Wireless Sensor Networks

5. Routing

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Routing in MANETs

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

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Routing Protocols

MANet
-Mobile -Ad hoc -Networks

- **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**)

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Trade-Off

- Latency because of route discovery
  - Proactive protocols are faster
  - Reactive protocols need to find routes
- Overhead of Route discovery and maintenance
  - Reactive protocols have smaller overhead (number of messages)
  - Proactive protocols may have larger complexity
- Traffic-Pattern and mobility
  - decides which type of protocol is more efficient

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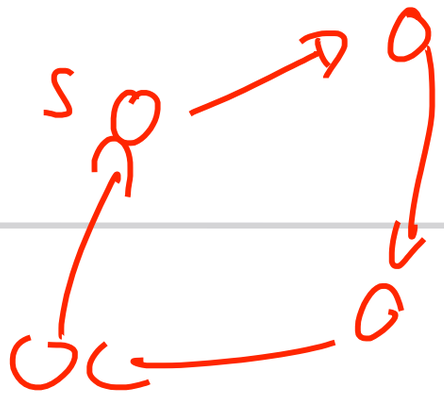
Flooding



- Algorithm
  - Sender S broadcasts data packet to all neighbors
  - Each node receiving a new packet
    - broadcasts this packet
    - if it is not the receiver
- Sequence numbers
  - identifies messages to prevent duplicates
- Packet always reaches the target
  - if possible

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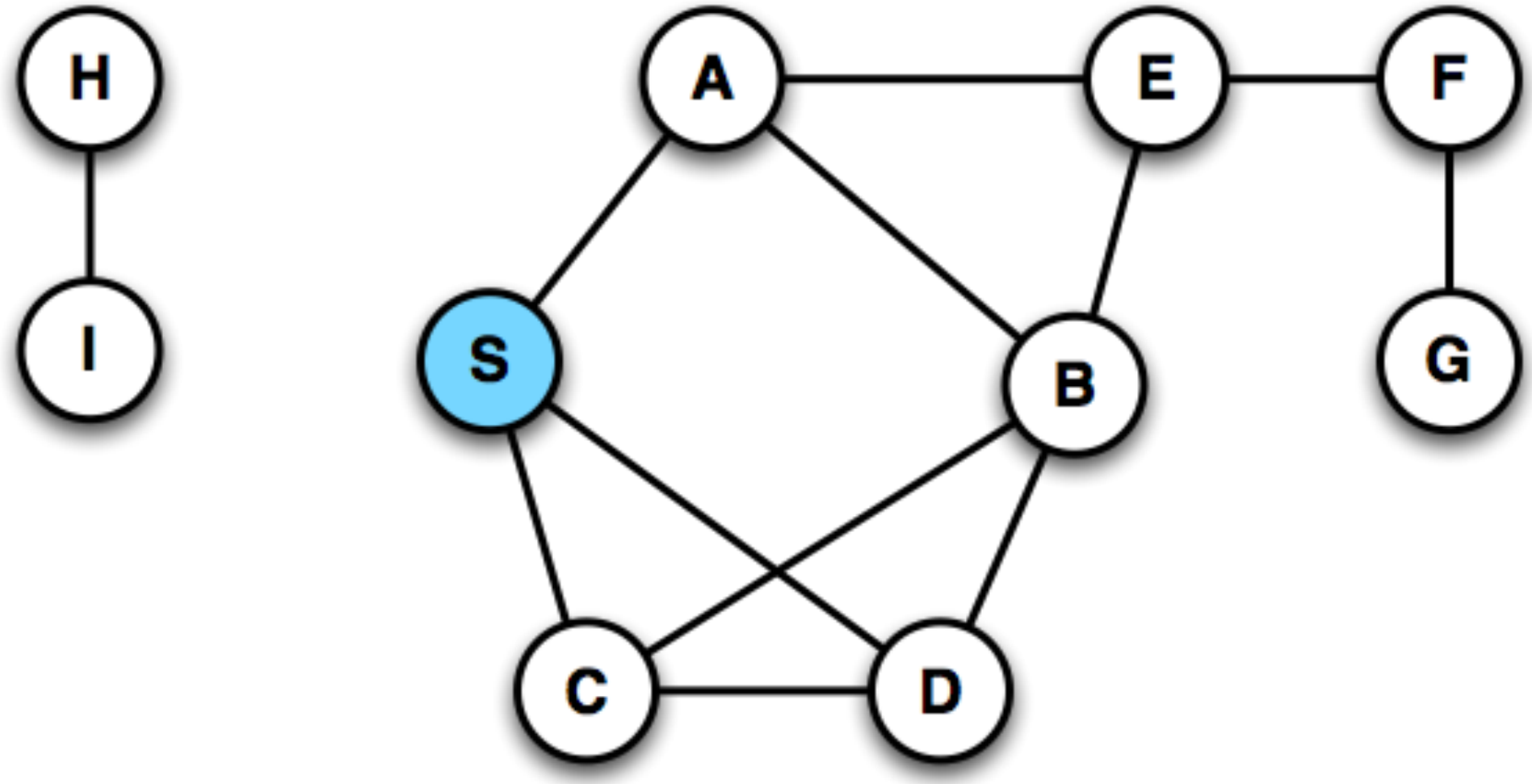
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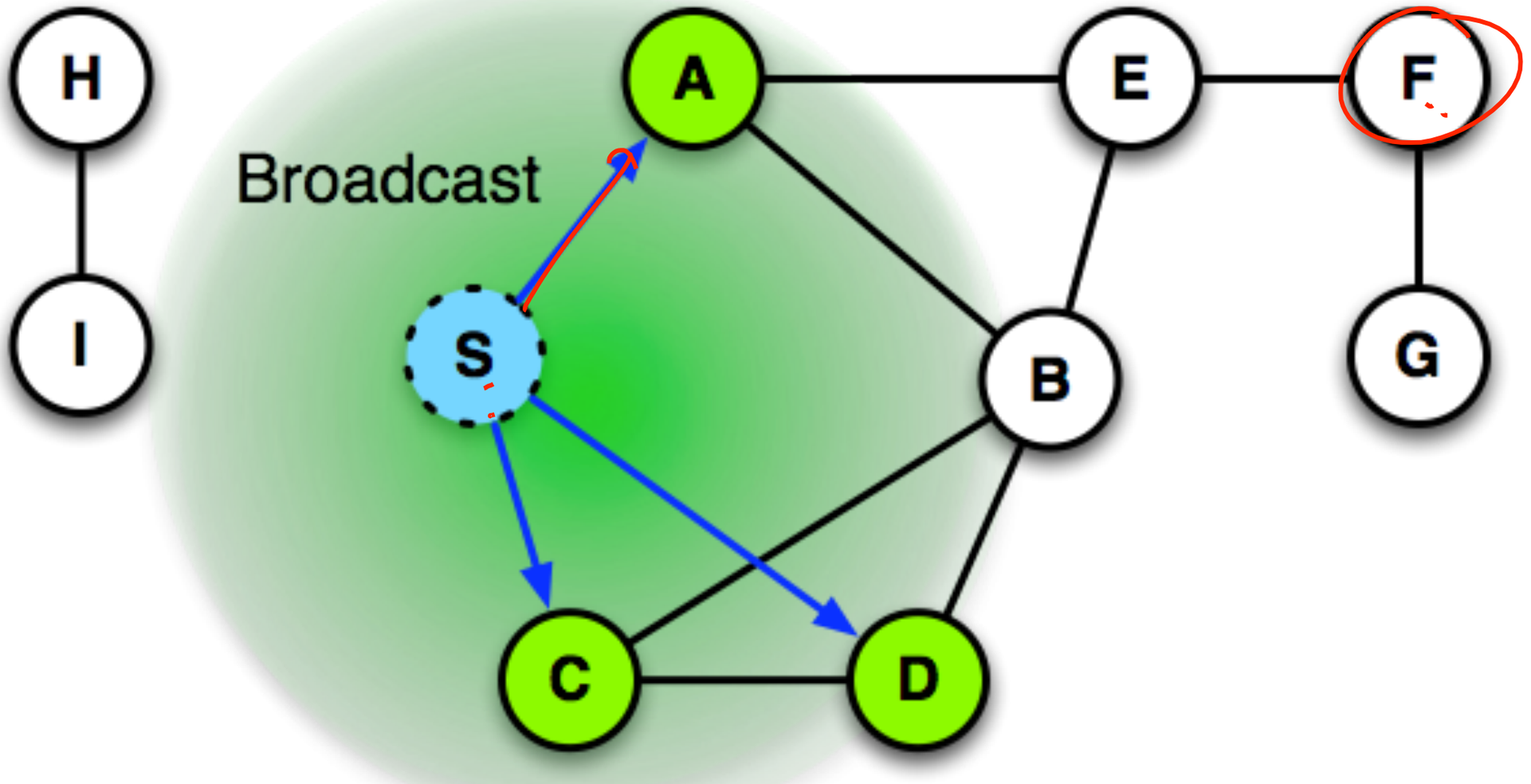
WSN

- Convergecast
  All-to-One

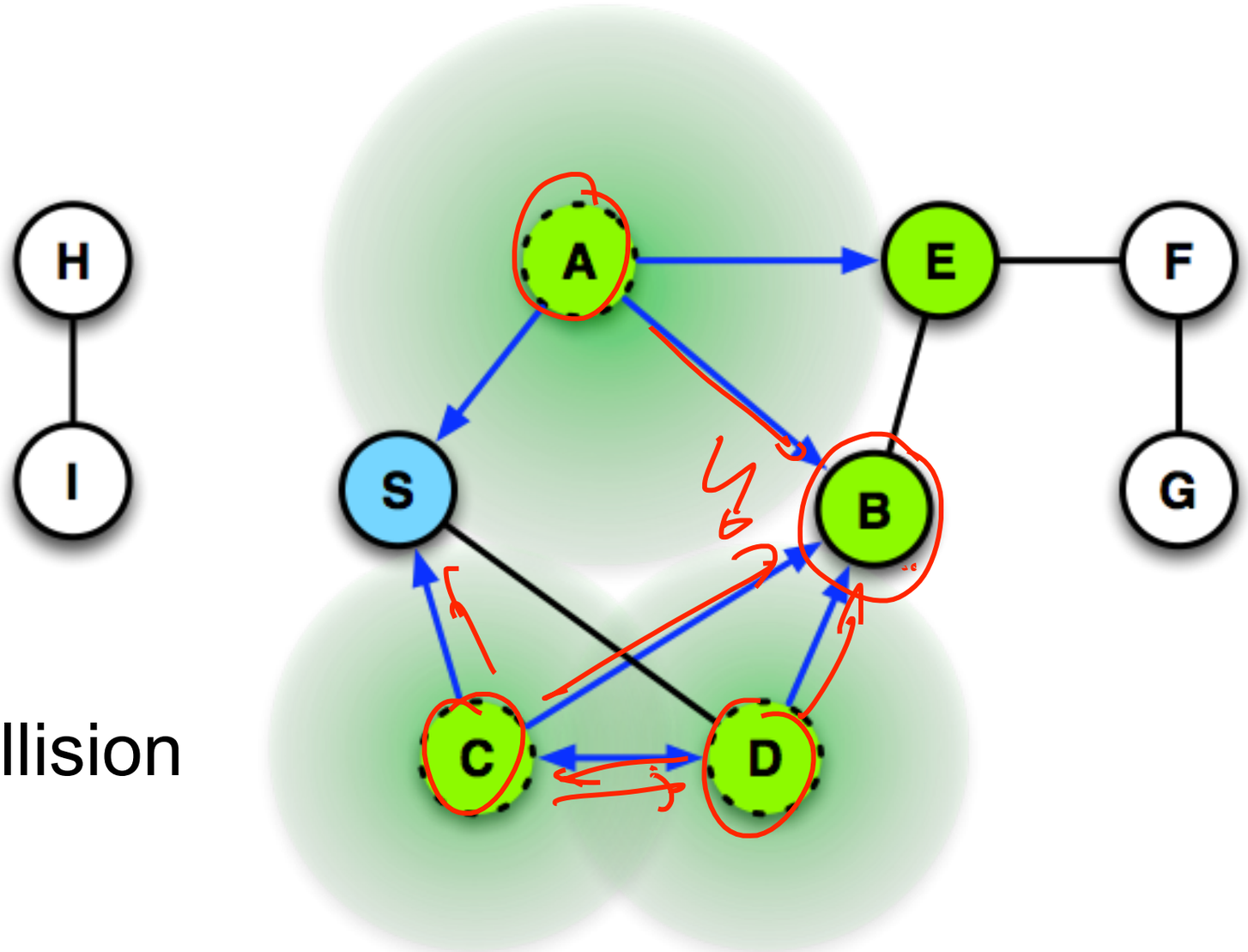
- Unicast
- Broadcast
- Multicast

Point-to-Point
One to all
One to Group/Some



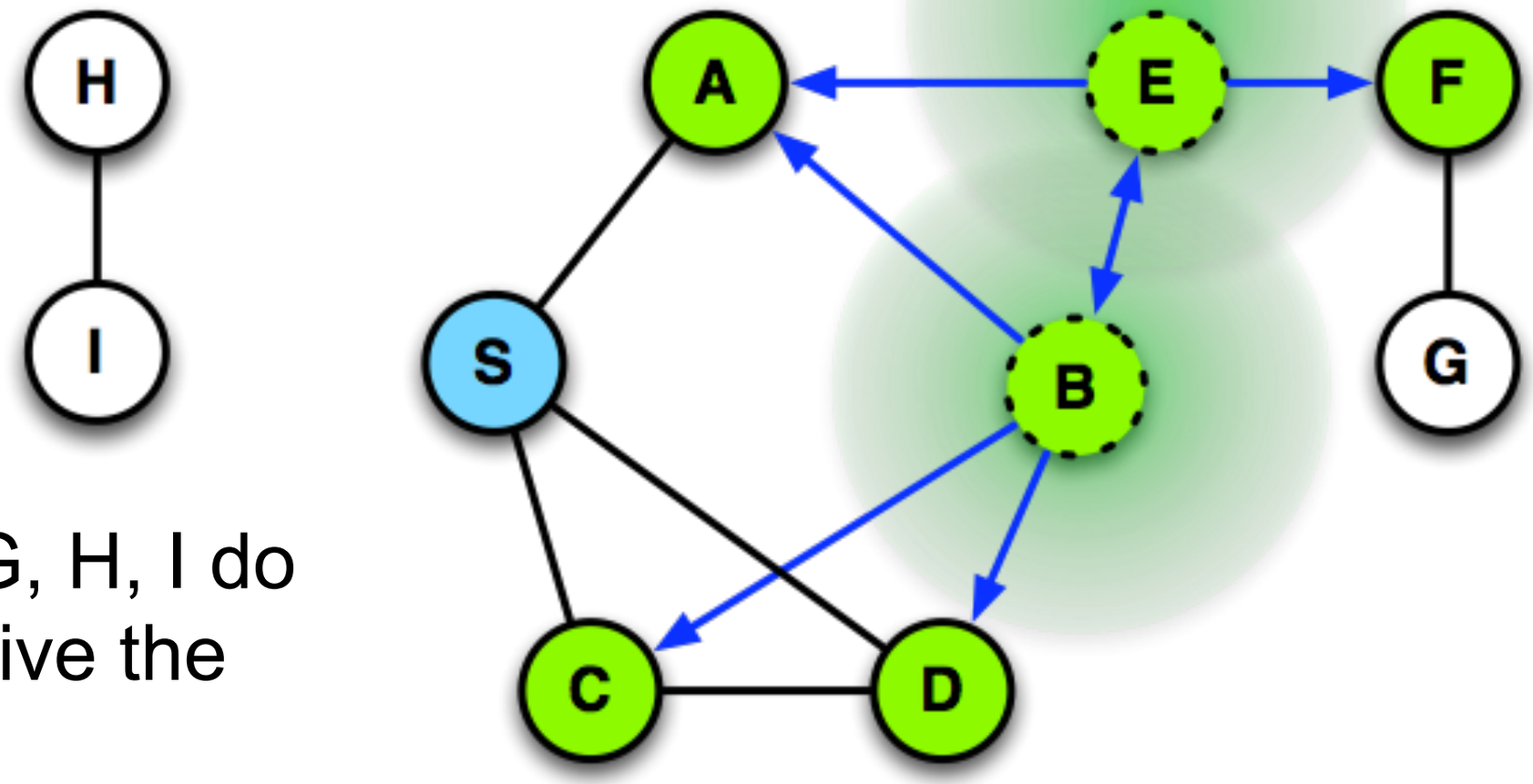
Packet for Receiver F

MAC - Layer



Possible collision at B

Receiver F gets packet and stops



Nodes G, H, I do not receive the packet

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Flooding

- Advantage
  - simple and robust
  - the best approach for short packet lengths, small number of participants in highly mobile networks with light traffic
- Disadvantage
  - High overhead
  - Broadcasting is unreliable
    - lack of acknowledgements
    - hidden, exposed terminals lead to data loss or delay

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Flooding

- Produces too many unnecessary (long) data packets
  - in the worst case, each participant sends each packet
  - many long transmissions collisions lead to long waiting times in the medium access
- Better approach:
  - Use of control packets for route determination
  - Flooding of control packet leads to DSR

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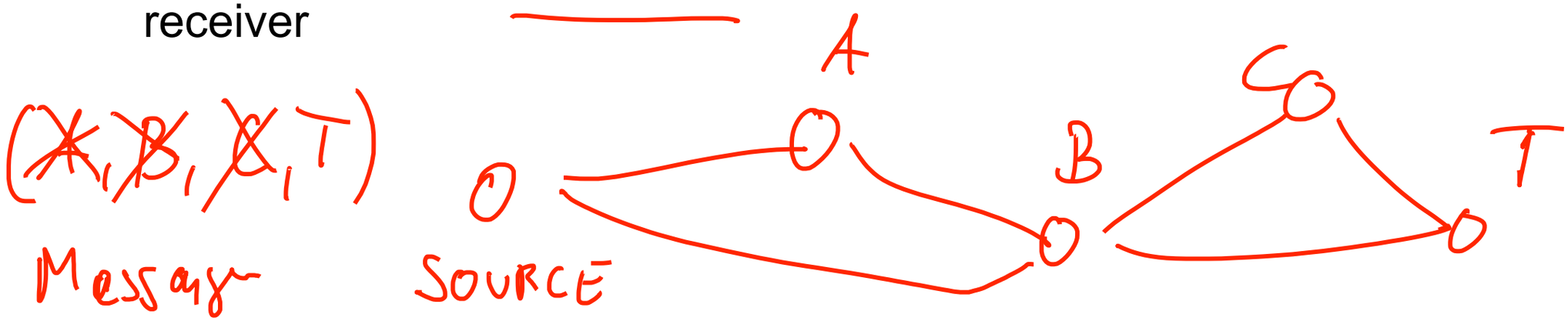
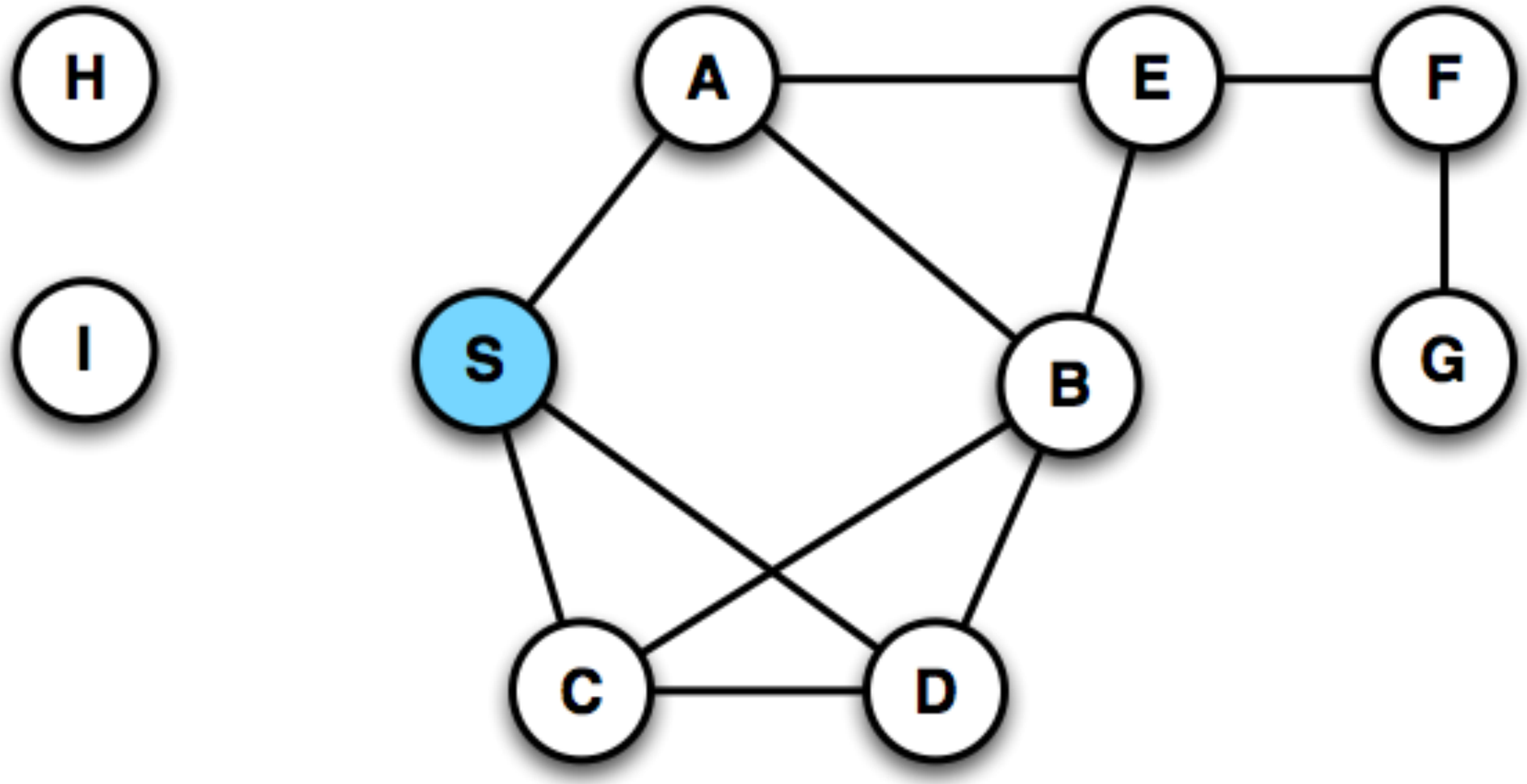
Dynamic Source Routing (DSR)

- Johnson, Maltz
  - *Dynamic Source Routing in Ad Hoc Wireless Networks*, Mobile Computing, 1996
- Algorithm
  - Sender initiates route discovery by flooding of **Route-Request (RREQ)**-packets
    - Each forwarding node appends his ID to the RREQ-packet
  - The receiver generates the routing information from the RREQ packet by producing a **Route-Reply (RREP)-**packet
    - using the route information of the packet is sent back to the sender
  - Transmitter sends **data packet** along with route information to the receiver

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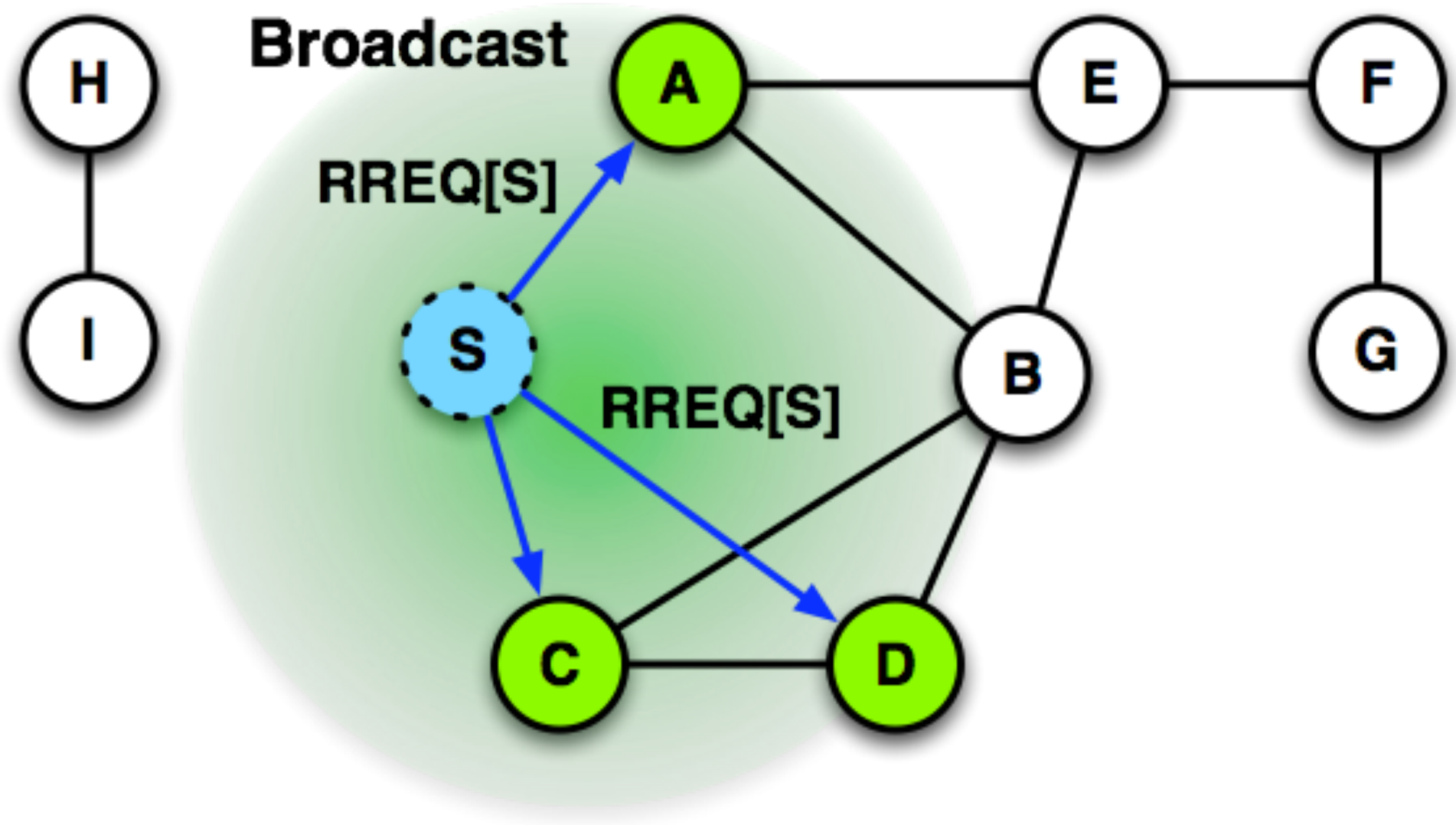
Broadcast
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RREQ[S]
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RREQ[S]
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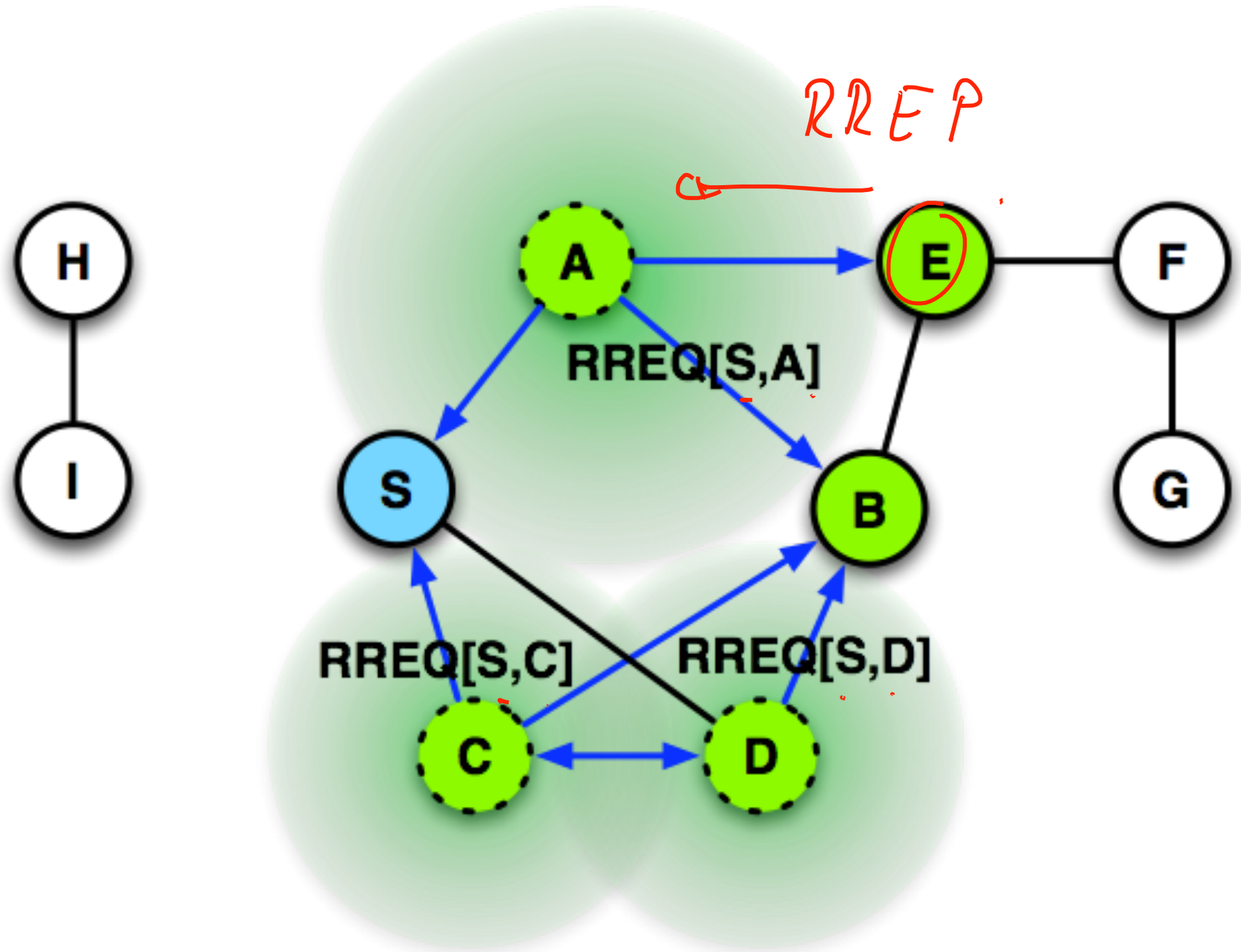
RREP
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RREQ[S,A]
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RREQ[S,C]
RREQ[S,D]
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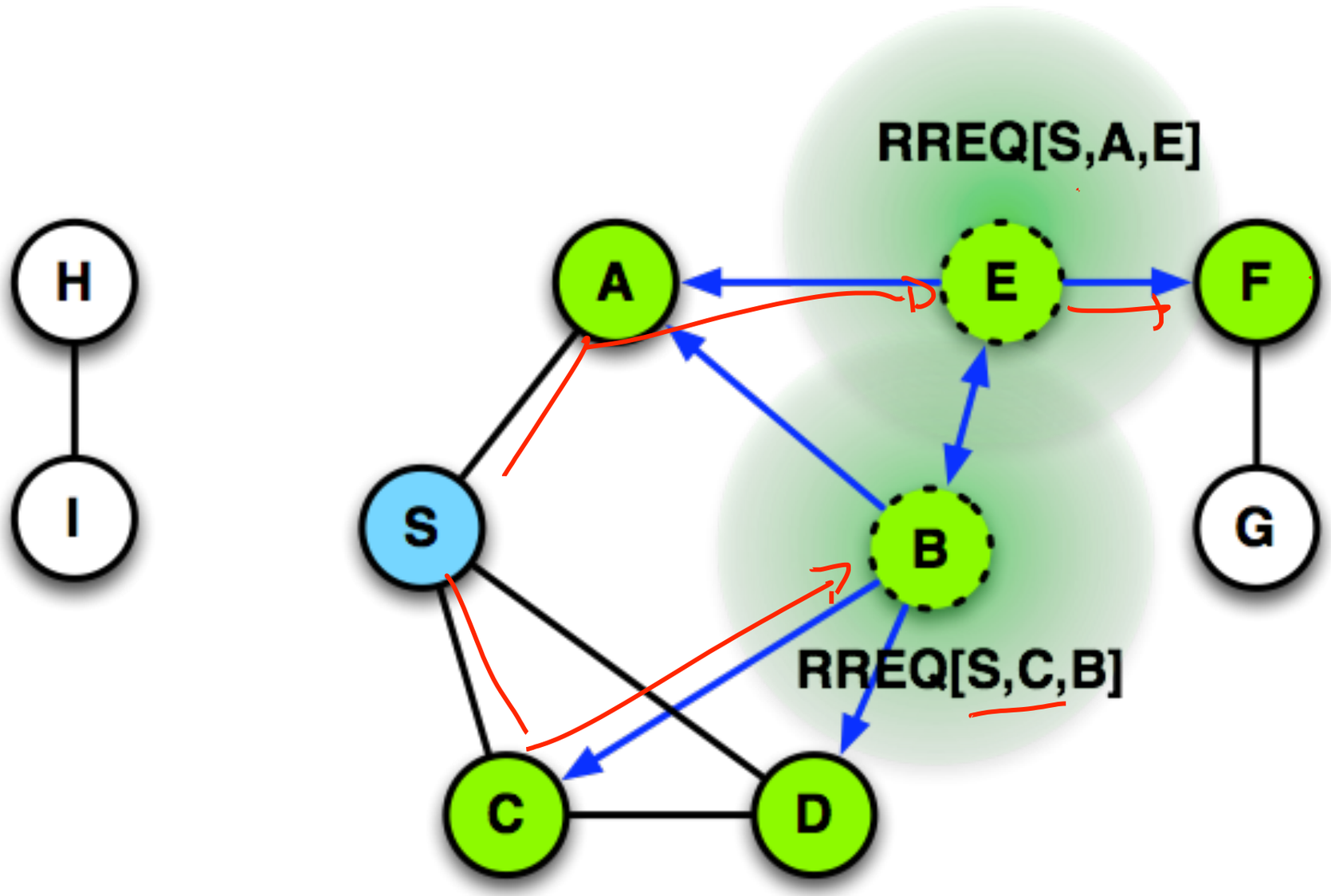
RREQ[S,A,E]
SAEF
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RREQ[S,C,B]
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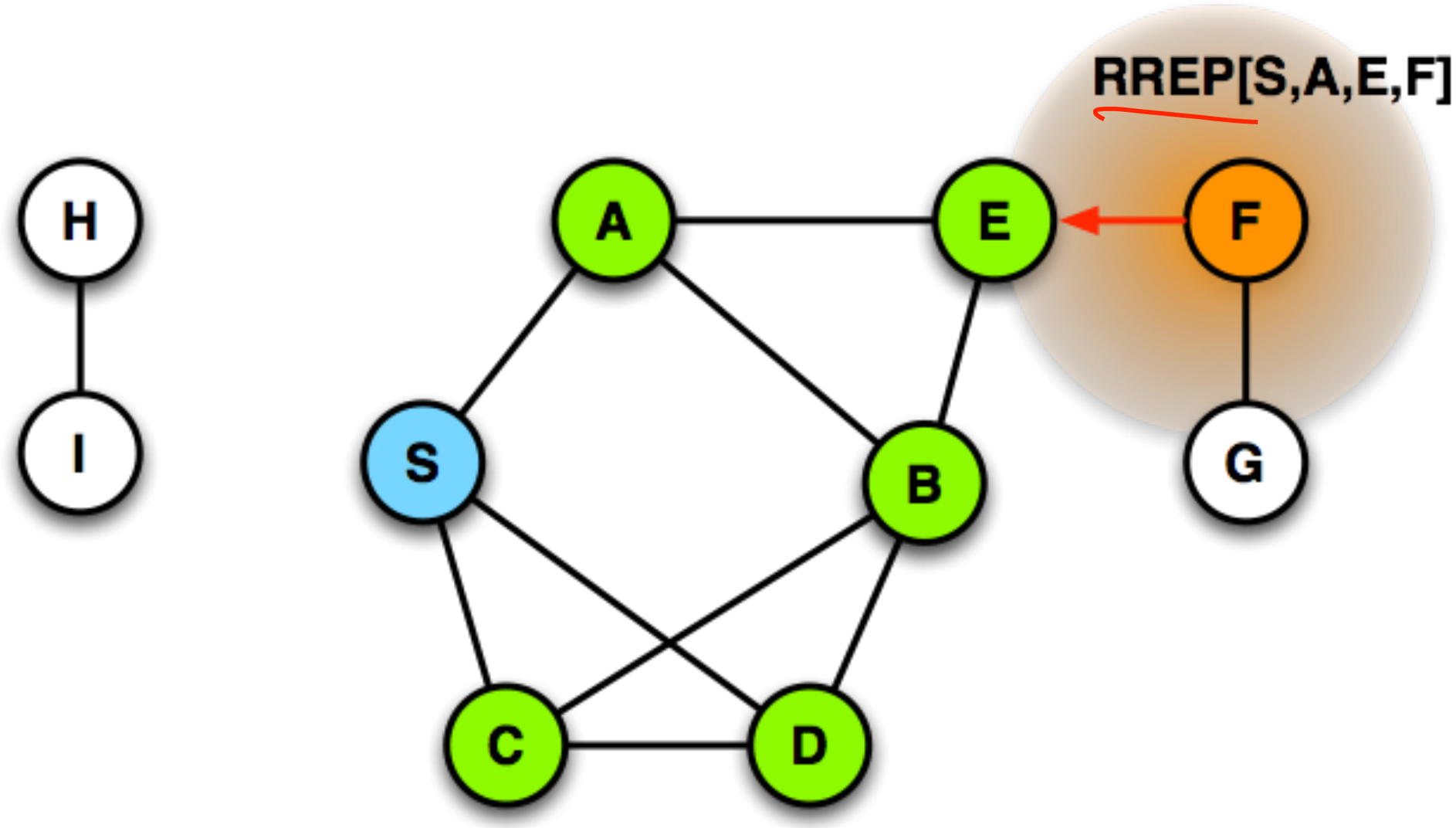
RREP[S,A,E,F]
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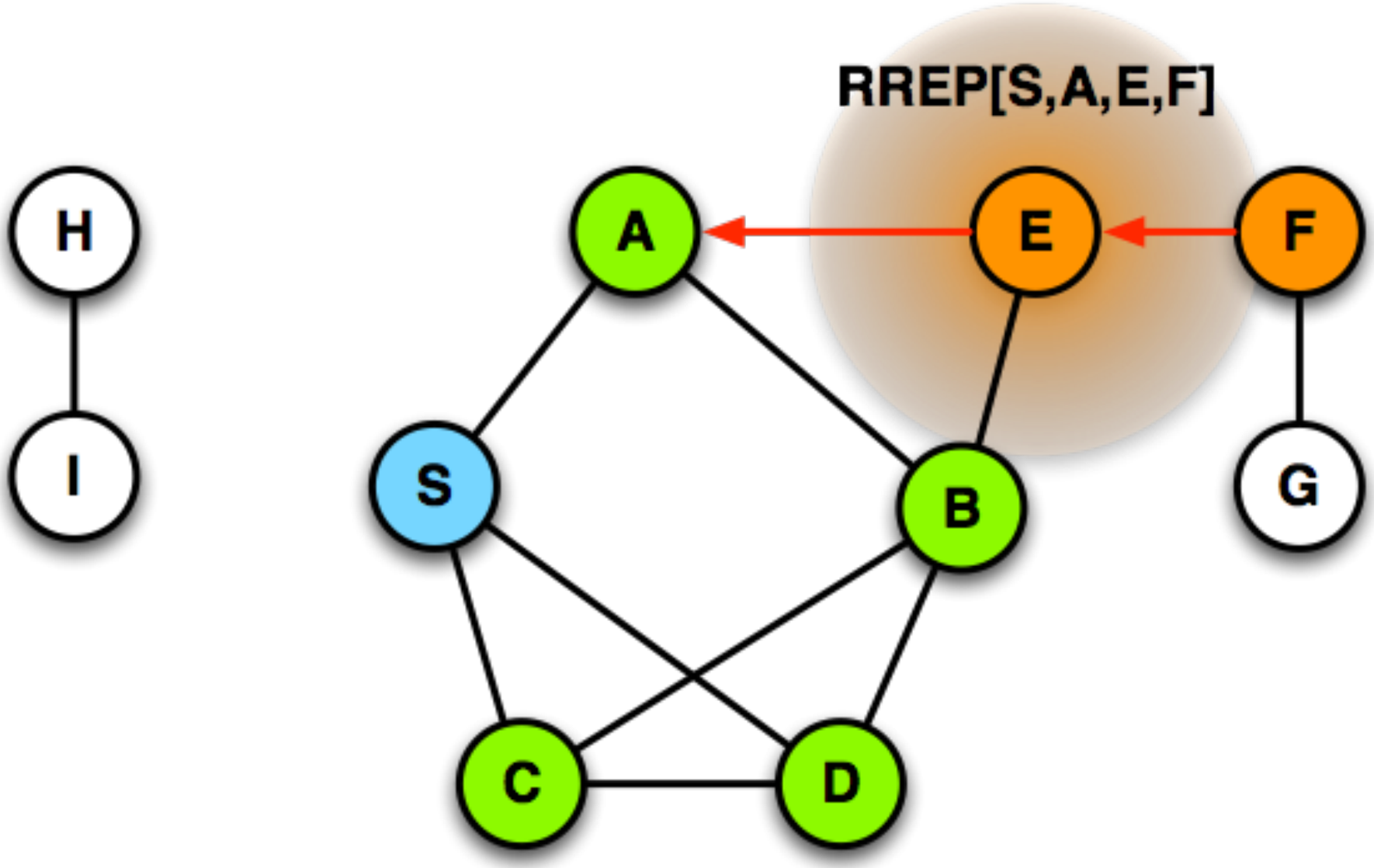
RREP[S,A,E,F]
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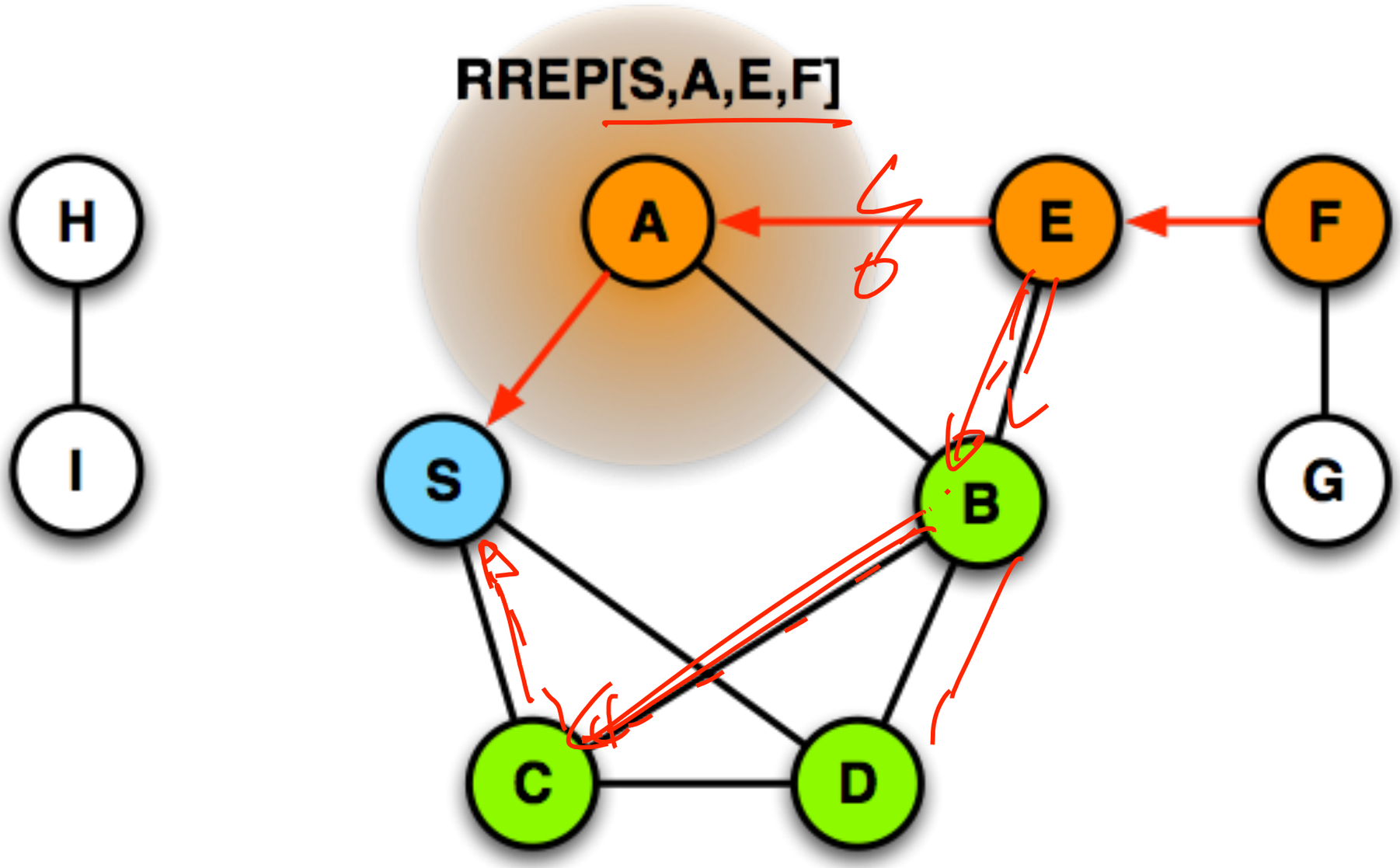
RREP[S,A,E,F]
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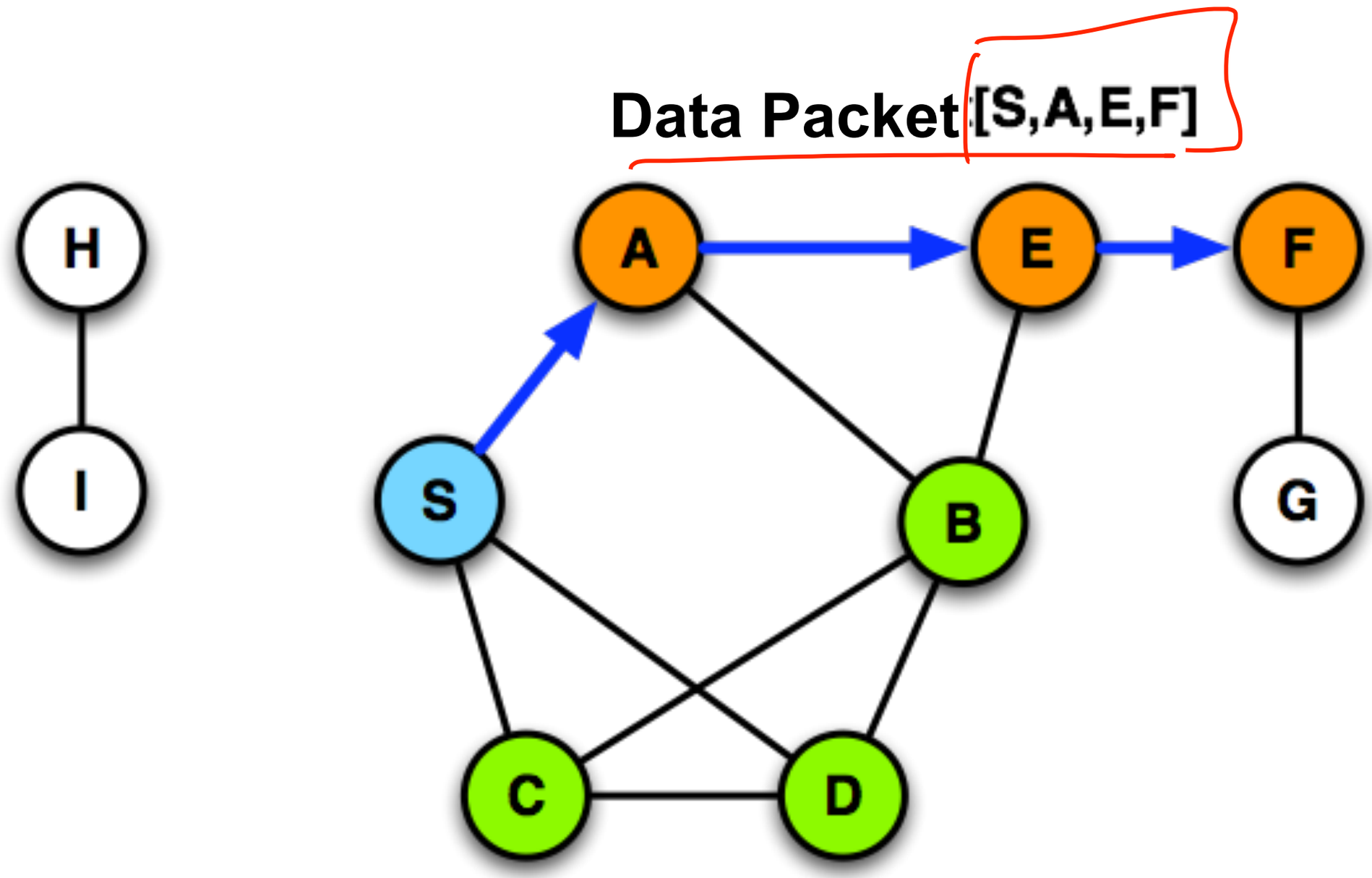
Data Packet [S,A,E,F]
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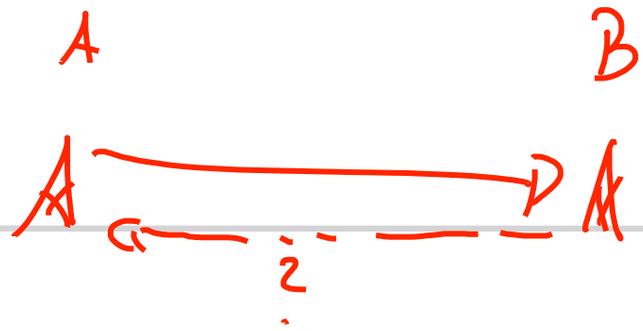
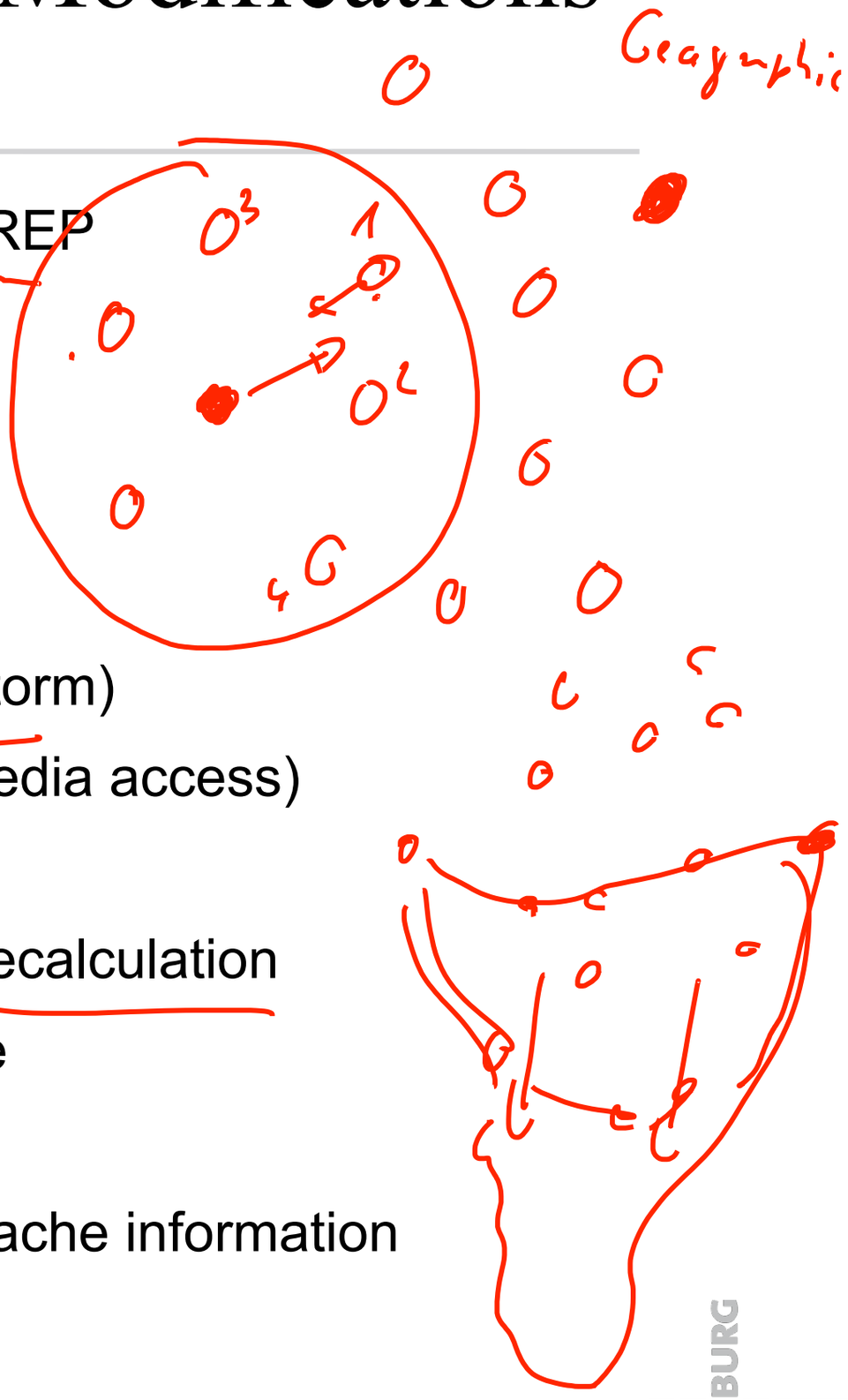
Requirements



- Route Reply
  - requires bidirectional connections
  - unidirectional links
    - must be tested for symmetry
    - or Route-Reply must trigger its own route-request
- Data packet has all the routing information in the header
  - hence: Source-Routing
- Route determination
  - if no valid route is known

DSR Extensions and Modifications

- Intermediate nodes can cache information RREP
  - Problem: stale information
- Listening to control messages
  - can help to identify the topology
- Random delays for answers
  - To prevent many RREP-packets (Reply-Storm)
  - if many nodes know the answer (not for media access)
- Repair
  - If an error is detected then usually: route recalculation
  - Instead: a local change of the source route
- Cache Management
  - Mechanisms for the deletion of outdated cache information



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DSR Optimization Route Caching

- Each node stores information from all available
  - Header of data packets
  - Route Request
  - Route-Reply
  - partial paths
- From this information, a route reply is generated

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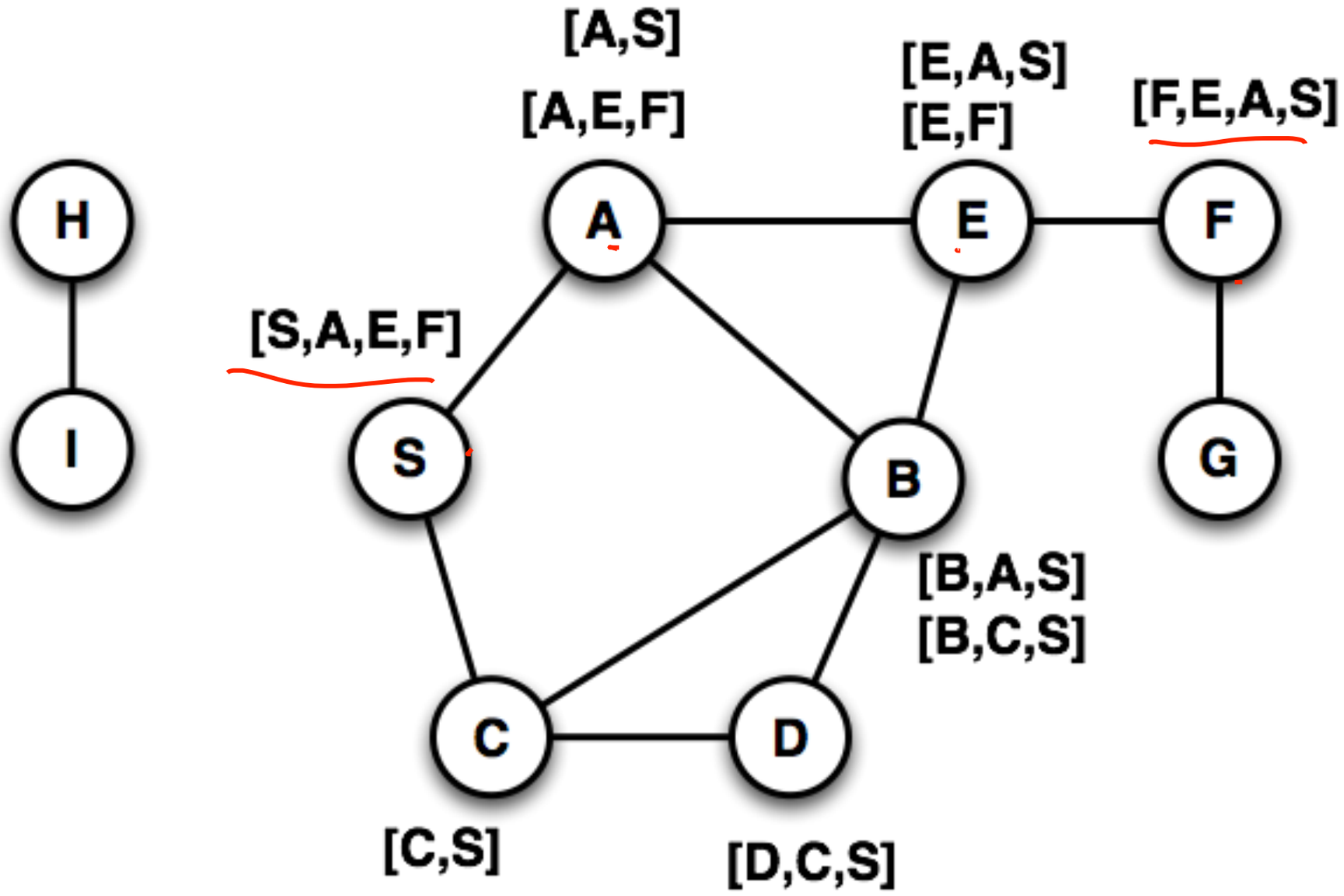
[A,S]
[A,E,F]
[E,A,S]
[E,F]
[F,E,A,S]
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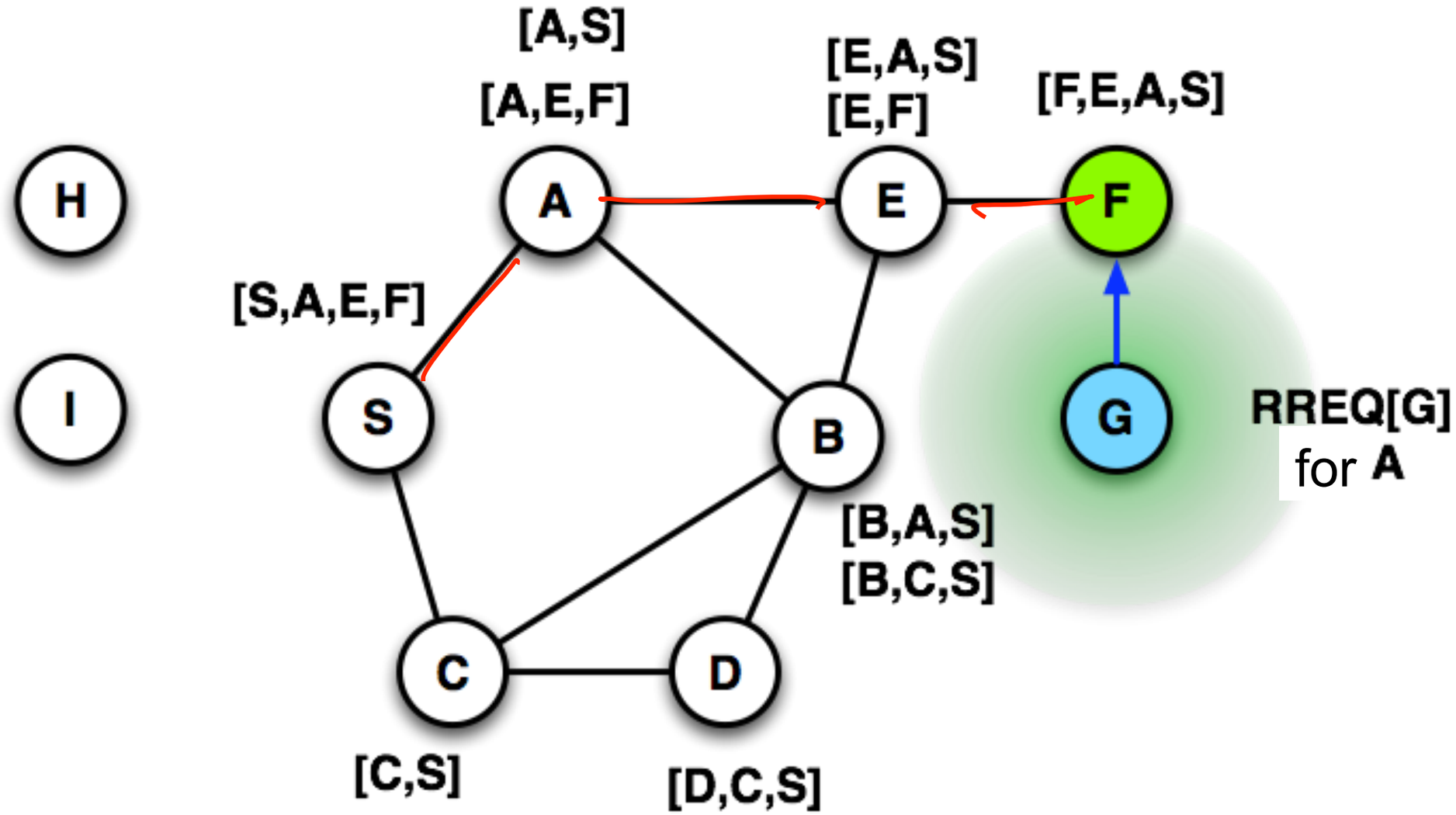
[A,S]
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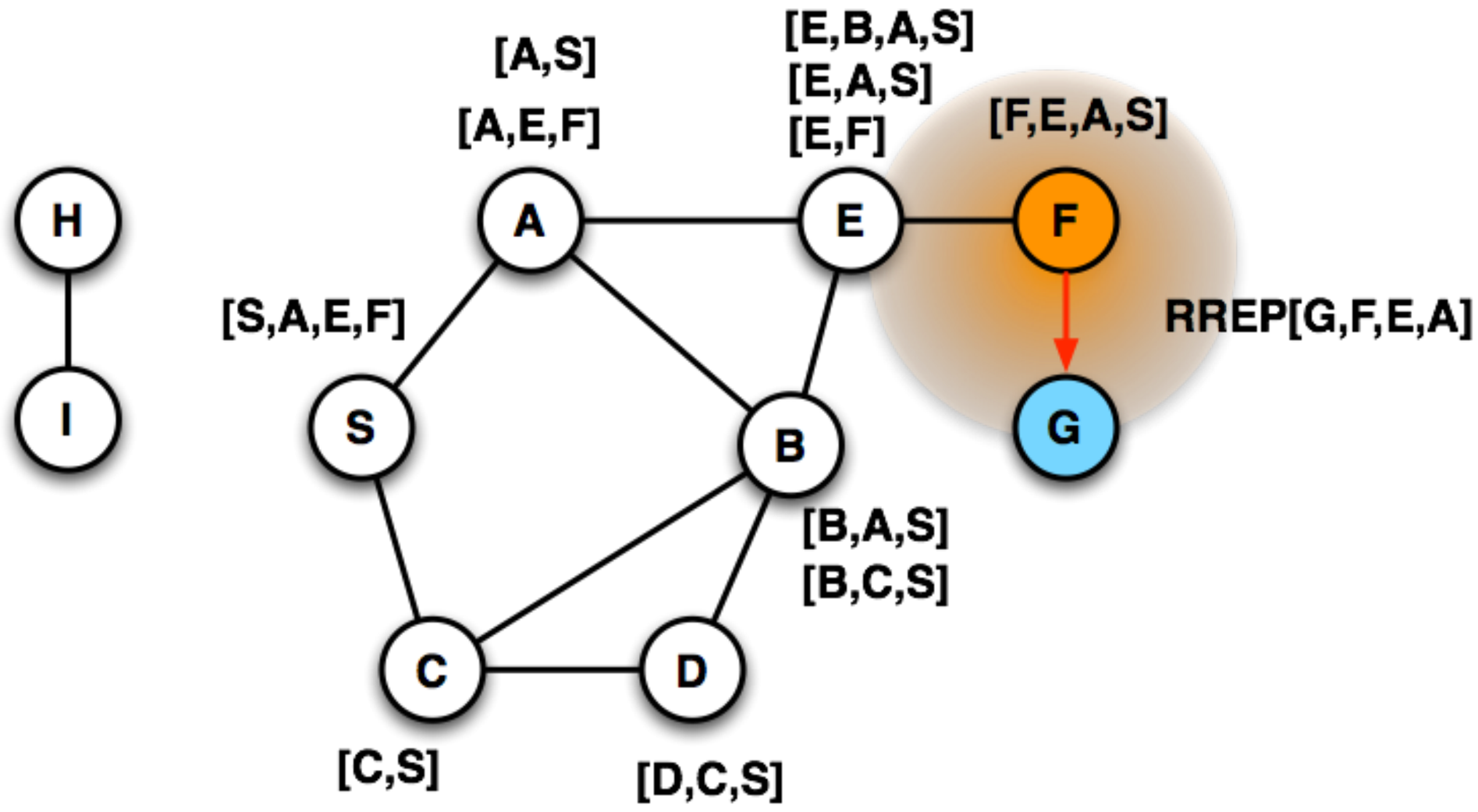
[A,S]
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RREP[G,F,E,A]
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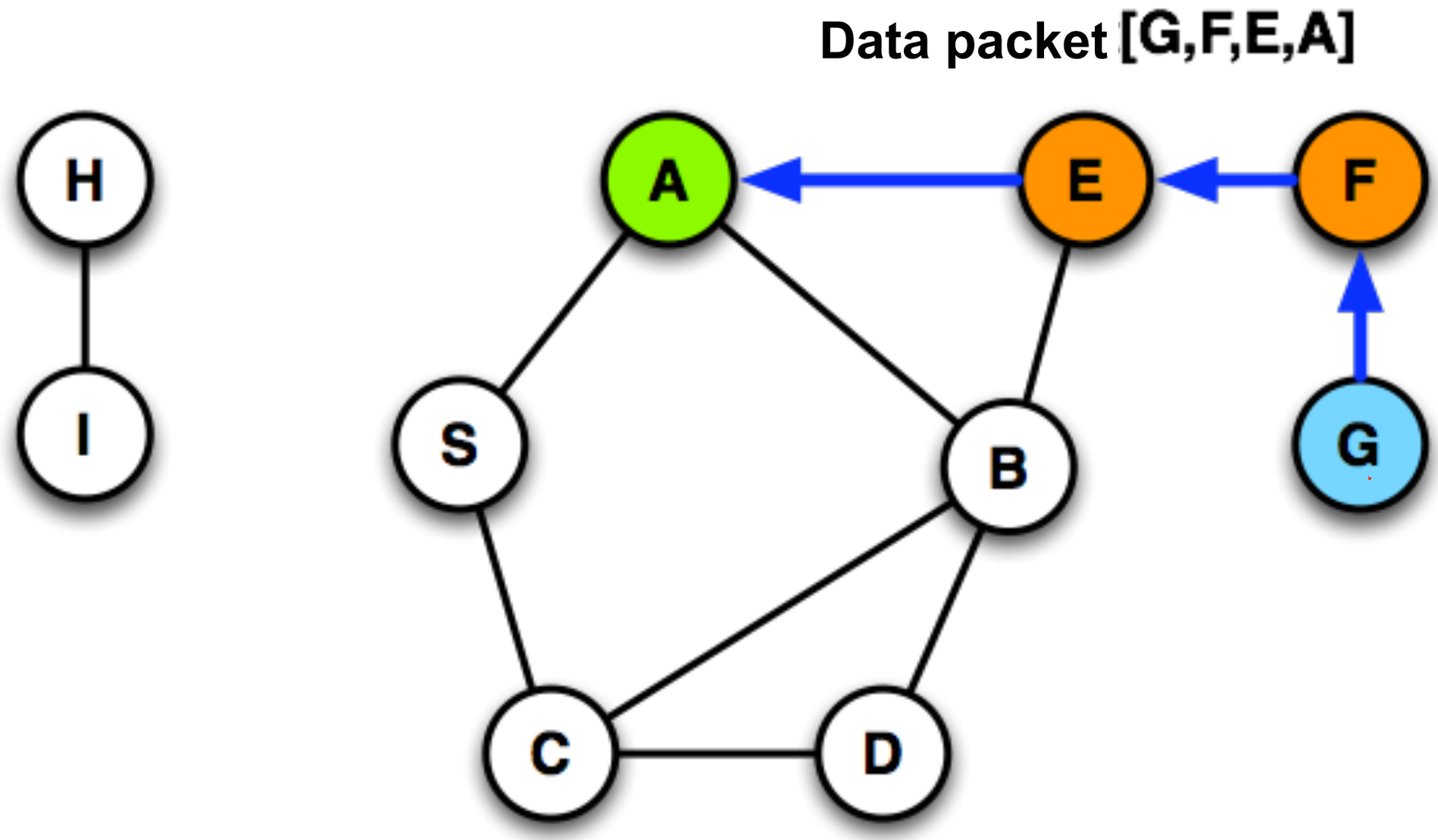
Data packet [G,F,E,A]
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DSR Optimization
Route Caching

Reactive

⋮

Proactive

- If any information is incorrect
  - because a route no longer exists
  - then this path is deleted from the cache
  - alternative paths are used
  - or RREQ is generated
- **Missing links are distributed by (RERR) packets in the network**

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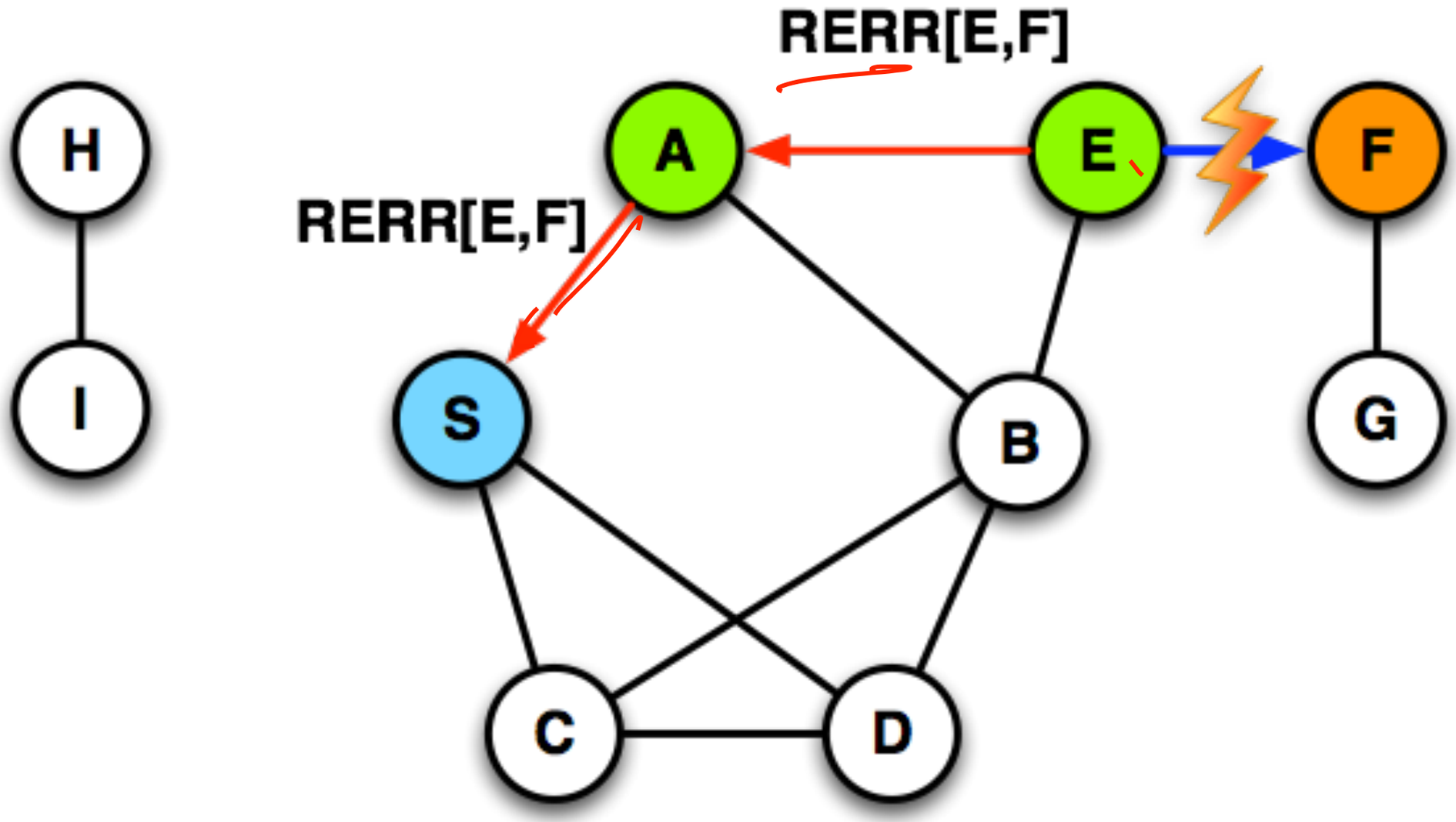
RERR[E,F]
RERR[E,F]
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DSR Discussion

- Benefits
  - Routes are maintained only between communicating nodes
  - Route caching reduces route search
  - Caches help many alternative routes to find
- Disadvantages
  - Header size grows with distance
  - Network may be flooded with route requests
  - Route-Reply-Storm
  - Outdated information may cause cache overhead

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AODV

- Perkins, Royer
  - Ad hoc On-Demand Distance Vector Routing, IEEE Workshop on Mobile Computing Systems and Applications,1999
- ~~Reaktives Routing-Protokoll~~
- Reactive routing protocol
  - Improvement of DSR
    - no source routing
    - Distance Vector Tables
      - but only for nodes with demand
    - Sequence number to help identify outdated cache info
    - Nodes know the origin of a packet and update the routing table

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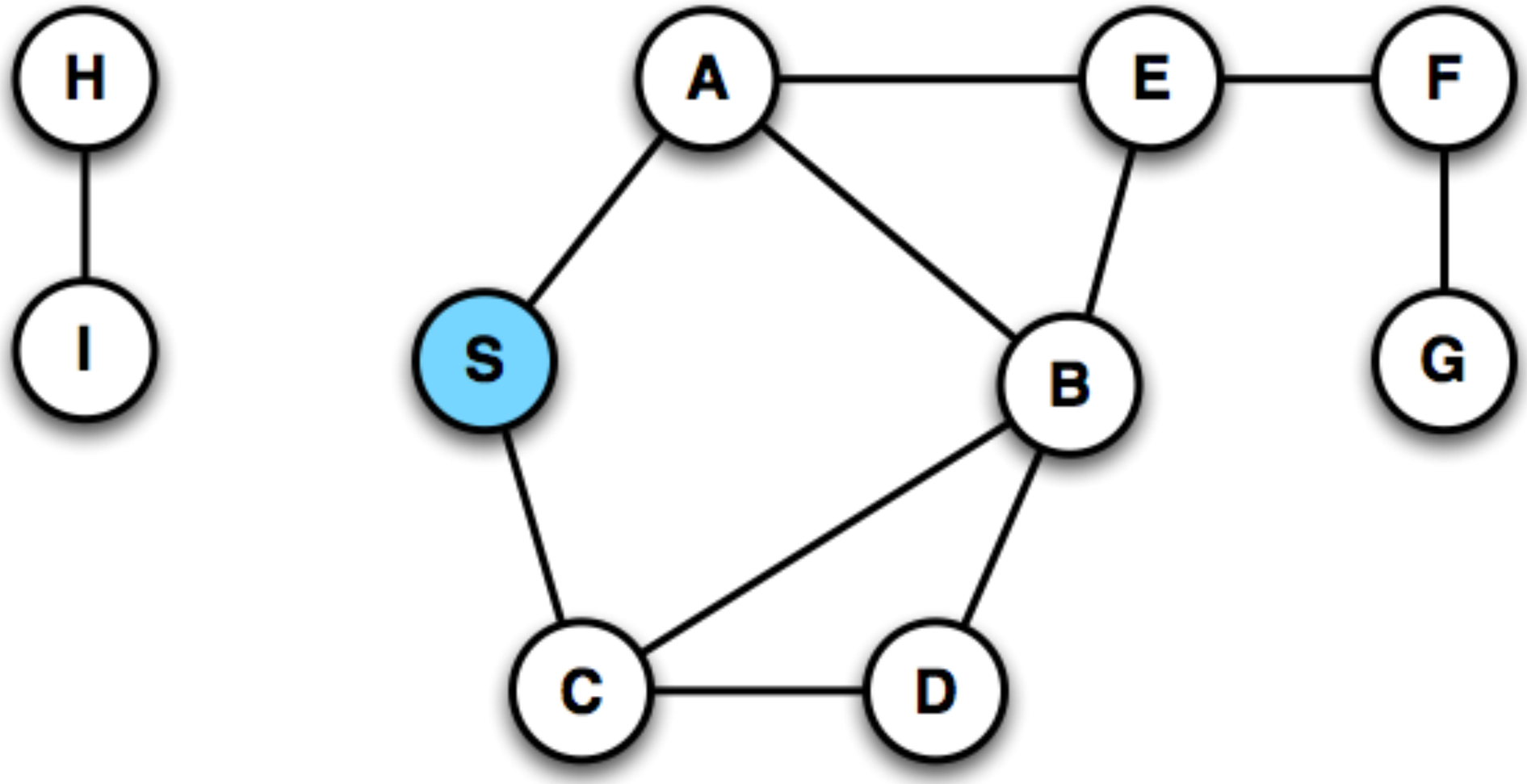
AODV

- Algorithm
  - Route Request (RREQ) like in DSR
  - Intermediate nodes set a reverse pointer towards thesender
  - If the target is reached, a Route Reply (RREP) is sent
  - Route Reply follow the pointers
- Assumption: symmetric connections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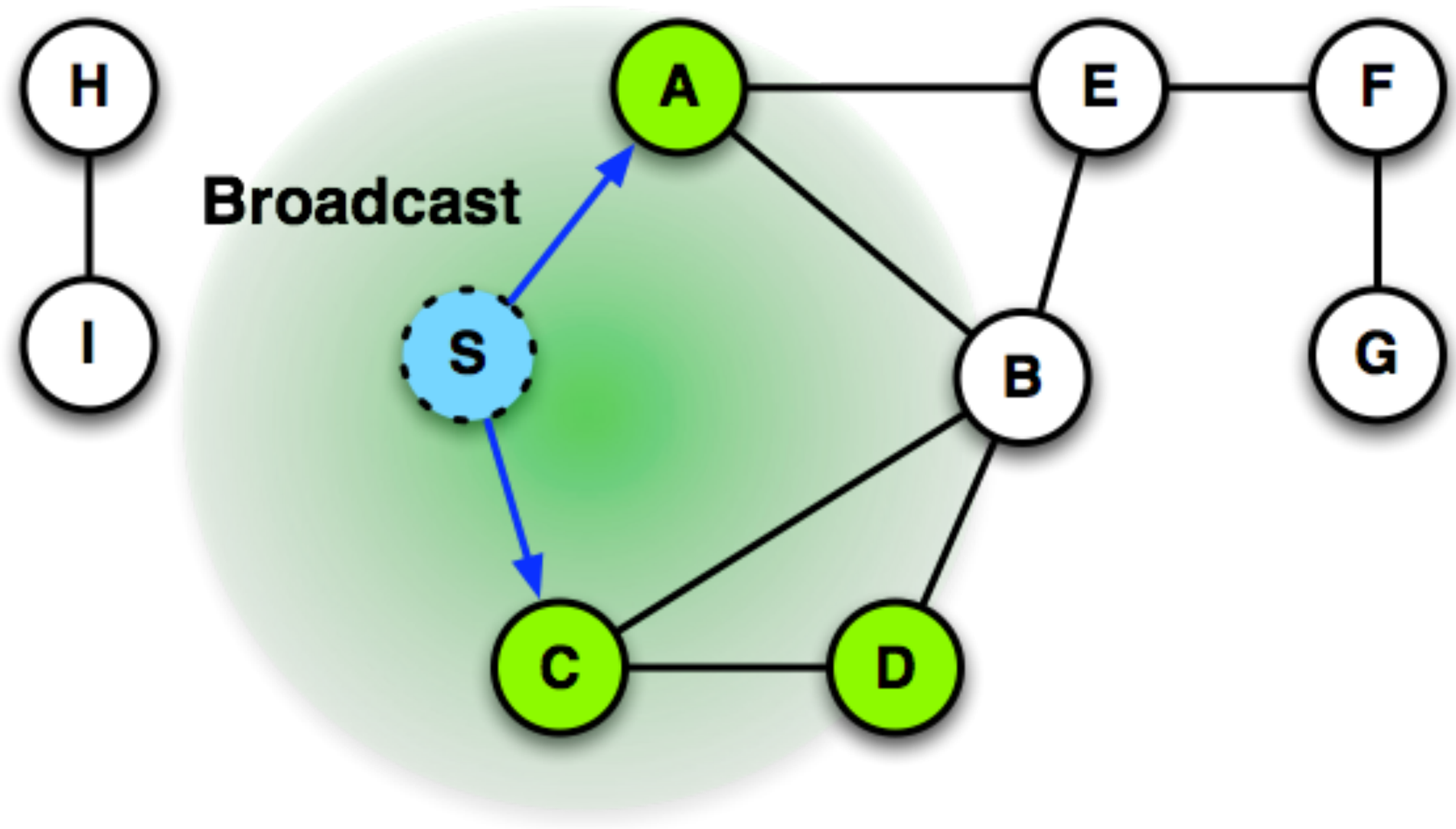
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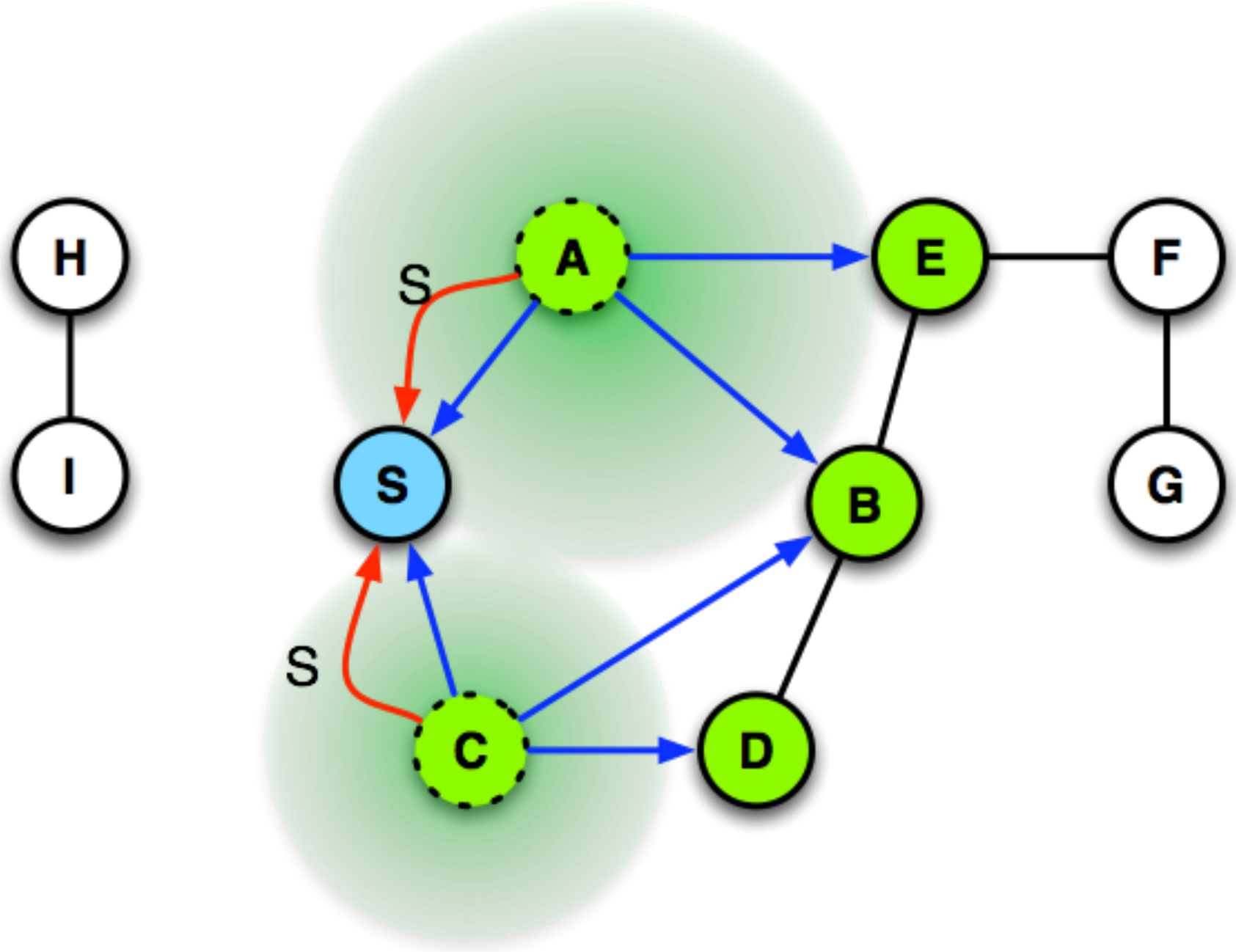
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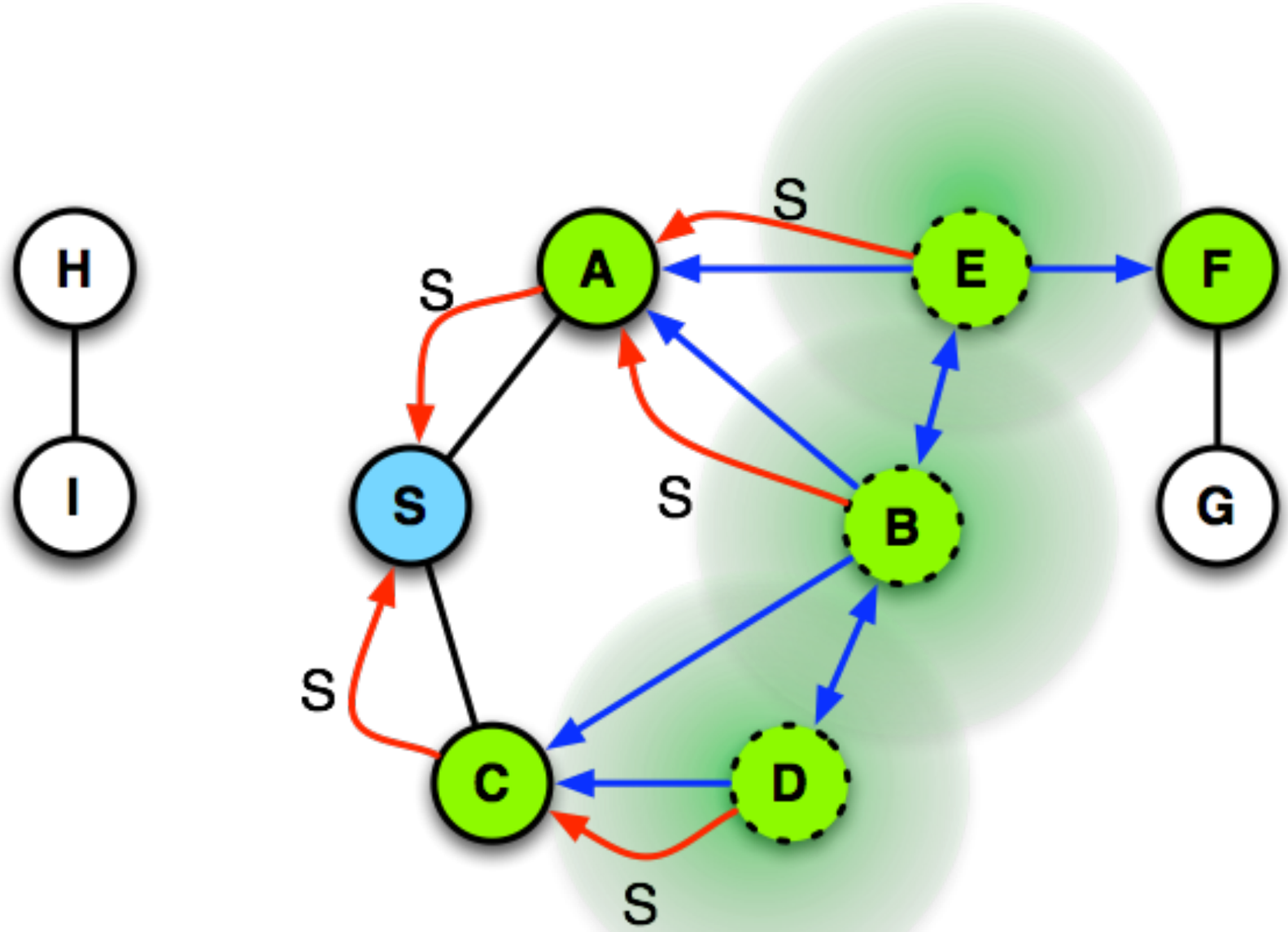
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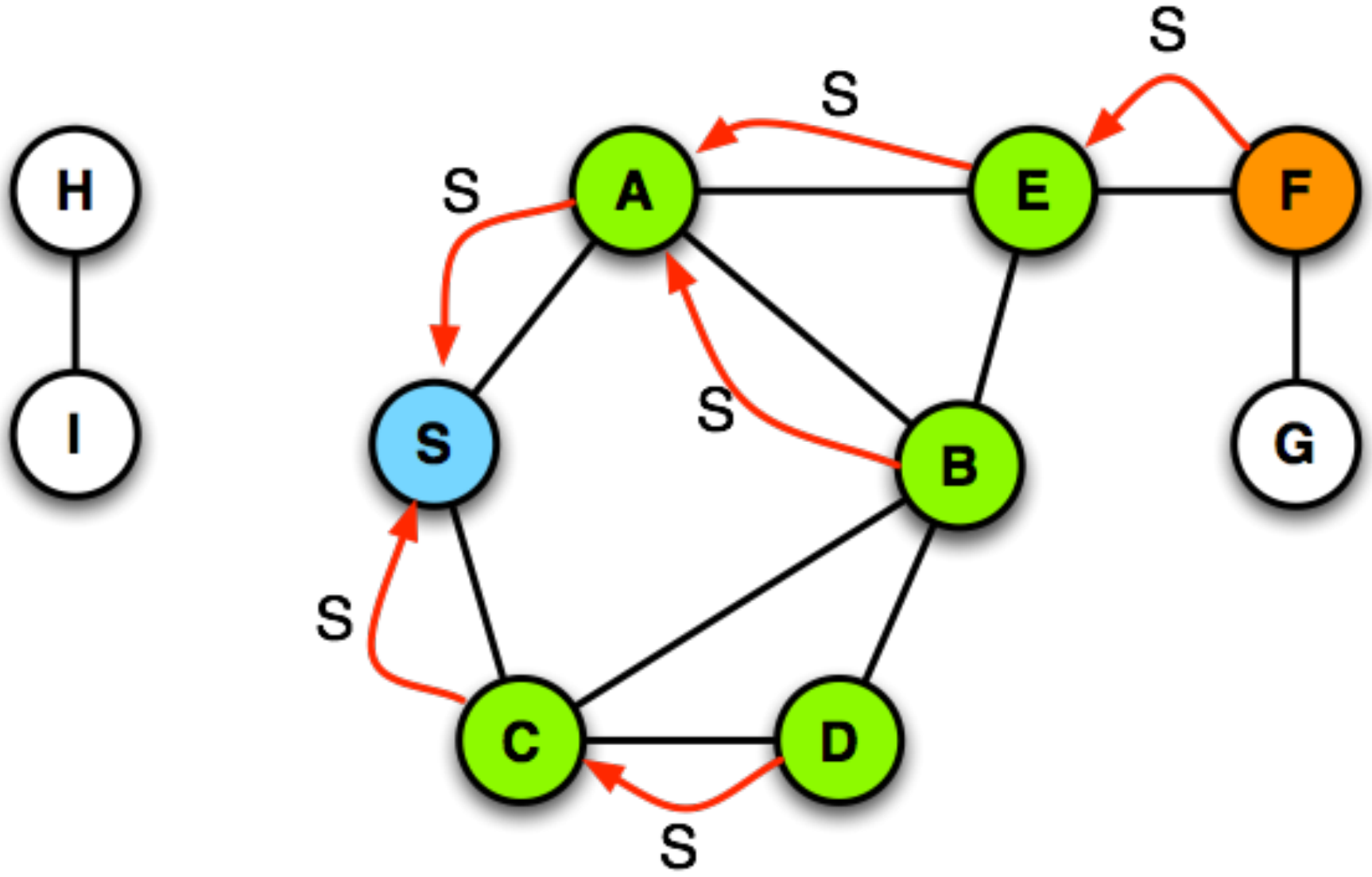
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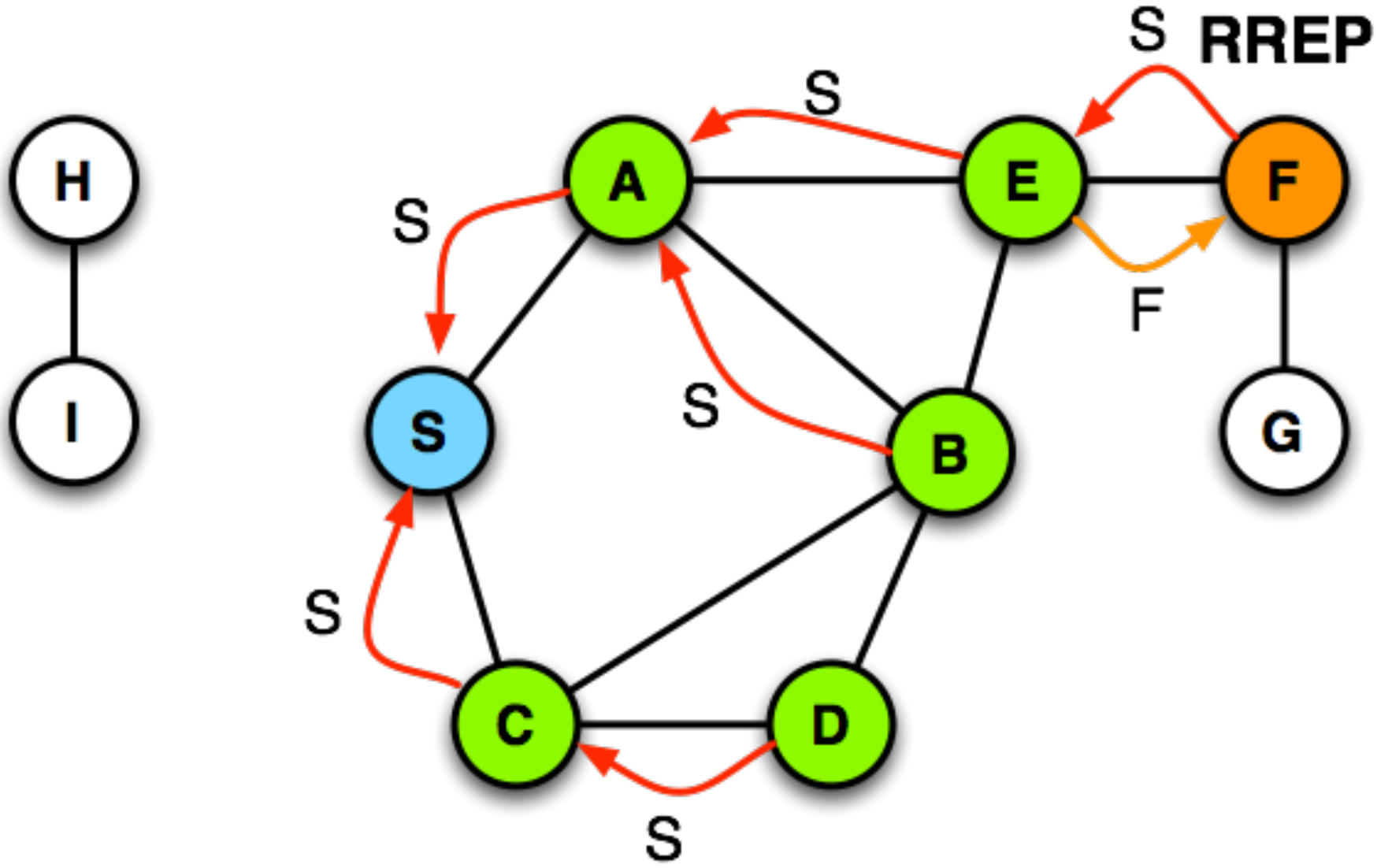
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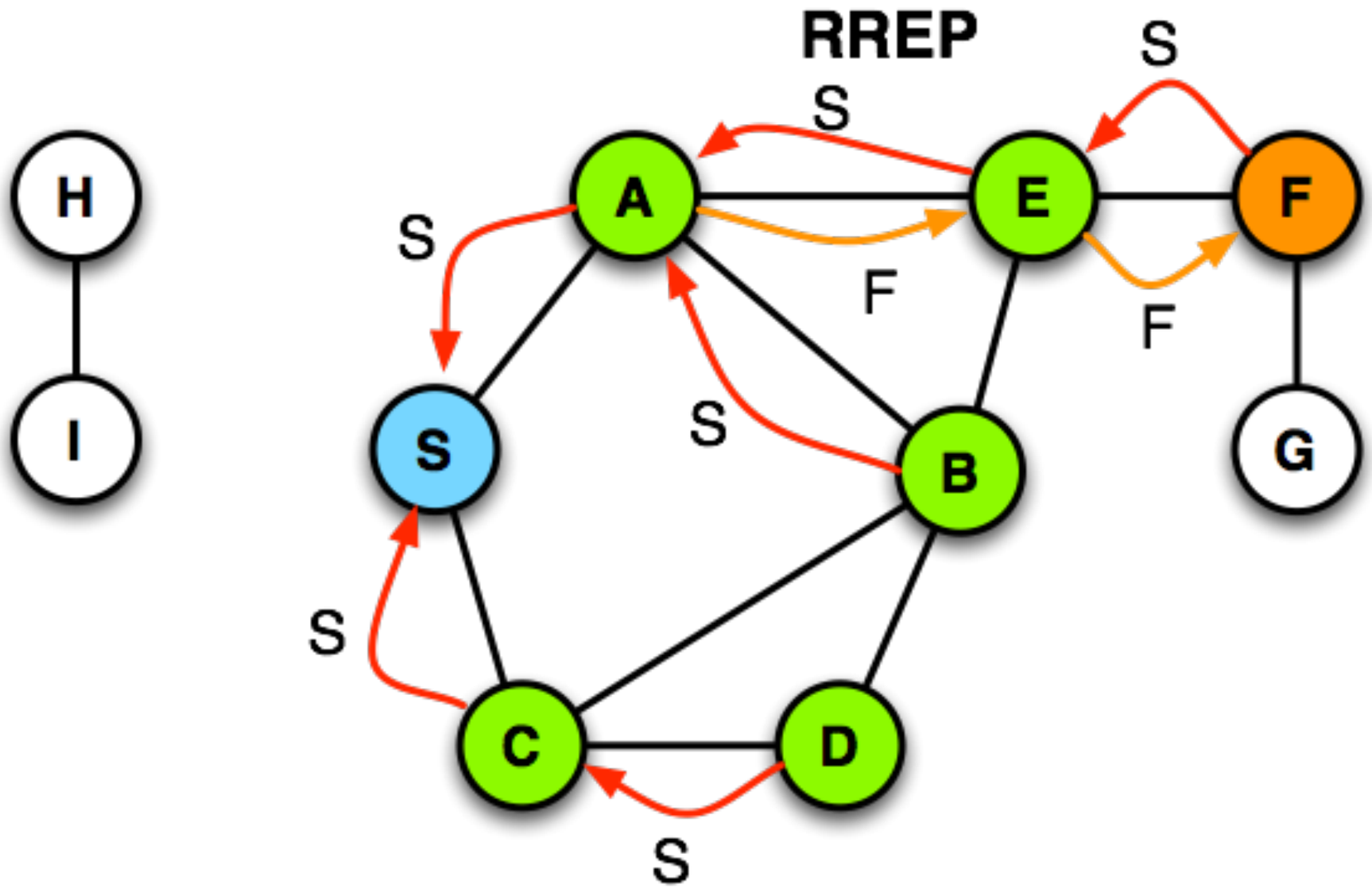
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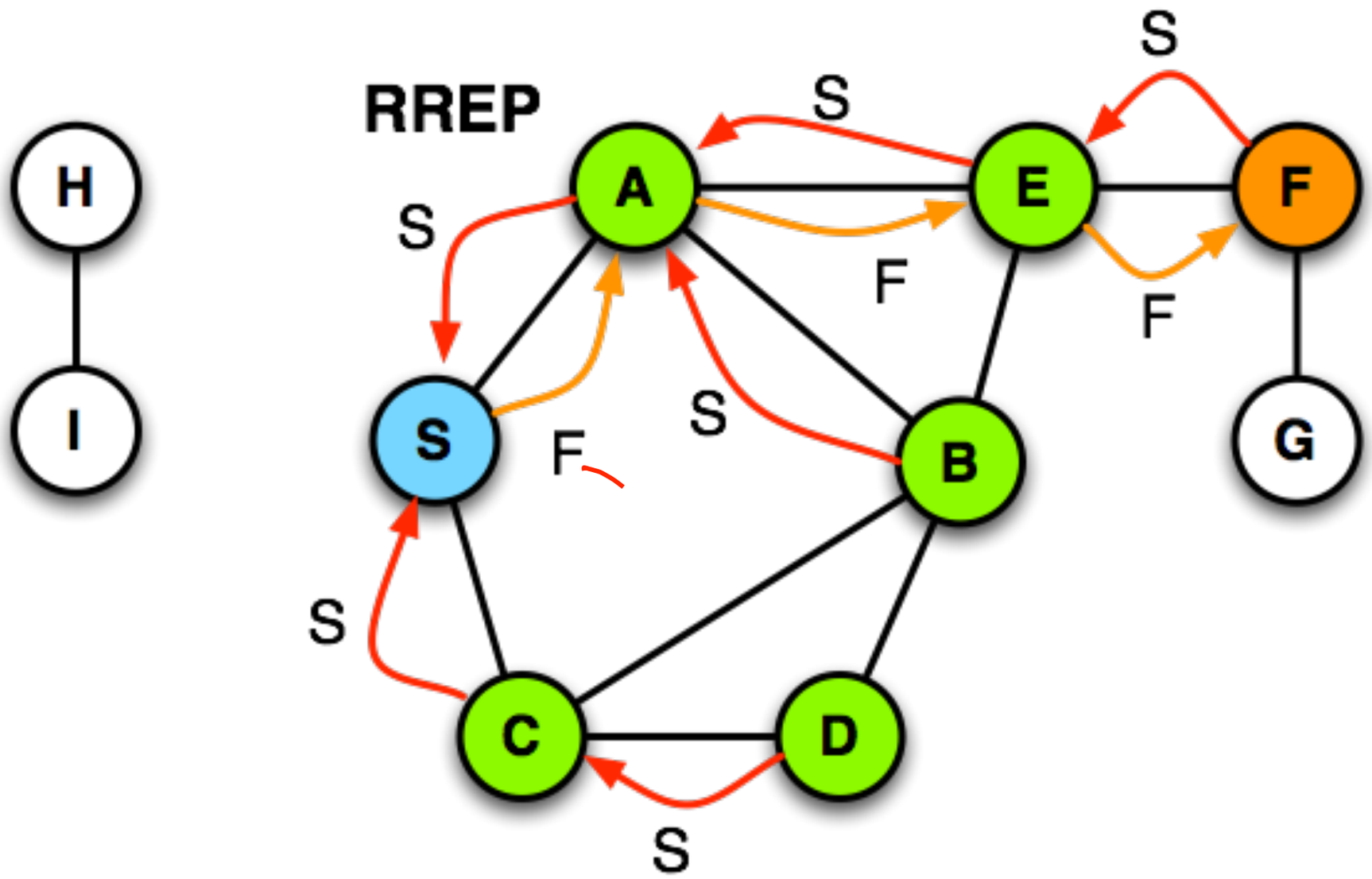
RREP
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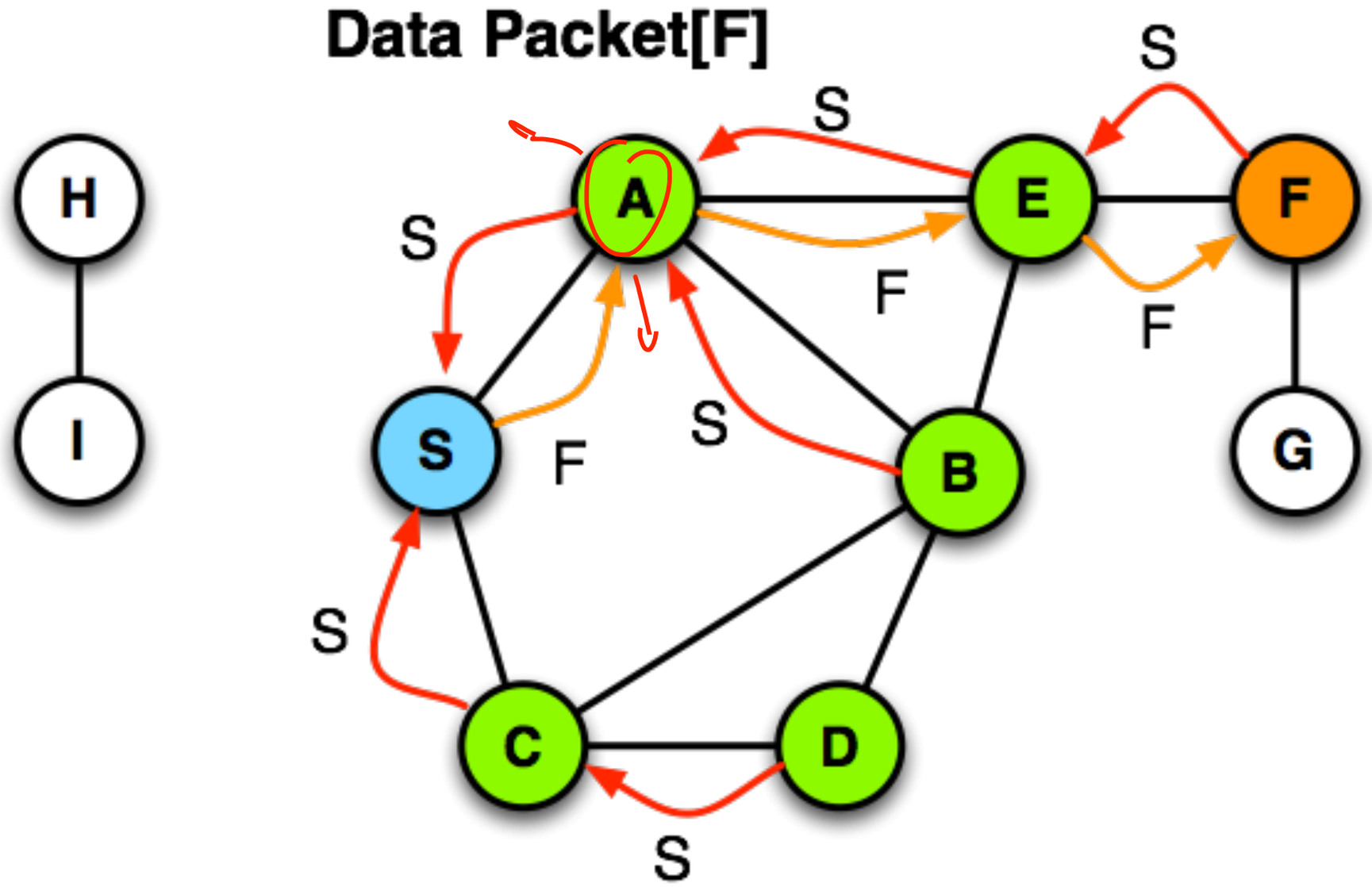
Data Packet[F]
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Route Reply in AODV

- Intermediate nodes
  - may send route-reply packets, if their cache information is up-to-date
- Destination Sequence Numbers
  - measure the up-to-dateness of the route information
  - AODV uses cached information less frequently than DSR
  - A new route request generates a greater destination sequence number
  - Intermediate nodes with a smaller sequence number may not generate a route reply (RREP) packets

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Timeouts

- Reverse pointers are deleted after a certain time
  - RREP timeout allows the transmitter to go back
- Routing table information to be deleted
  - if they have not been used for some time
  - Then a new RREQ is triggered

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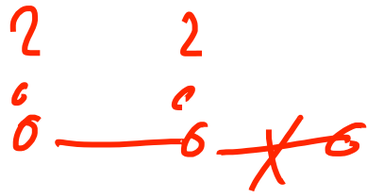
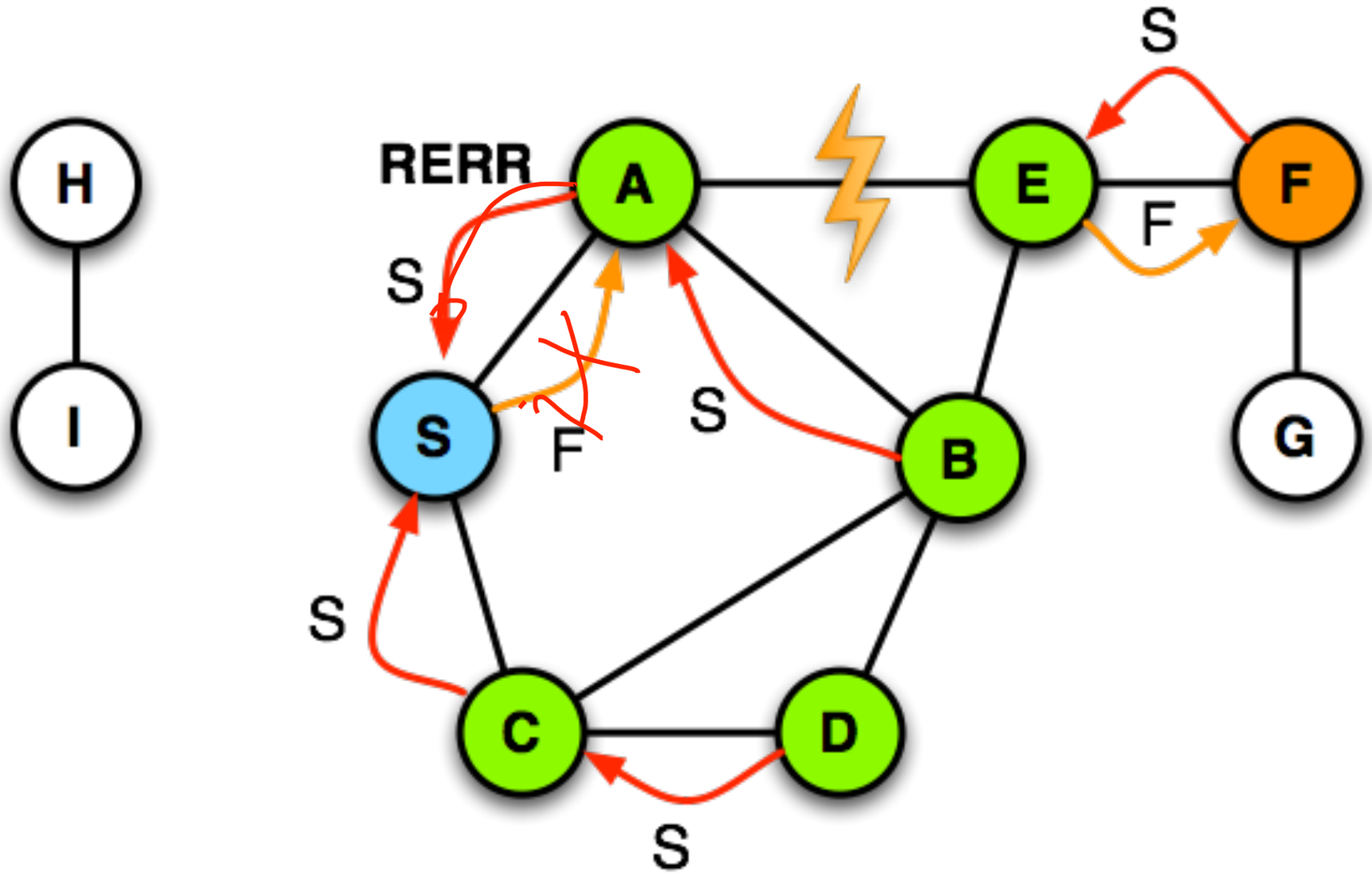
Link Failure Reporting



- Neighbors of a node X are active,
  - if the routing table cache are not deleted
- If a link of the routing table is interrupted,
  - then all active neighbors are informed
- Link failures are distributed by Route Error (RERR) packets to the sender
  - also update the Destination Sequence Numbers
  - This creates new route request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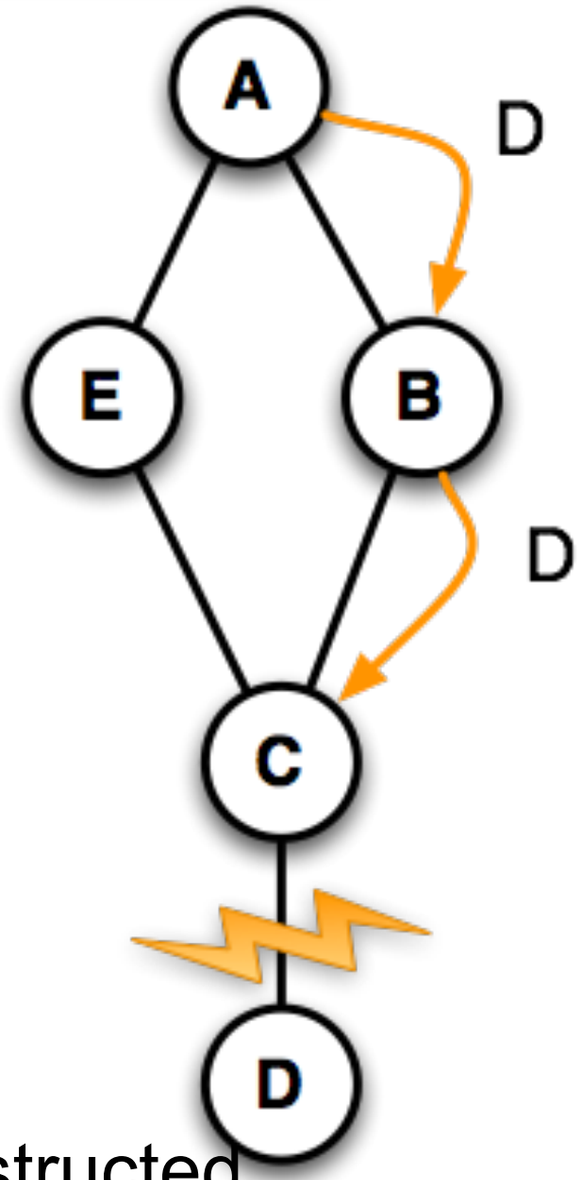
Detection of Link Failure

- Hello messages
  - neighboring nodes periodically exchange hello packets from
  - Absence of this message indicates link failure
- Alternative
  - use information from MAC protocol

Sequence Numbers

- When a node receives a message with destination sequence number N
  - then this node sets its number to N
  - if it was smaller before
- In order to prevent loops
  - If A has not noticed the loss of link (C, D)
    - (for example, RERR is lost)
  - If C sends a RREQ
    - on path C-E-A
  - Without sequence numbers, a loop will be constructed
    - since A "knows" a path to D, this results in a loop (for instance, CEABC)



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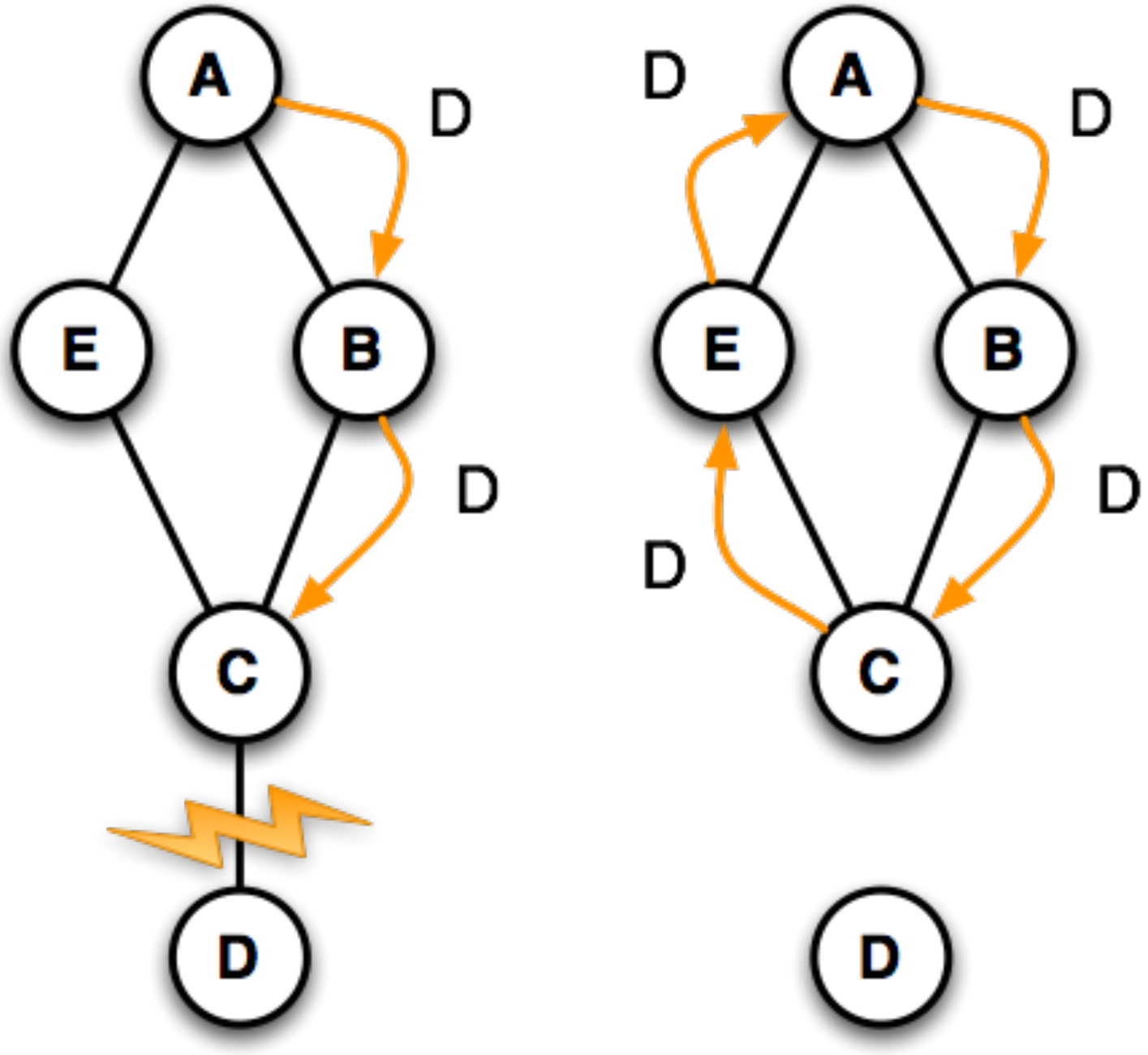
Sequence Numbers



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Optimization
Expanding Ring Search

- Route Requests
  - *start with small time-to-live value (TTL)*
  - if no Route Reply (RREP) is received, the value is increased by a constant factor and resent
- This optimization is also applicable for DSR

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Routing in MANETs

- Routing
  - Determination of message paths
  - Transport of data
- Protocol types
  - proactive
    - Routing tables with updates
  - reactive
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  - hybrid
    - combination of proactive and reactive