literature**
  - RFC3626: Clausen, Jacquet, *Optimized Link State Routing Protocol, 2003*
  - First published 1999
- **Most proaktive protocols are are based on**
  - Link-state routing
  - Distance-Vector routing

Link State Routing

- **Connections are periodically published throughout the network**
- **Nodes propagate information to their neighbors**
  - i.e. flooding
- **All network information is stored**
  - with time stamp
- **Each node computes shortest paths**
  - possibly also other route optimizations

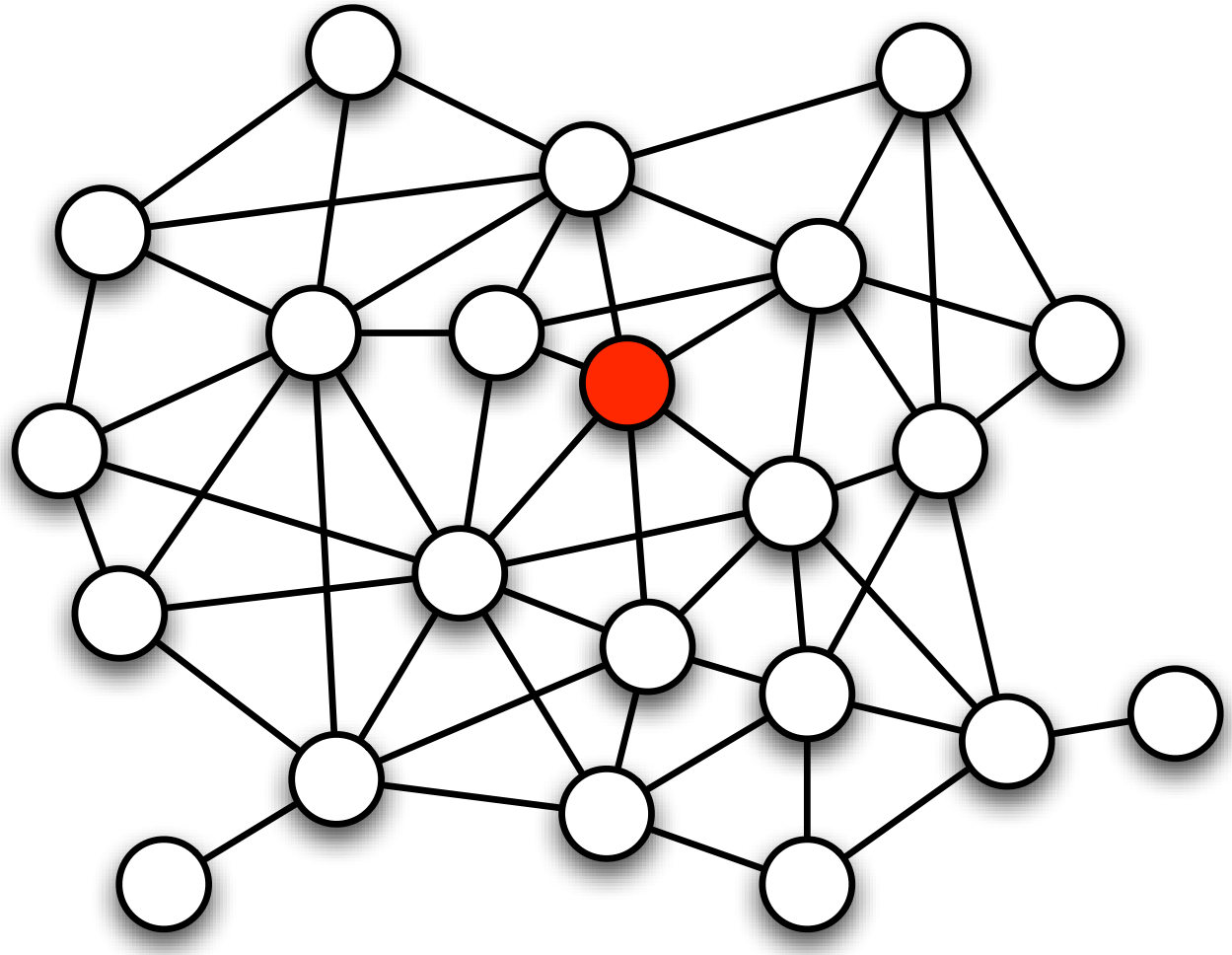
Optimized Link State Routing (OLSR)

- **Each nodes broadcasts its neighborhood list**
  - Each node can determinat its 2-hop neighborhood ~~werden~~
- **Reducing the number of messages**
  - fewer nodes participate in flooding
- **Multipoint relay node (MPRs)**
  - are chosen such that each node has at least one multipoint relay node as in its 2-hop neighborhood
  - Only multipoint relay nodes propagate link information
- **Node sends their neighborhood lists**
  - such that multipoint relay nodes in the 2-hop neighborhood can be chosen

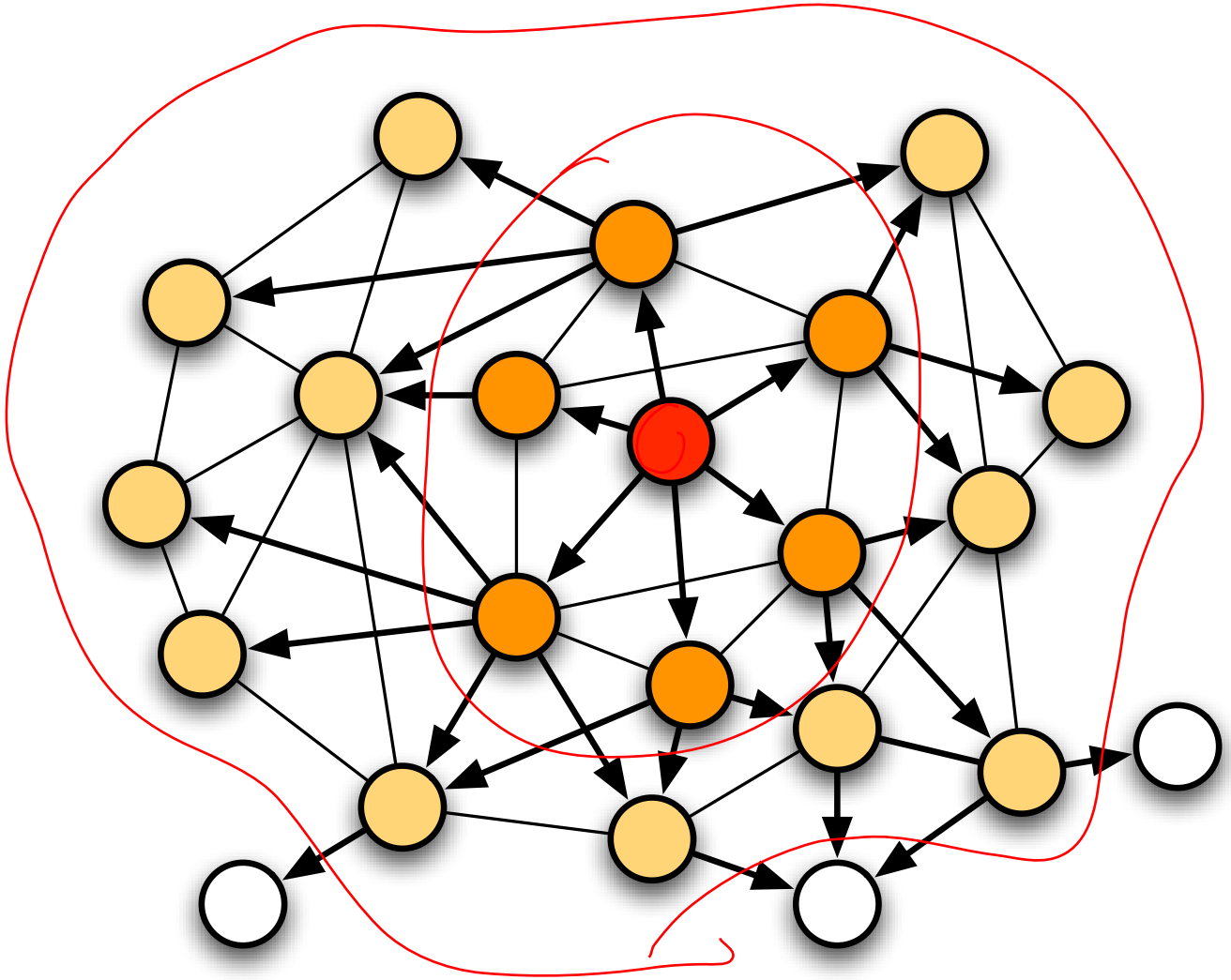
Optimized Link State Routing (OLSR)

- **Combines Link-State protocol and topology control**
- **Topology control**
  - Each node chooses a minimal dominating set of the 2 hope neighborhood
    - ***multipoint relays (MPR)***
    - Only these nodes propagate link information
    - More efficient flooding
- **Link State component**
  - Standard link state algorithm on a reduced network

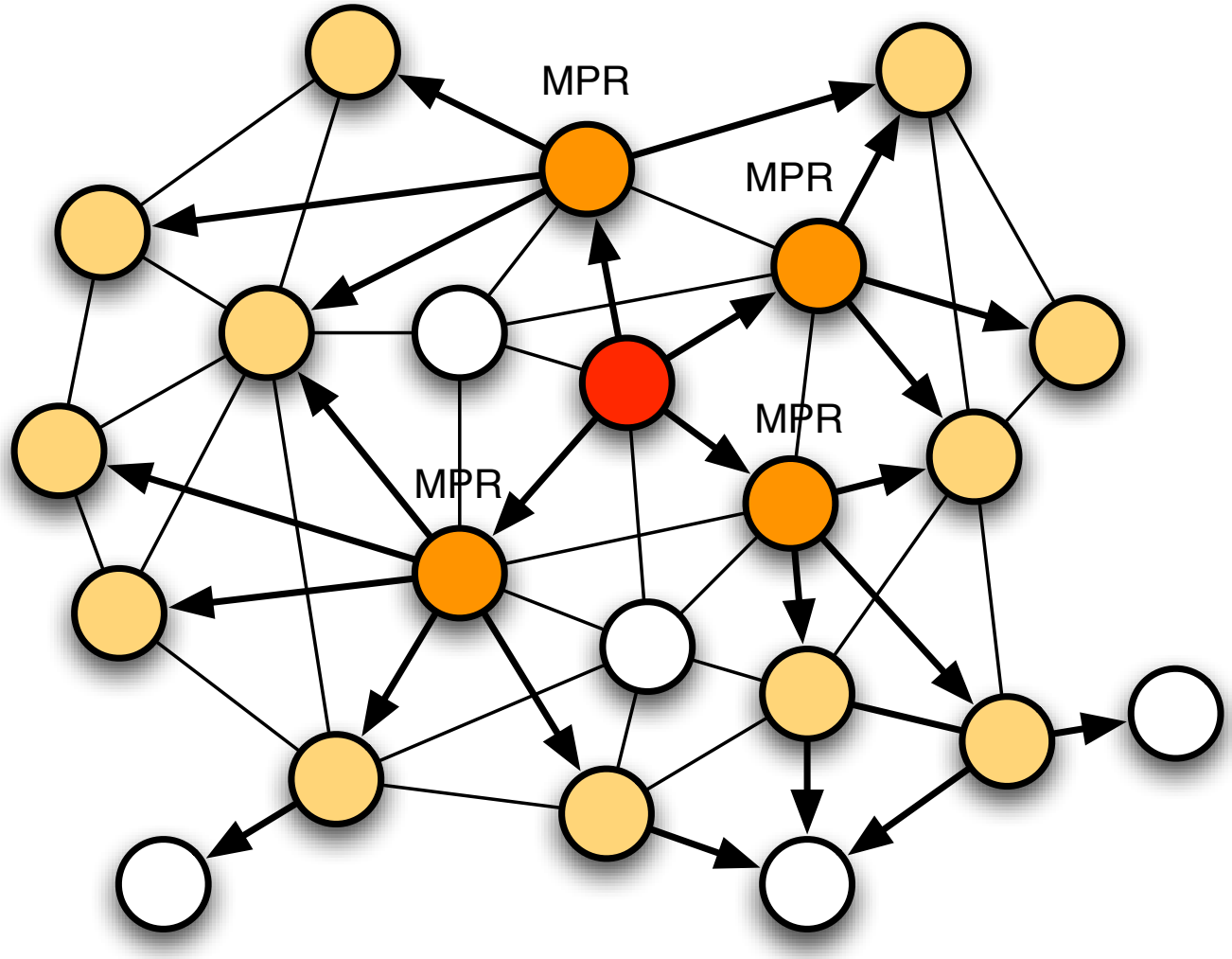
Optimized Link State Routing (OLSR)



Optimized Link State Routing (OLSR)



Optimized Link State Routing (OLSR)



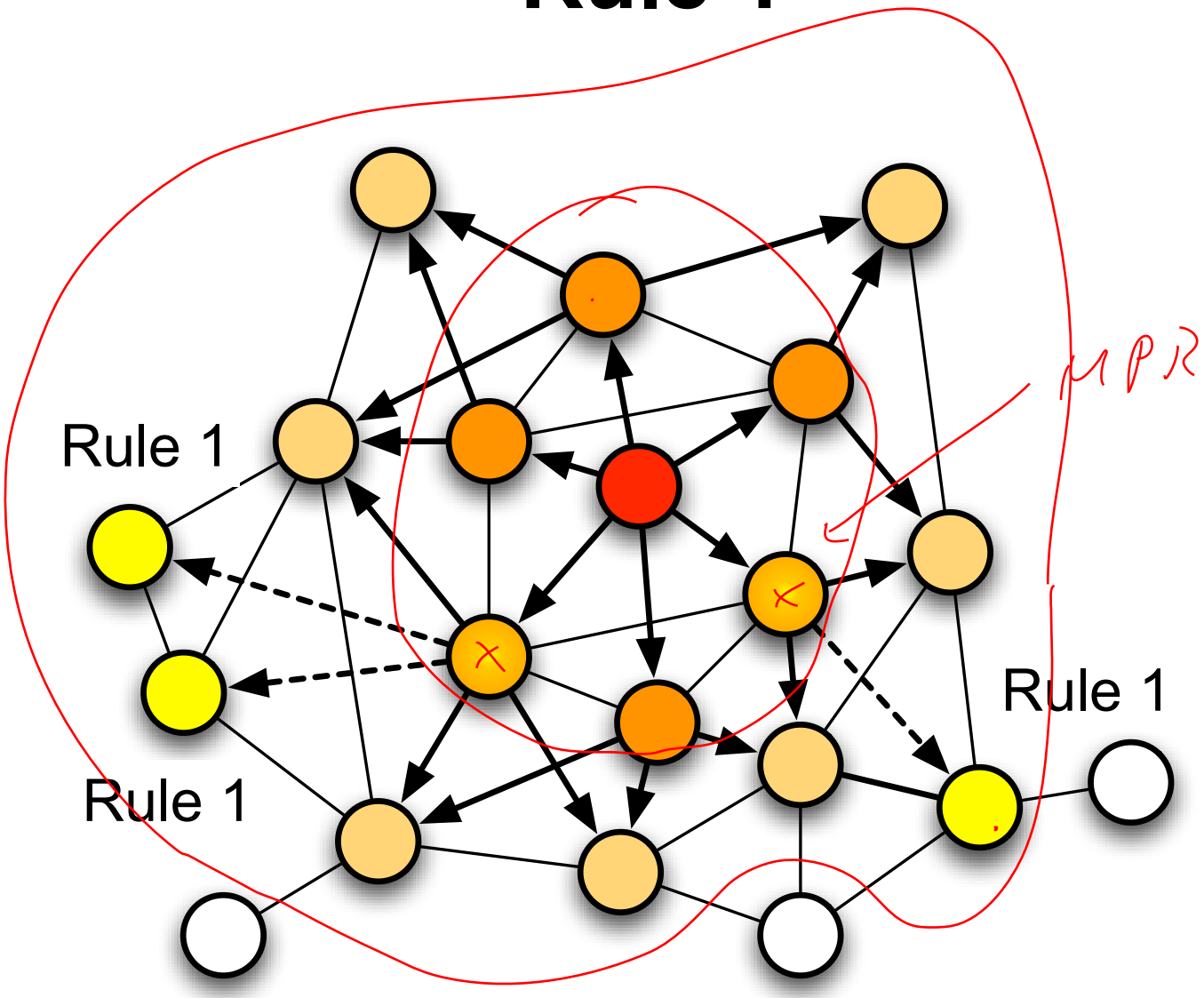
Selection of MPRs

- **Multipoint Relaying for Flooding Broadcast Messages in Mobile Wireless Networks, Amir Qayyum, Laurent Viennot, Anis Laouiti, HICCS 2002**
- **Problem is NP-complete**
- **Heuristics**
  - recommended for OLSR
- **Notations**
  - N(x): 1 hop neighborhood of x
  - $N^2(x)$: 2 hop neighborhood of x
  - Alle connections are symmetrical

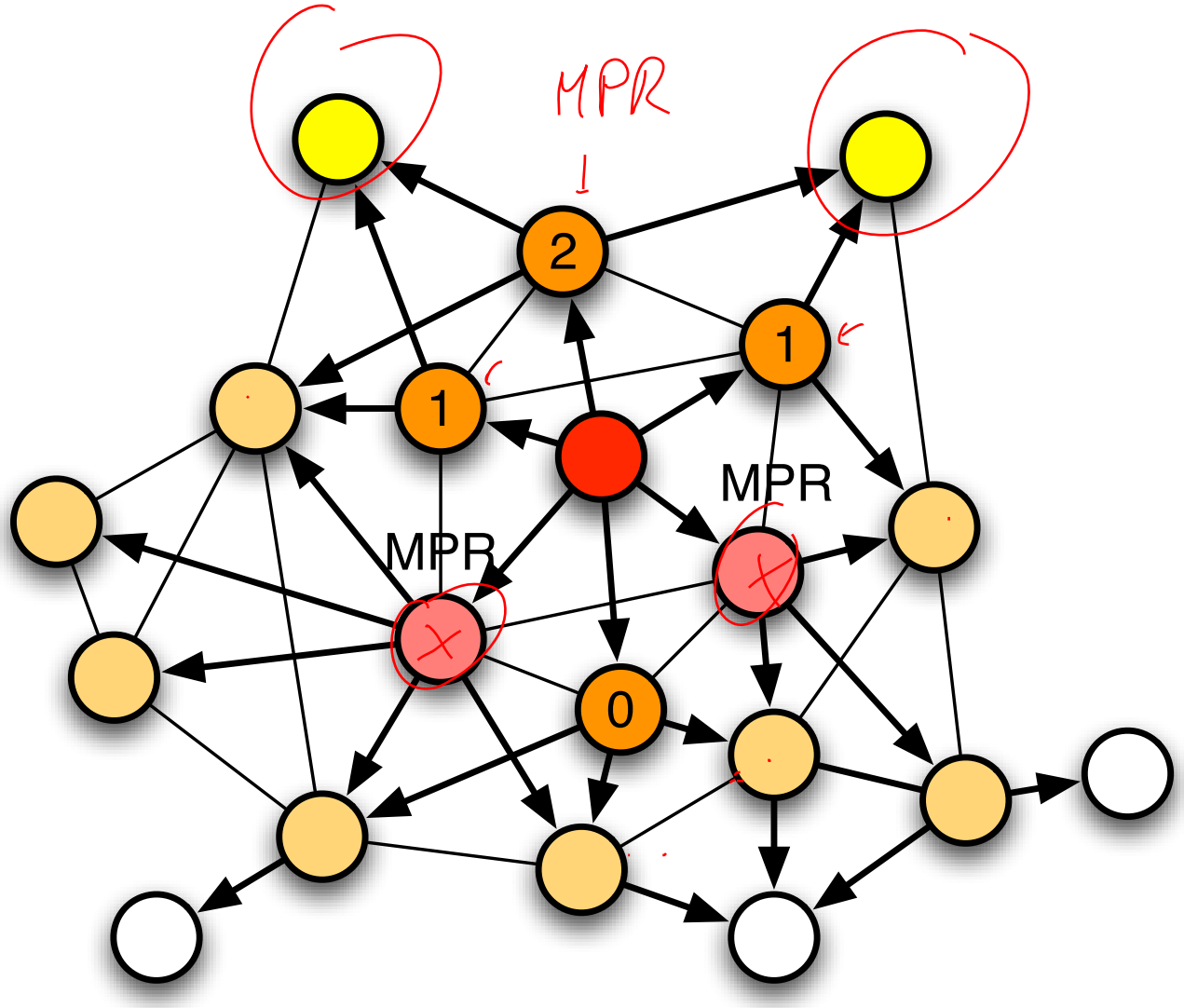
Selection of MPRs

- **At the beginning there is no MPR**
  - Each node chooses its MPRs
- **Rule 1: A node of x is selected as MPR, if**
  - it in N(x) and
  - it is the only neighborhood node in the node $N^2(x)$
- **Rule 2: If nodes in N^2 (x) are not covered:**
  - Compute for each node in N(x) the number of uncovered nodes in $N^2(x)$
  - Select as MPR the node that maximizes the value

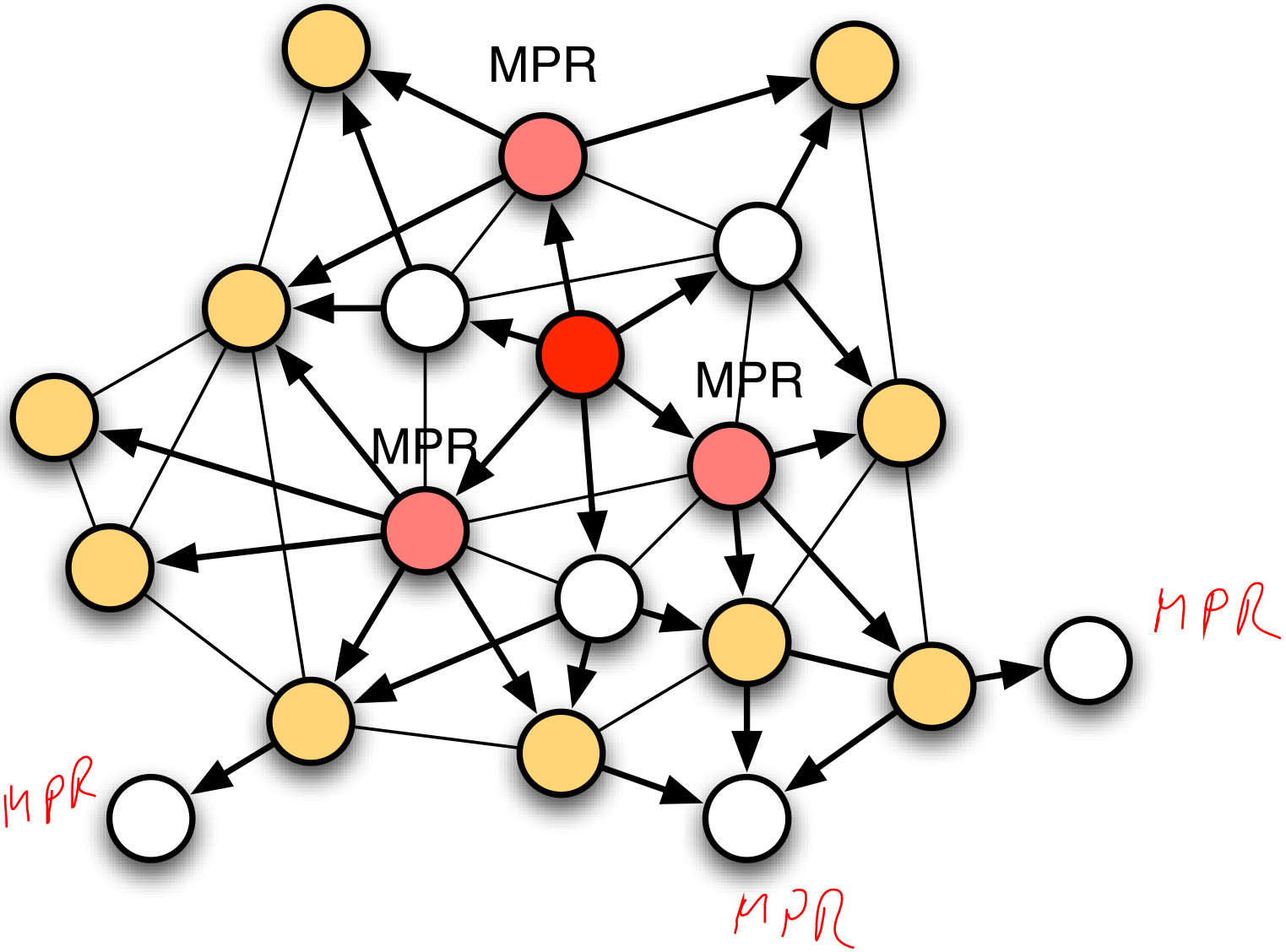
Rule 1



Rule 2



MPRs



OLSR

- **OLSR is flooding link information using MPRs**
  - Multipoint-Relays
- **Receivers choose their own MPRs for propagating**
  - Each node chooses its own MPRs
- **Routes use only MPRs as intermediate nodes**

Zone Routing Protocol (ZRP)

hybrid

- **Haas 1997**
  - *A new routing protocol for the reconfigurable wireless networks*, Proc. of IEEE 6th International Conference on Universal Personal Communications, 562–566
- **Zone Routing Protocol combine**
  - Proactive protocol
    - for local routing
  - reactive protocol
    - for global routing

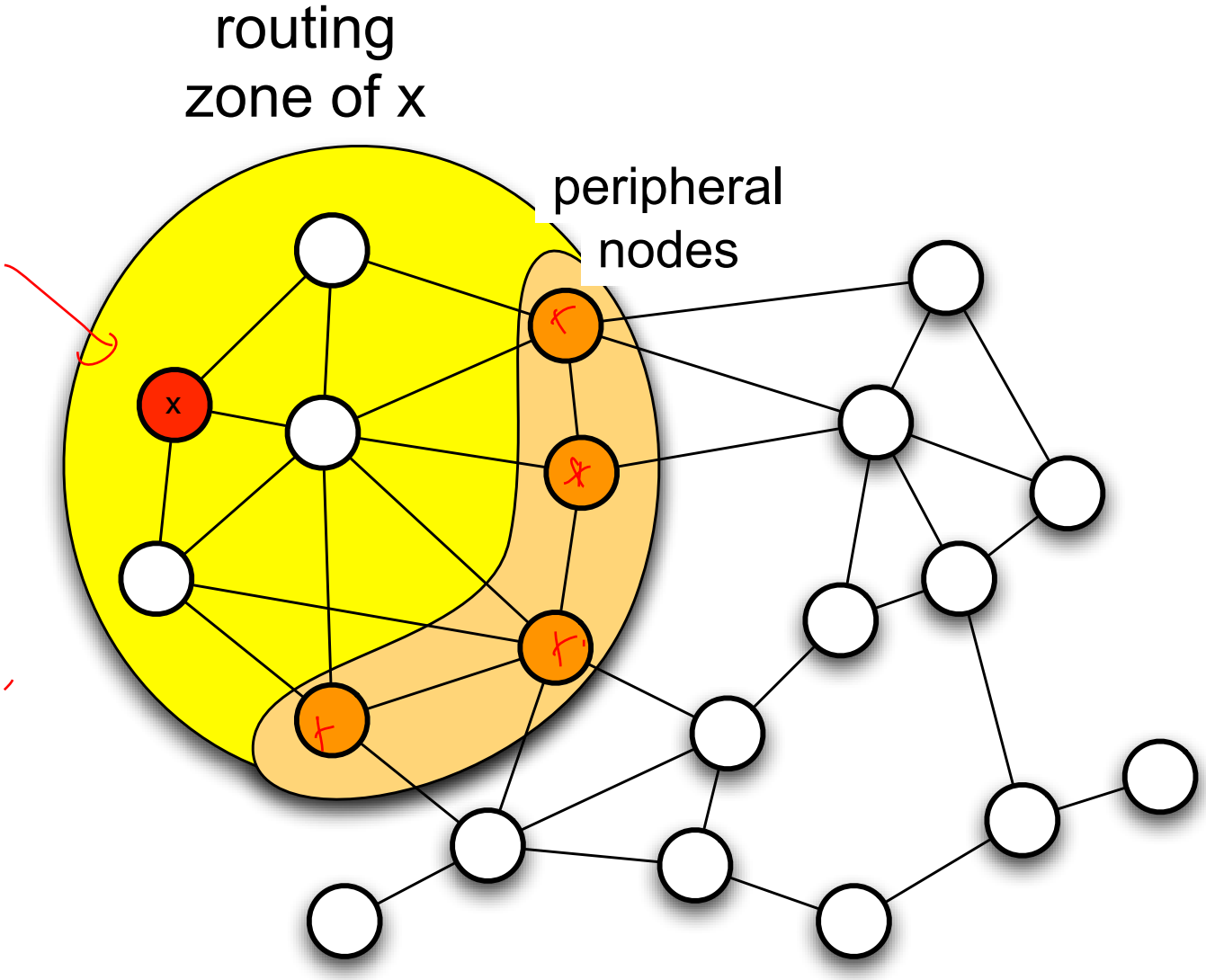
ZRP

- **Routing zone of a node x**
  - Nodes in a given maximum hop-distance d
- **Peripheral nodes**
  - all nodes have exactly the hop-distance d have
  - within the routing zone x

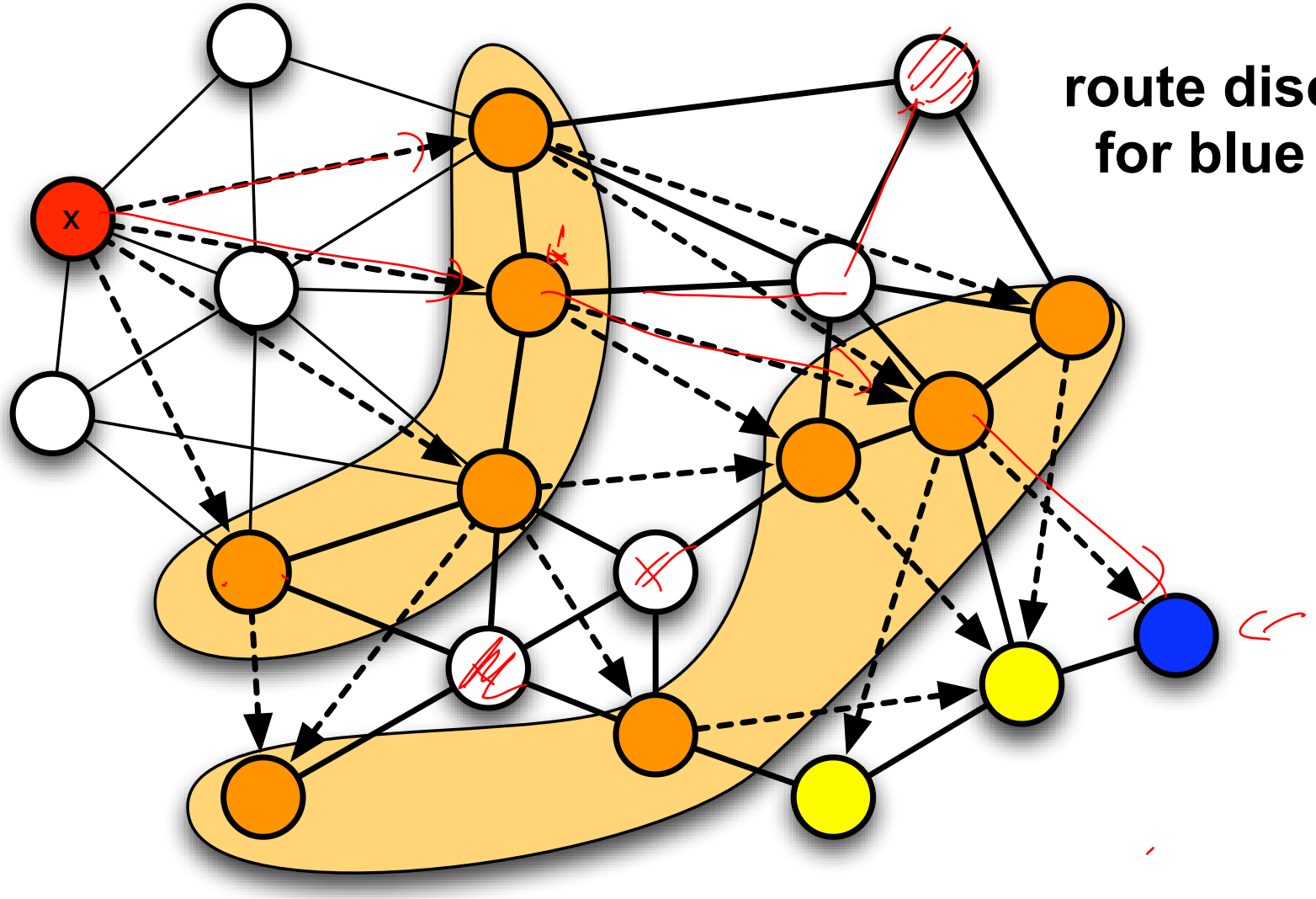
ZRP

- **Intra zone routing**
  - proactive update the connection information in the routing zone of node
    - e.g. with link state or distance vector protocols
- **Inter zone routing**
  - Reactive route discovery is used for distant / unknown nodes
  - Procedure similar to DSR
  - Only peripheral nodes reach further information

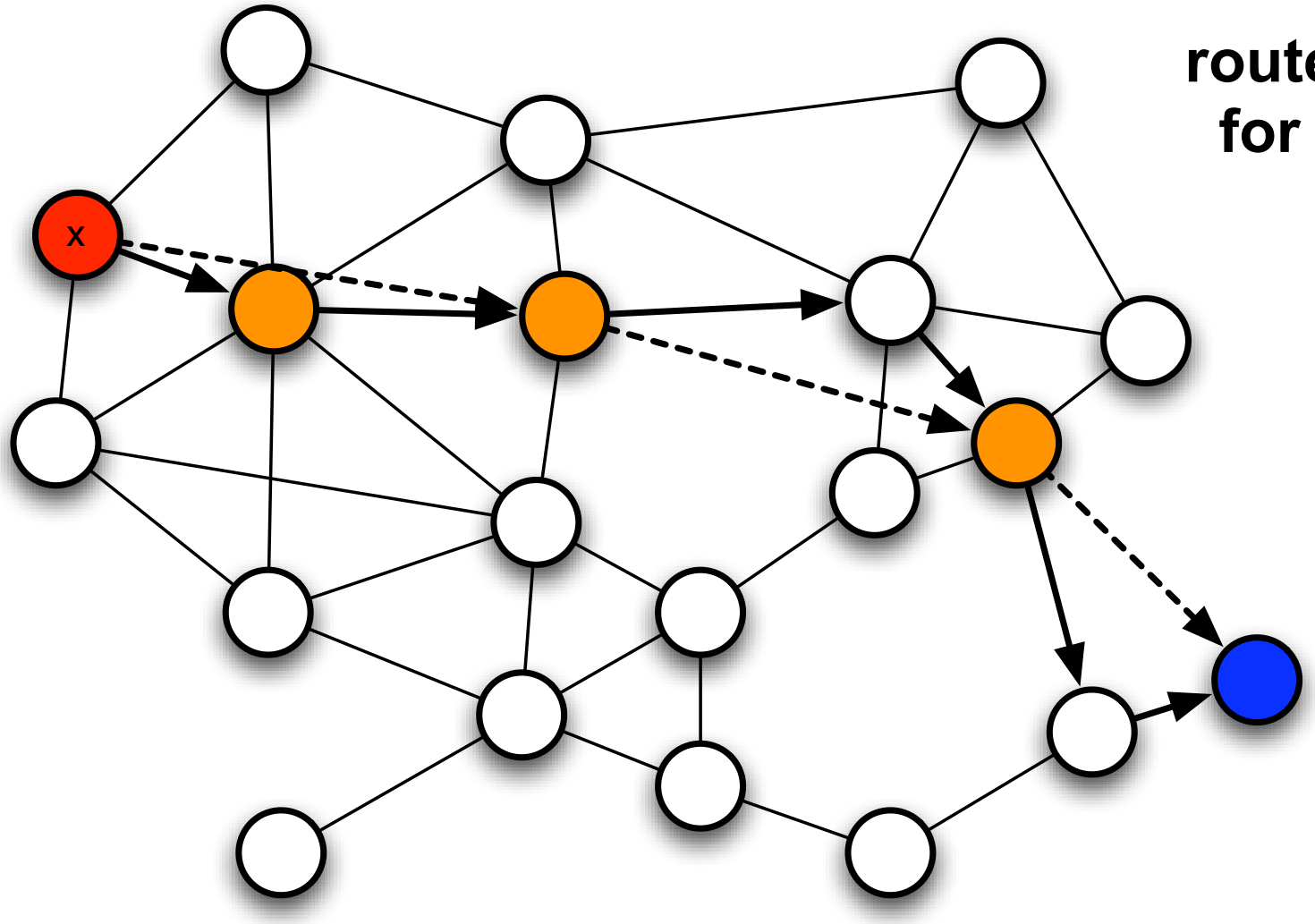
ZRP: Example with radius d=2



ZRP: Example with radius d=2

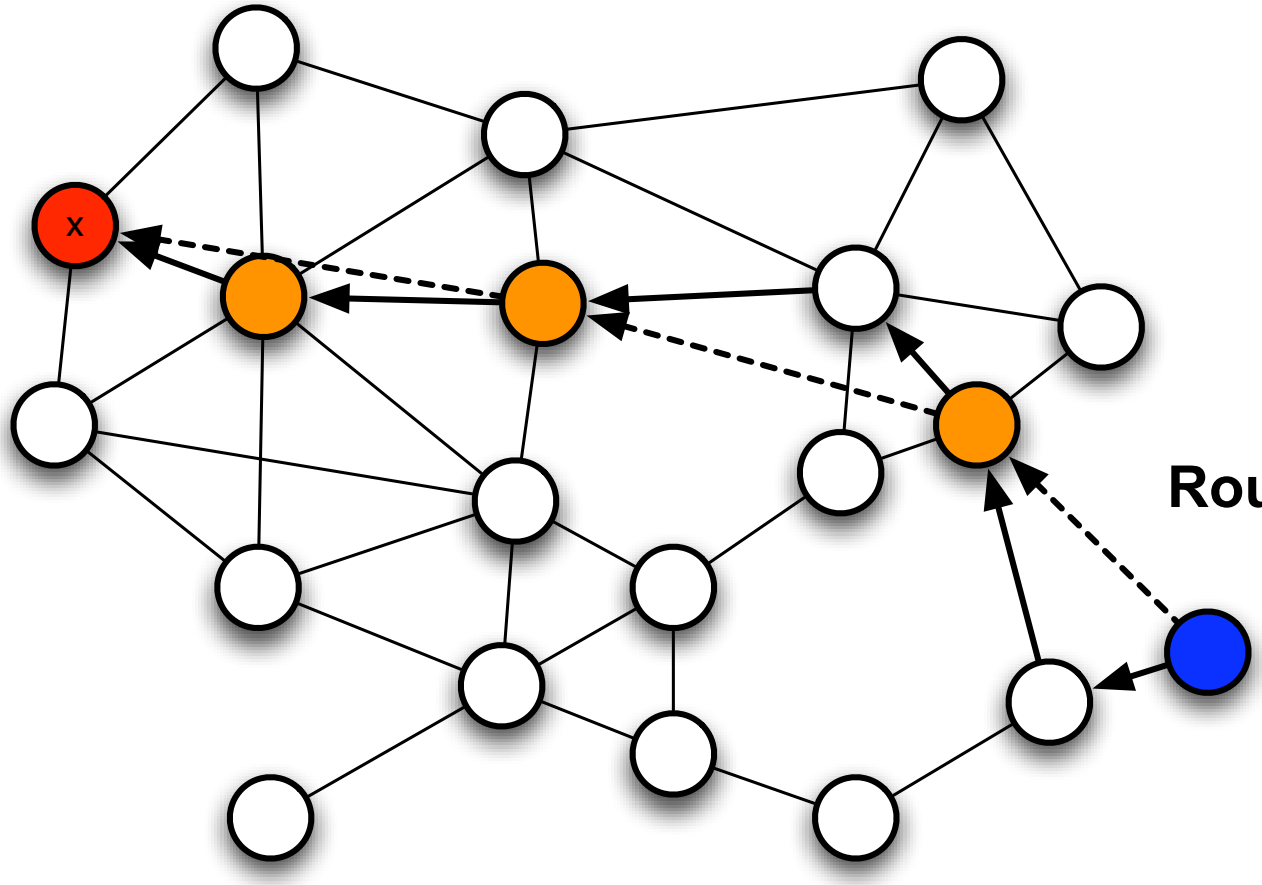


ZRP: Example with radius d=2



route discovery for blue node

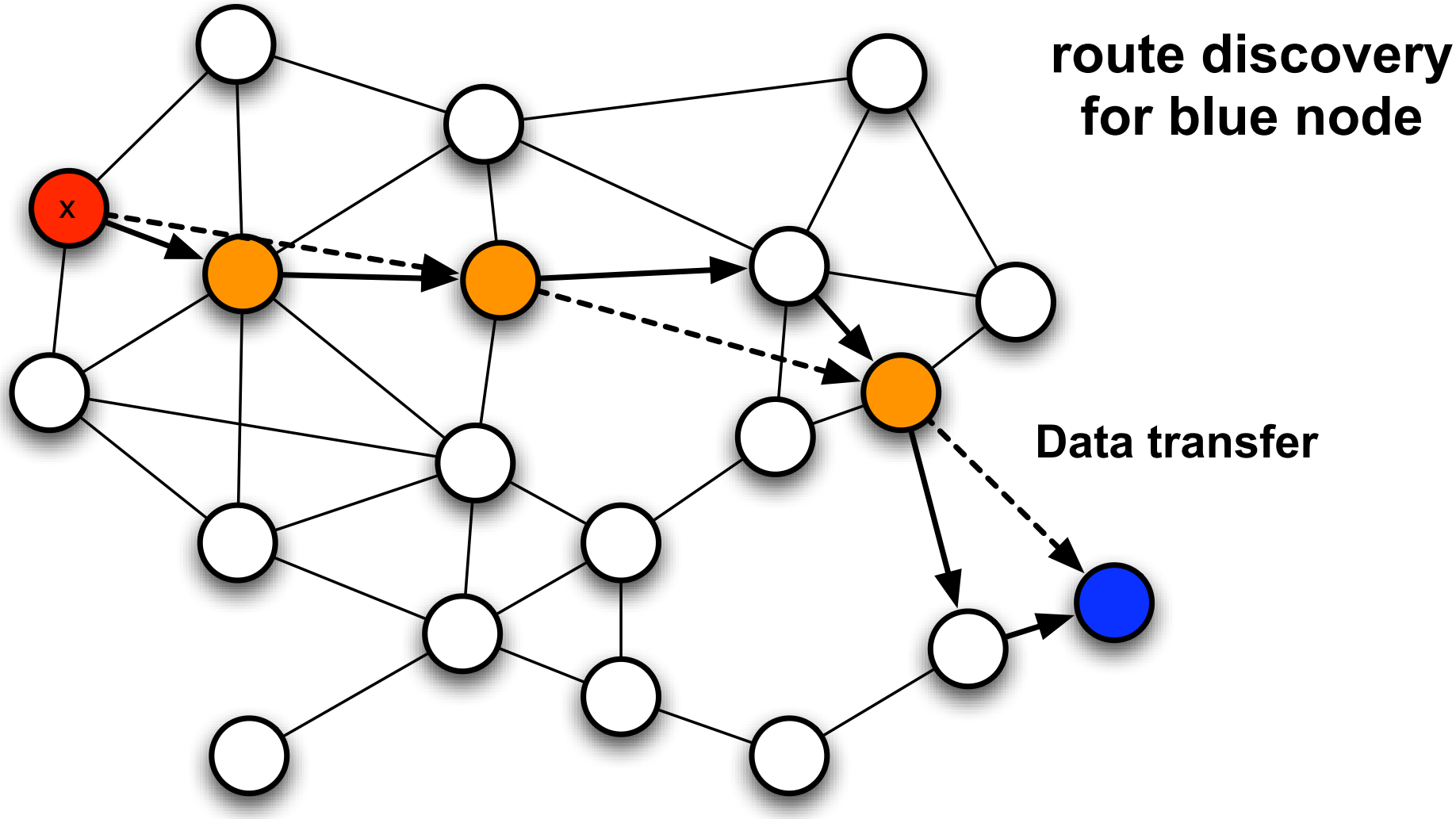
ZRP: Example with radius d=2



route discovery
for blue node

Route Reply

ZRP: Example with radius d=2



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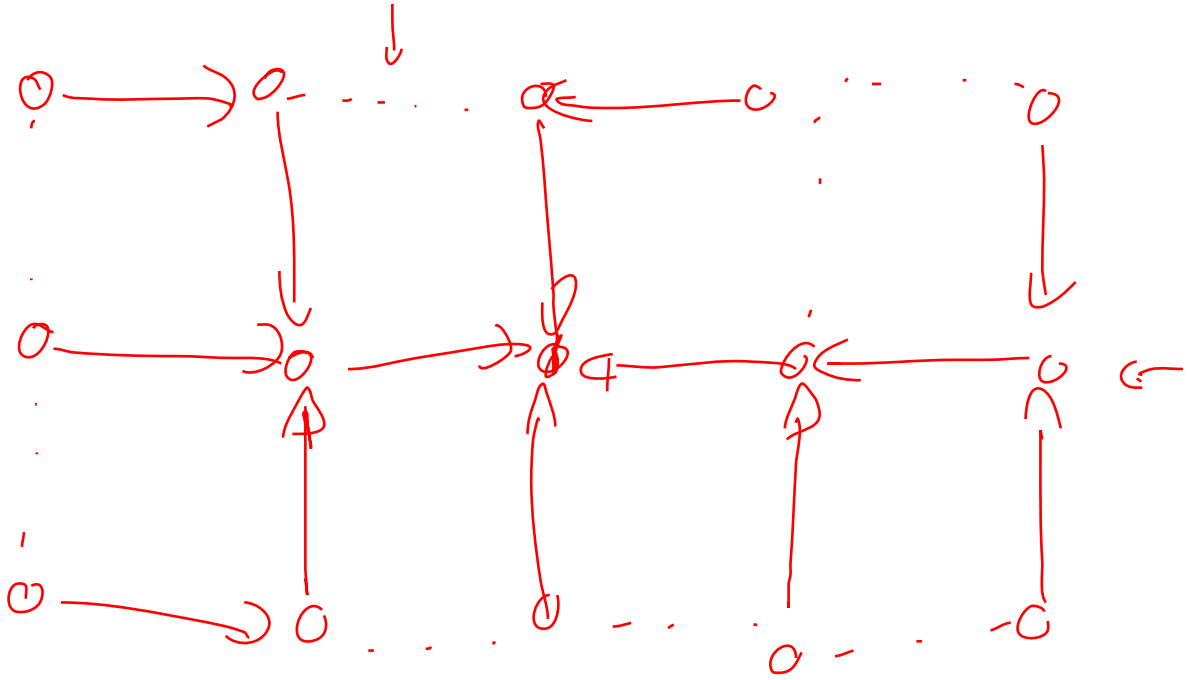
Shortest Path Tree

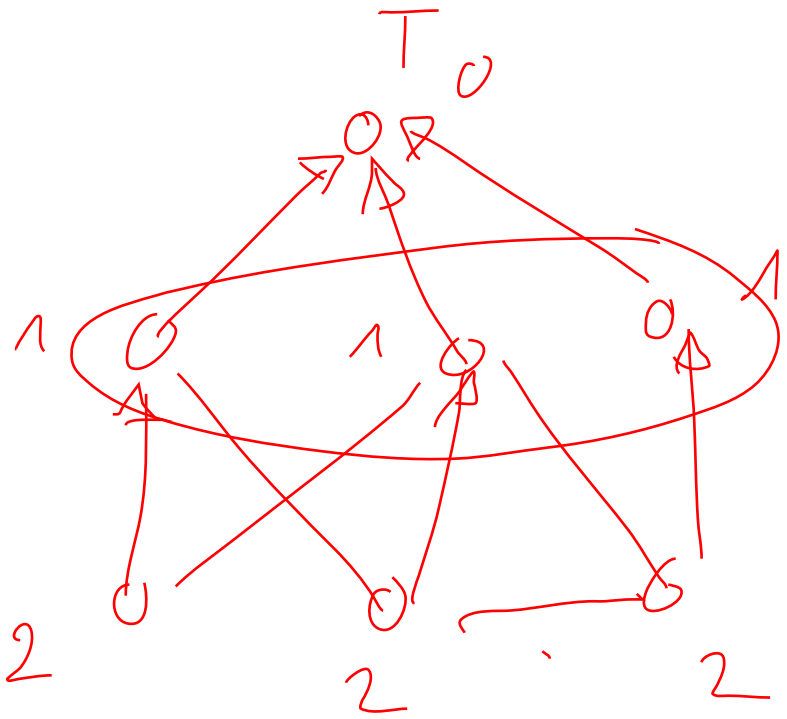
Union of shortest paths to the target

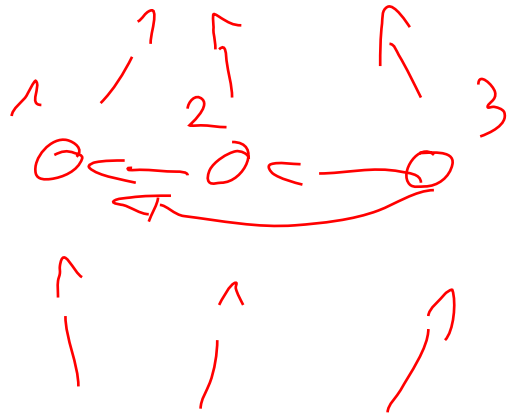


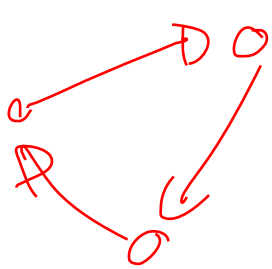
Topologic Sorting

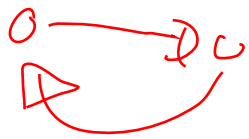
→ DAG

directed acyclic graph

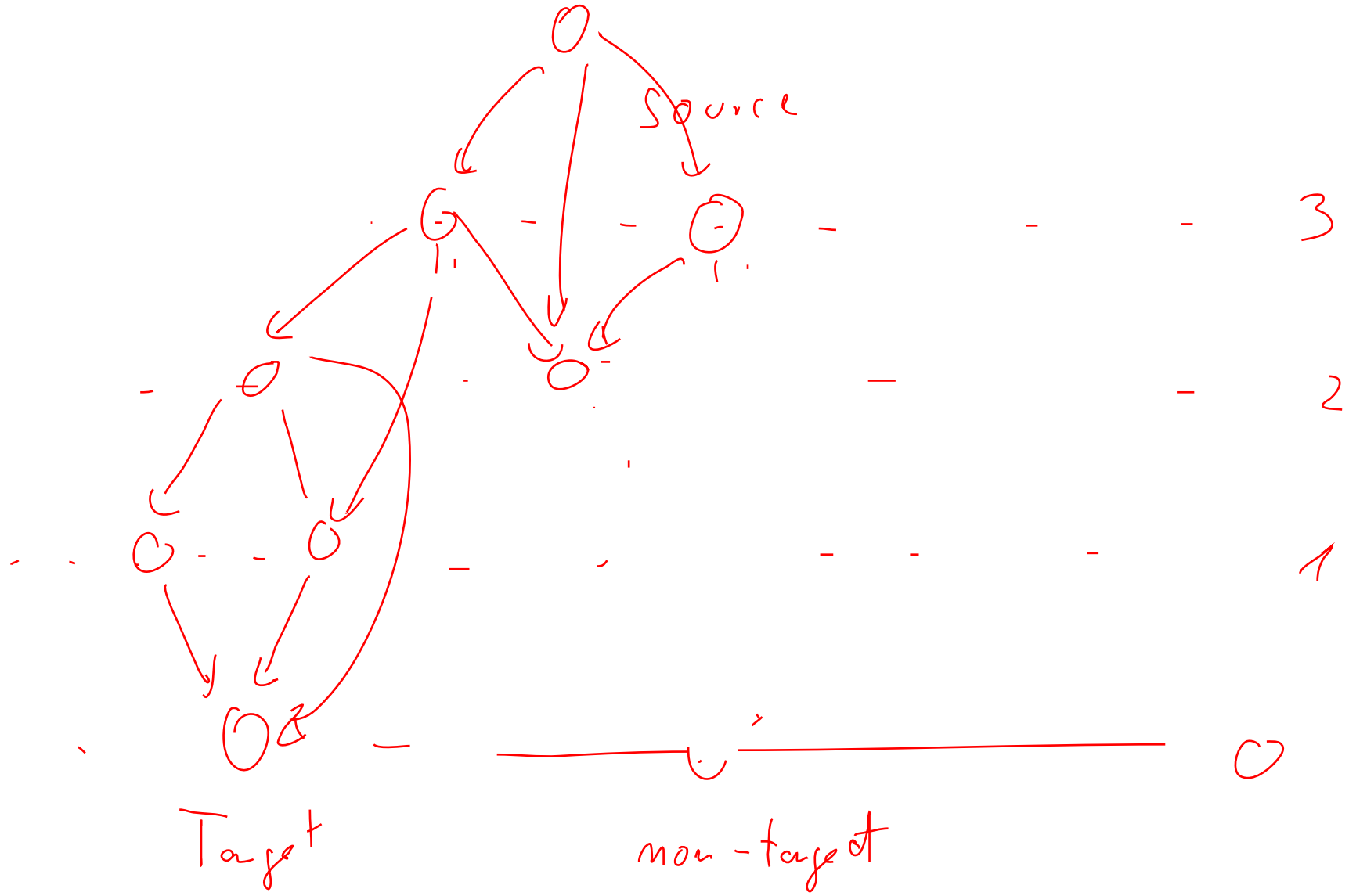


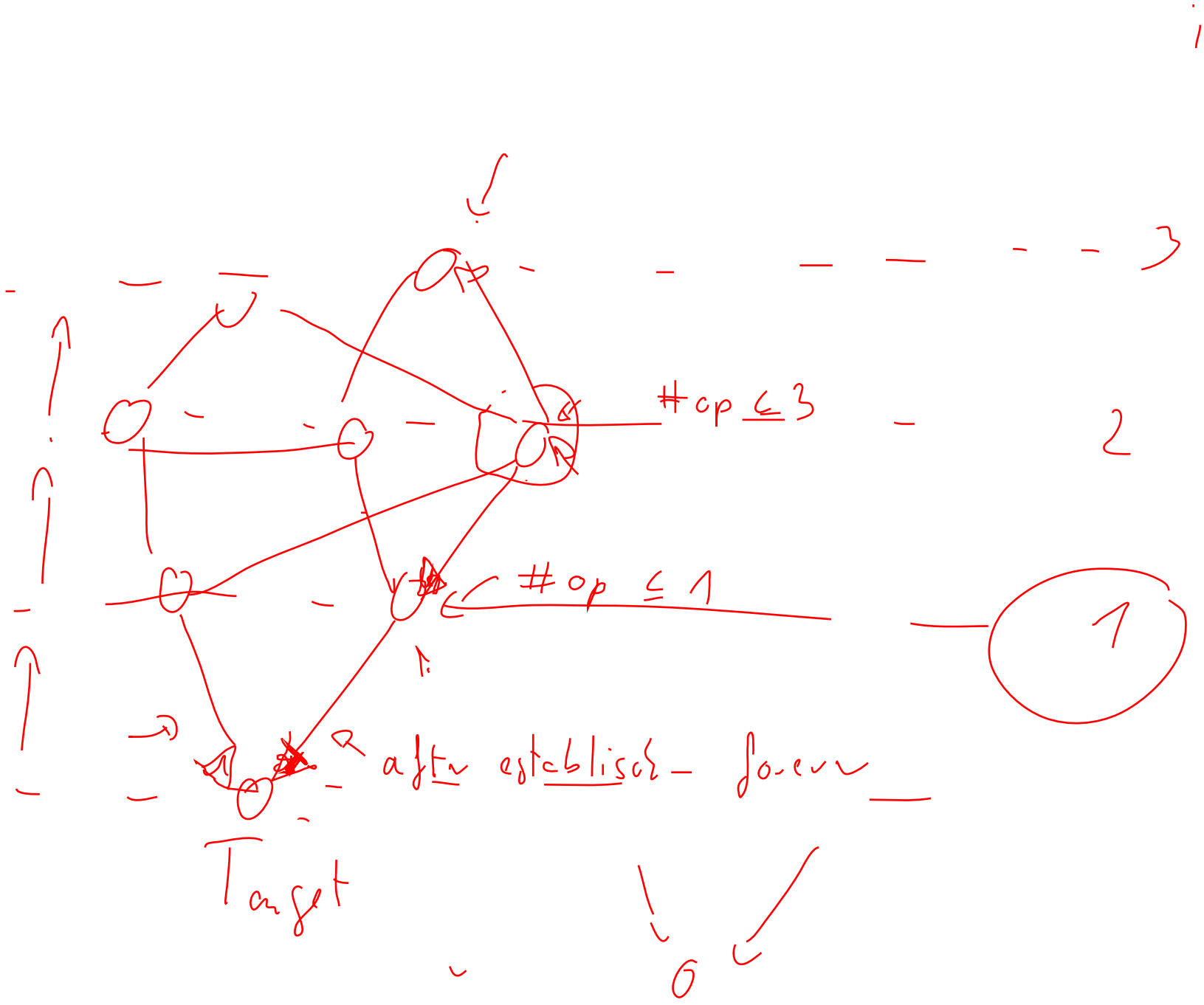


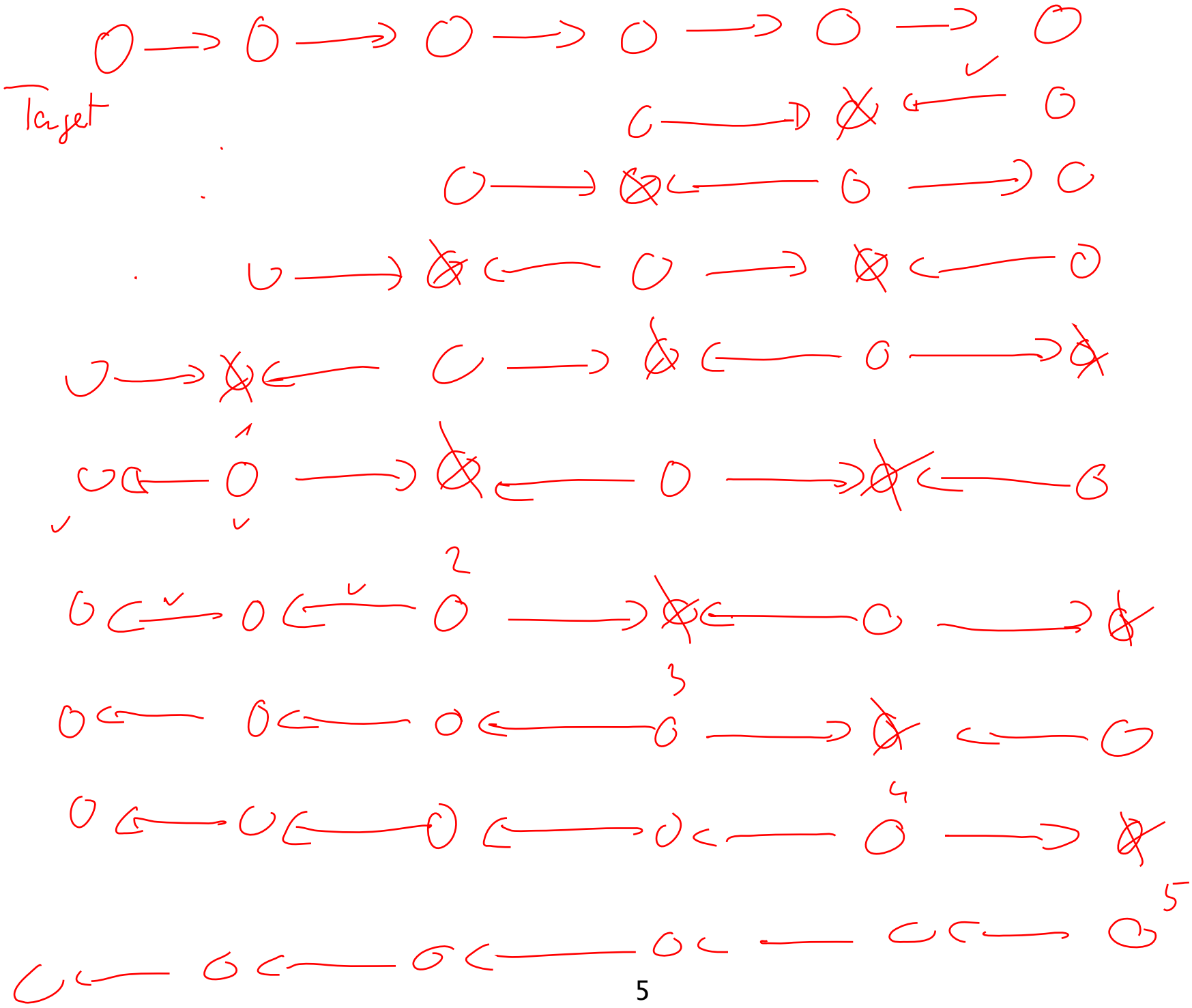


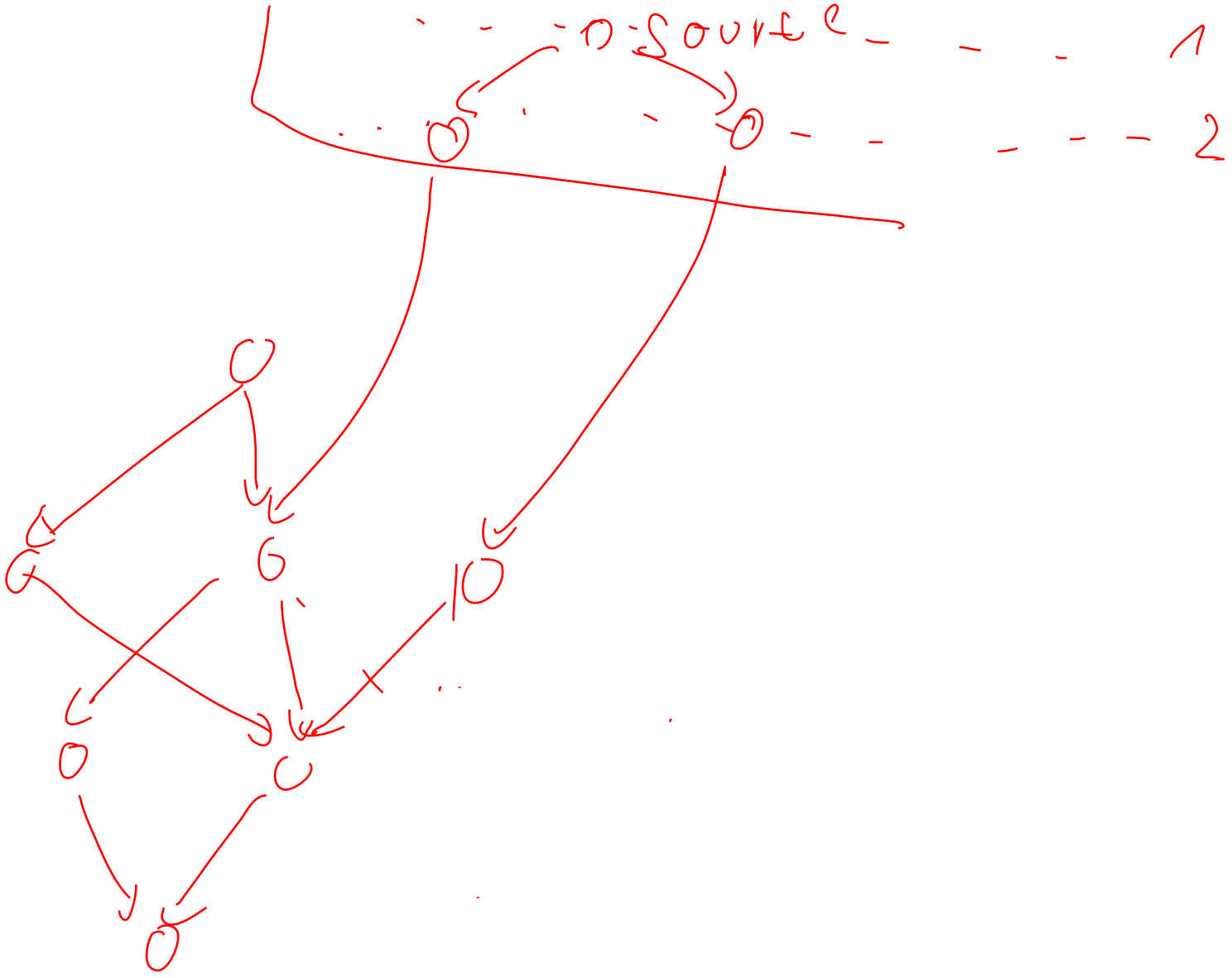


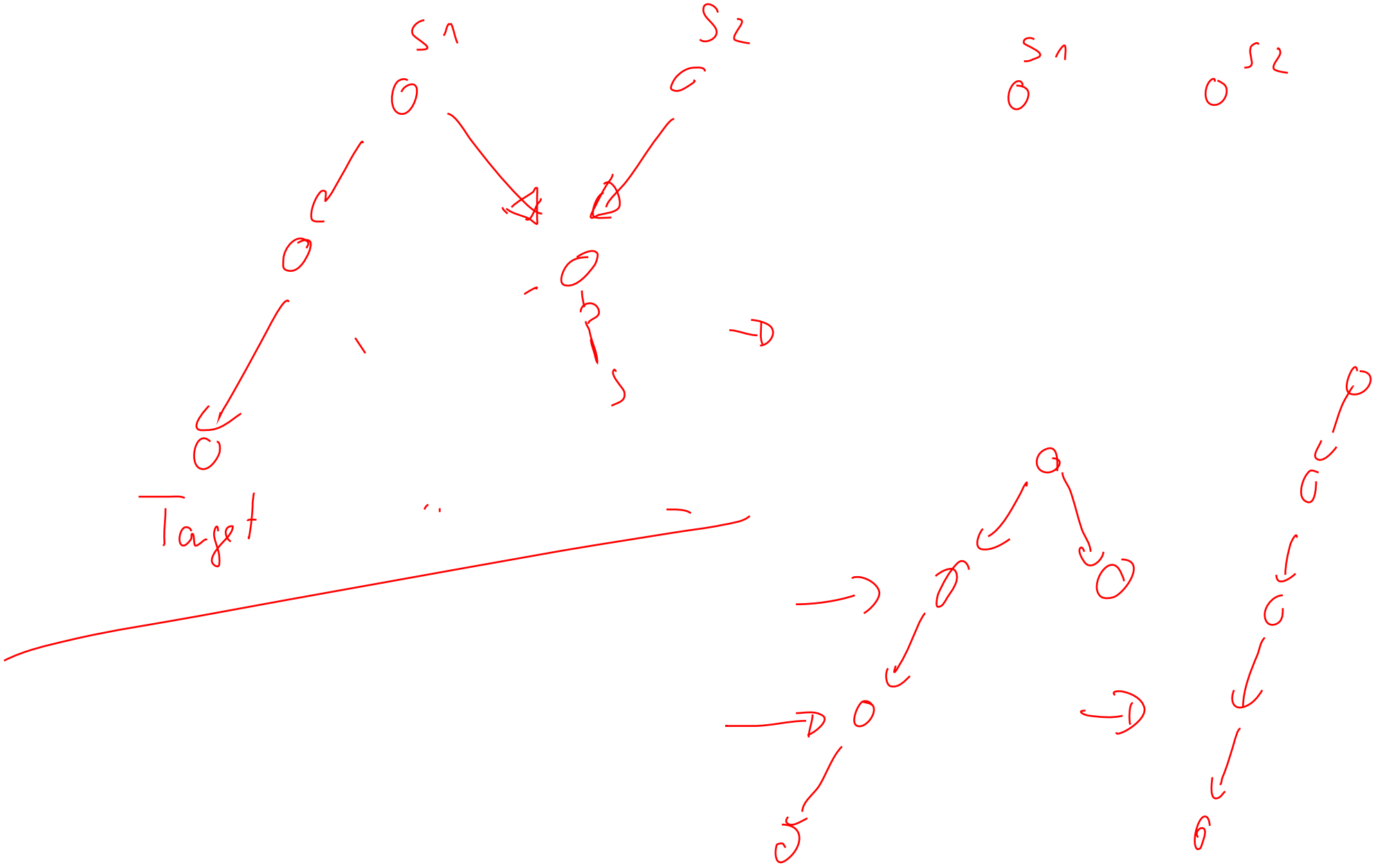
DAG

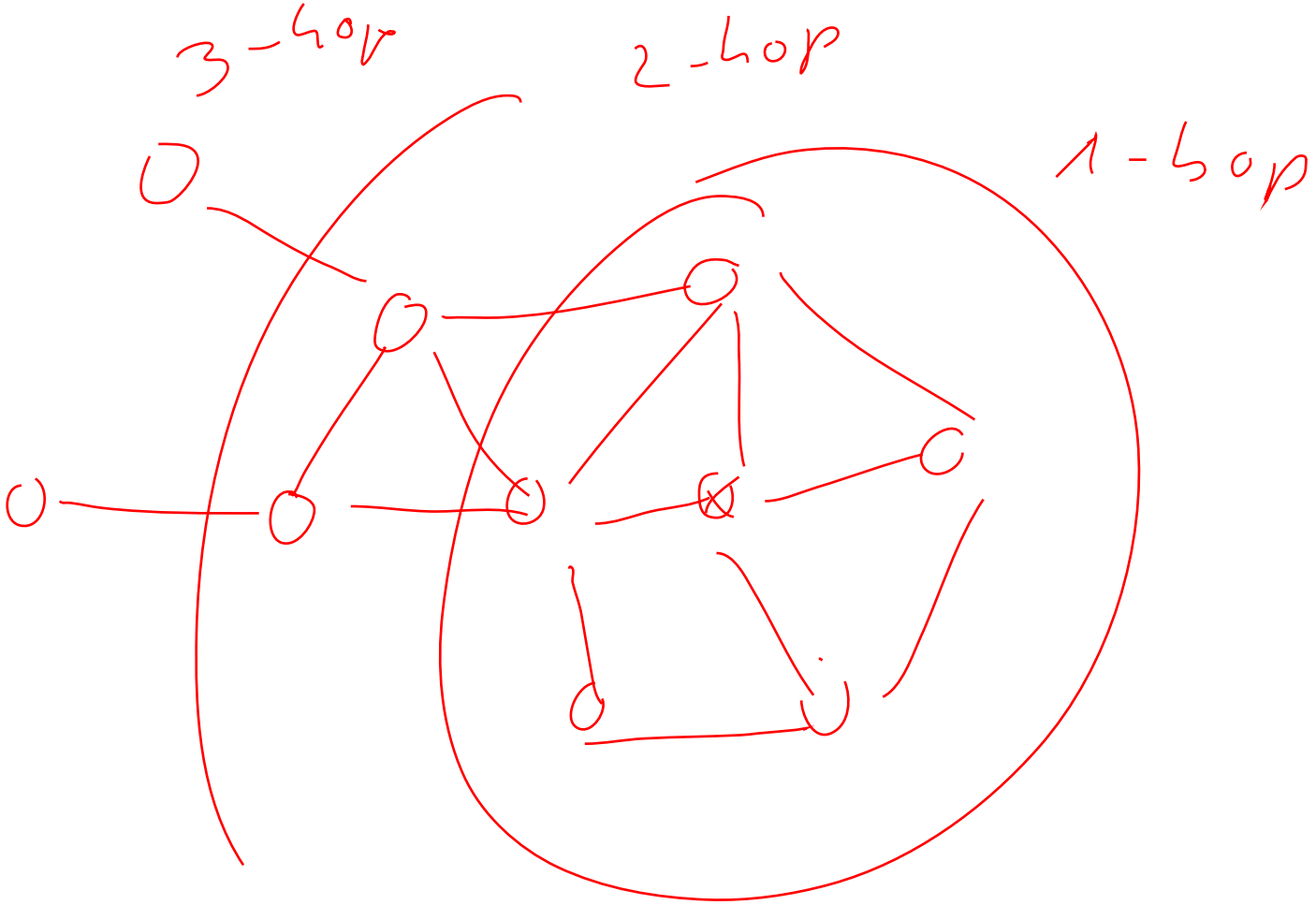


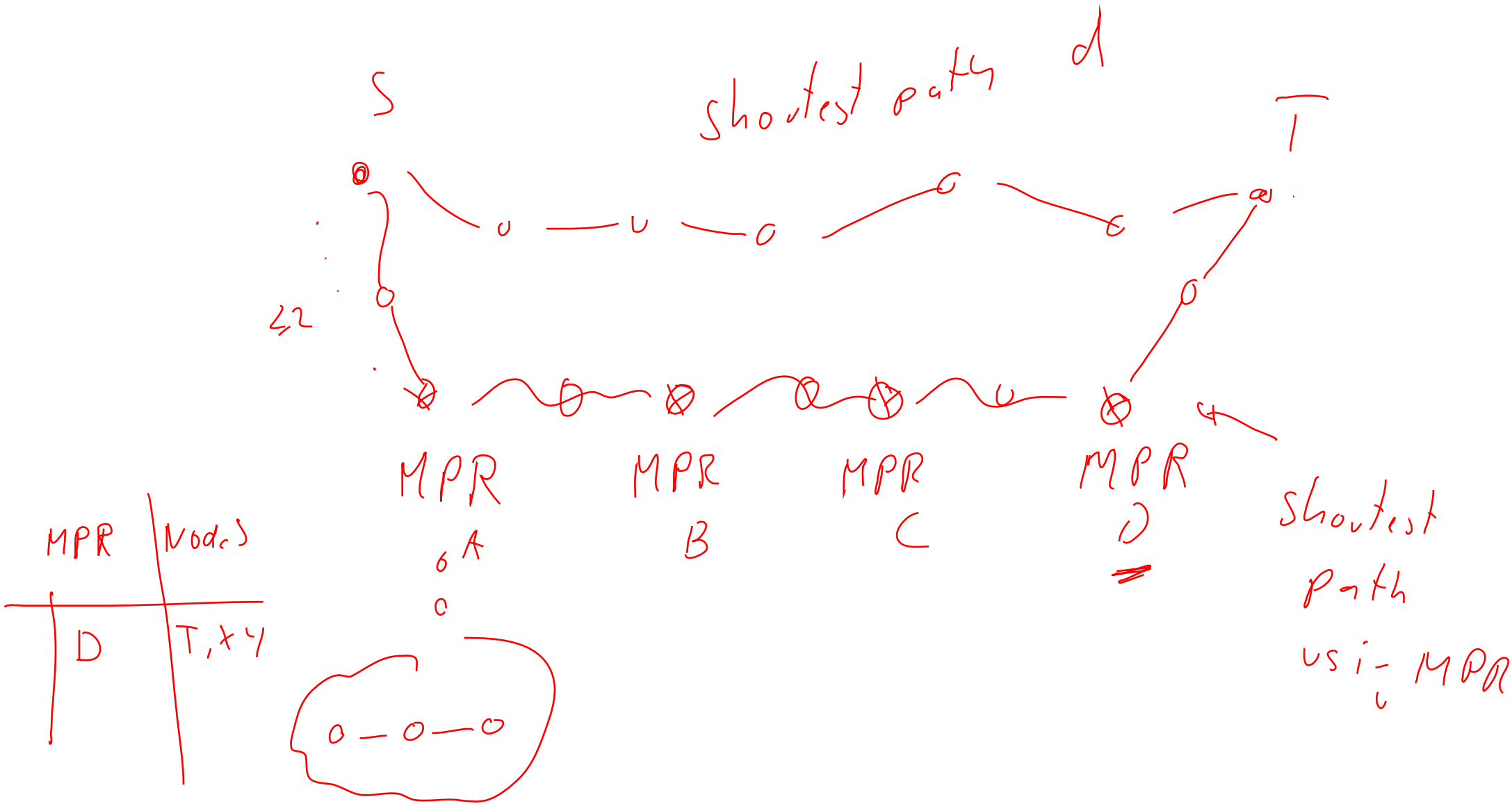

#op ≤ 3
#op ≤ 1
after establish
Target


Target


source
target
of the sink


S1
S2
Target


3-hop
2-hop
1-hop


S
shortest path
d
T
≤2
MPR
A
MPR
B
MPR
C
MPR
D
shortest
path
using MPR
MPR
Node's
D
T, xy

SP

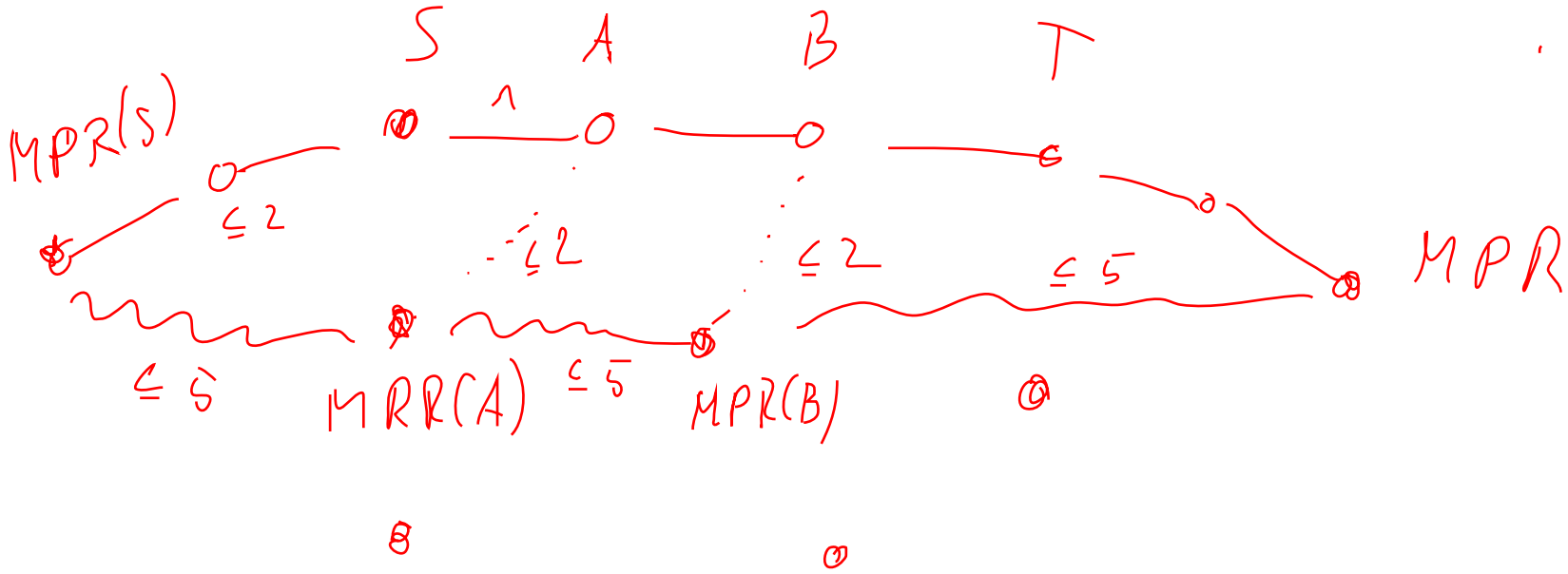
d

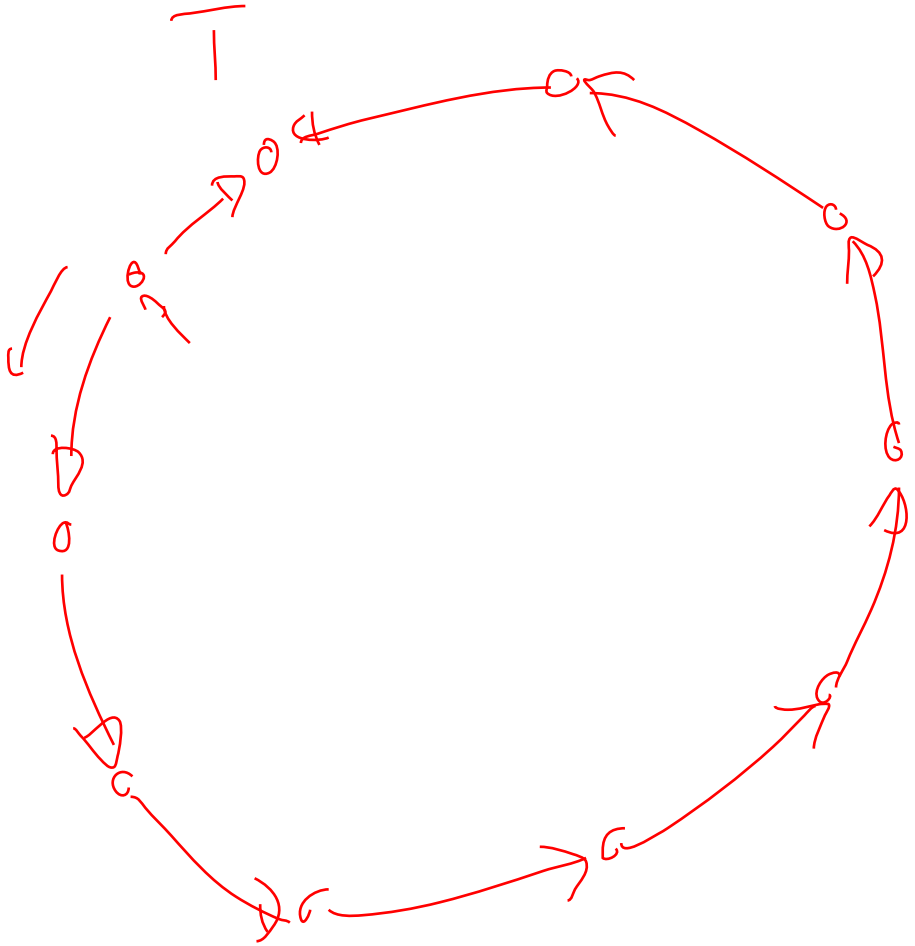
$3 \rightarrow 2 + 3 \cdot \bar{5} + 2$

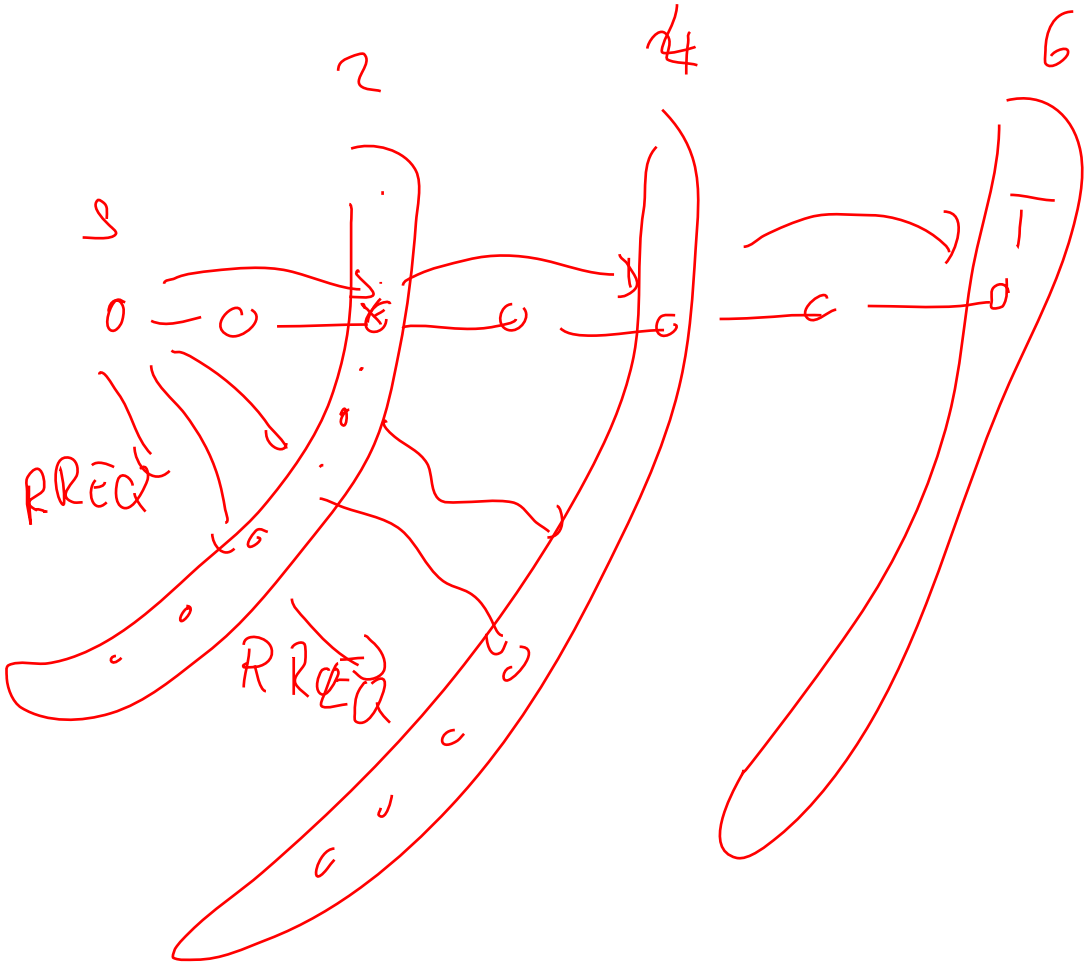
$d \rightarrow 2 + d \cdot \bar{5} + 2$

OLSR

$\leq \bar{5} d + 4$






2
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6
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RREQ
RREQ