RPL: IPv6 Routing Protocol for Low power and Lossy Networks

Siarhei Kuryla

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Low power and Lossy Networks (LLNs)

LLNs are composed of many embedded devices:

- restricted in processing power, memory and energy (battery);
- interconnected by a variety of links, such as IEEE 802.15.4 or Low Power WiFi, characterized by high loss rates, low data rates and instability;

Routing Over Low power and Lossy networks (ROLL)

IETF working group focused on routing issues for LLNs:

- routing requirements specification for various application areas of LLNs;
- evaluation of existing routing protocols in the scope of LLNs;
- Routing Protocol for Low power and lossy networks (RPL, pronounced ripple);

Survey of existing routing protocols

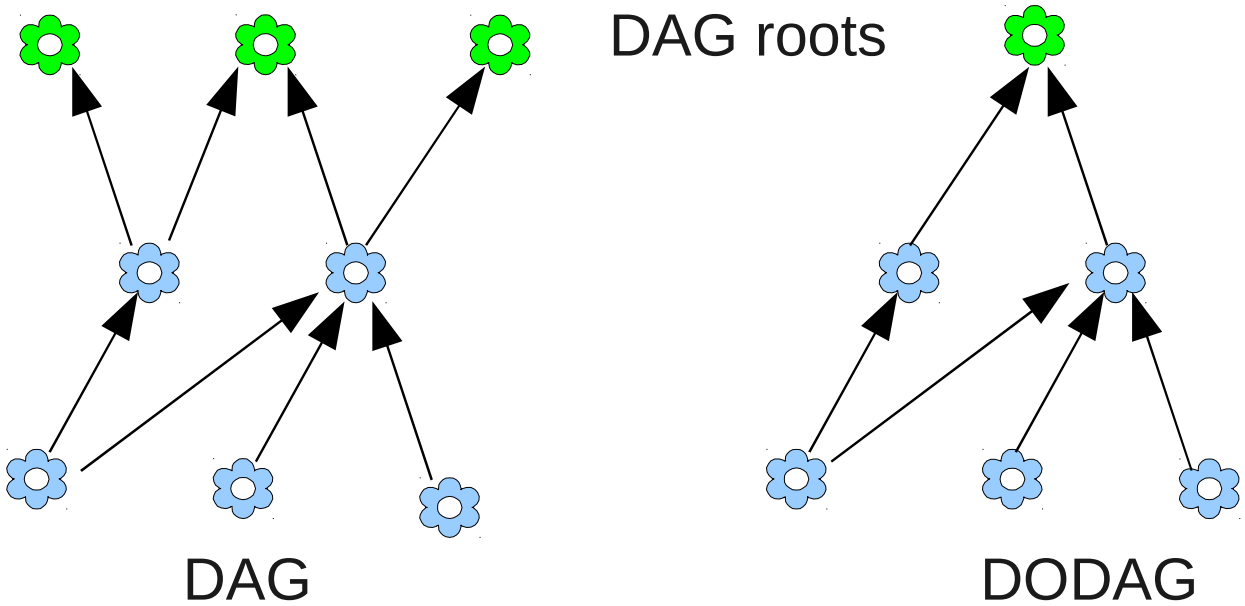
Protocol	State	Loss	Control	Link Cost	Node Cost
OSPF/IS-IS	fail	fail	fail	pass	fail
OLSRv2	fail	?	?	pass	pass
TBRPF	fail	pass	fail	pass	?
RIP	pass	fail	pass	?	fail
AODV	pass	fail	pass	fail	fail
DYMO	pass	?	pass	?	?
DSR	fail	pass	pass	fail	fail

- Routing State - limited memory resources of low-power nodes.
- Loss Response - what happens in response to link failures.
- Control cost - constraints on control traffic.
- Link&Node cost - link and node properties are considered when choosing routes.

RPL: IPv6 Routing Protocol for LLNs

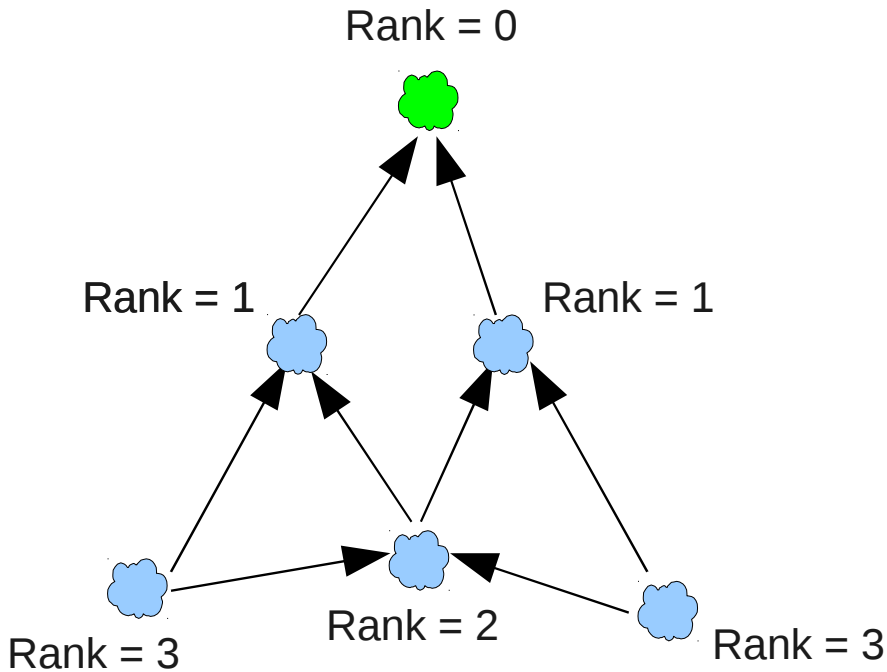
Definitions:

- Directed Acyclic Graph (DAG) - a directed graph with no cycles exist.
- Destination Oriented DAG (DODAG) - a DAG rooted at a single destination.



RPL Node Rank

Defines a node's relative position within a DODAG with respect to the DODAG root.

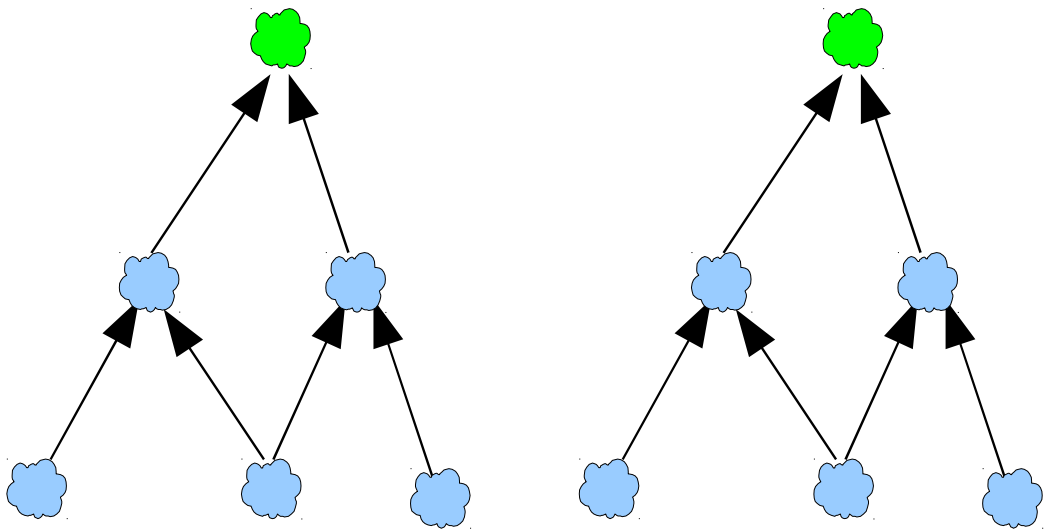


RPL: IPv6 Routing Protocol for LLNs

Assumption: most traffic in LLNs flows through few nodes

- many-to-one;
- one-to-many;

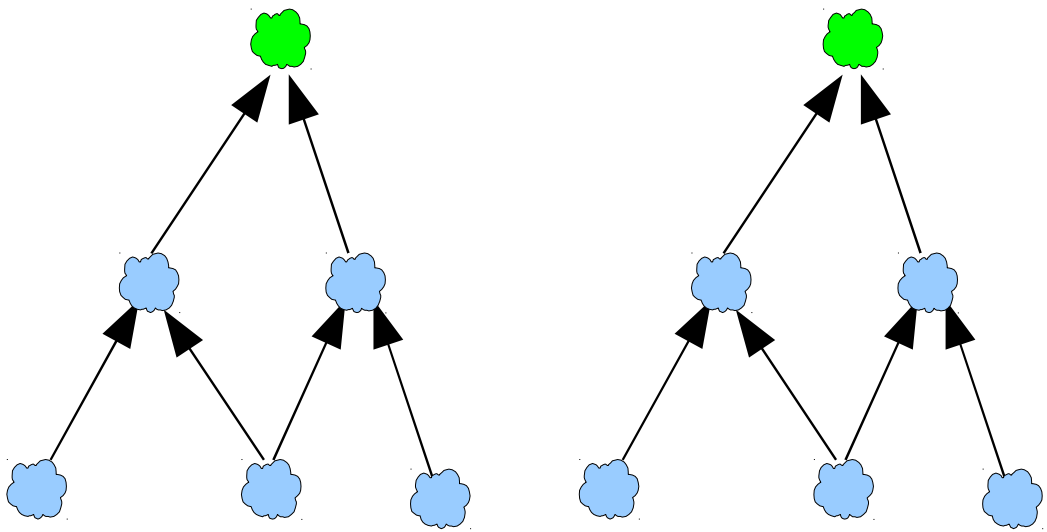
Approach: build a topology (Instance) where routes to these nodes are optimized (DODAG(s) rooted at these nodes)



Instance may include several DODAGs

RPL Instance

- Defines Optimization Objective when forming paths towards roots based on one or more metrics
- Metrics may include both Link properties (Reliability, Latency) and Node properties (Powered on not)
- A network may run multiple instances concurrently with different optimization criteria



Instance may include several DODAGs

RPL Control Messages

RPL defines a new ICMPv6 message with three possible types:

- DAG Information Object (DIO) - carries information that allows a node to discover an RPL Instance, learn its configuration parameters and select DODAG parents
- DAG Information Solicitation (DIS) - solicit a DODAG Information Object from a RPL node
- Destination Advertisement Object (DAO) - used to propagate destination information upwards along the DODAG.

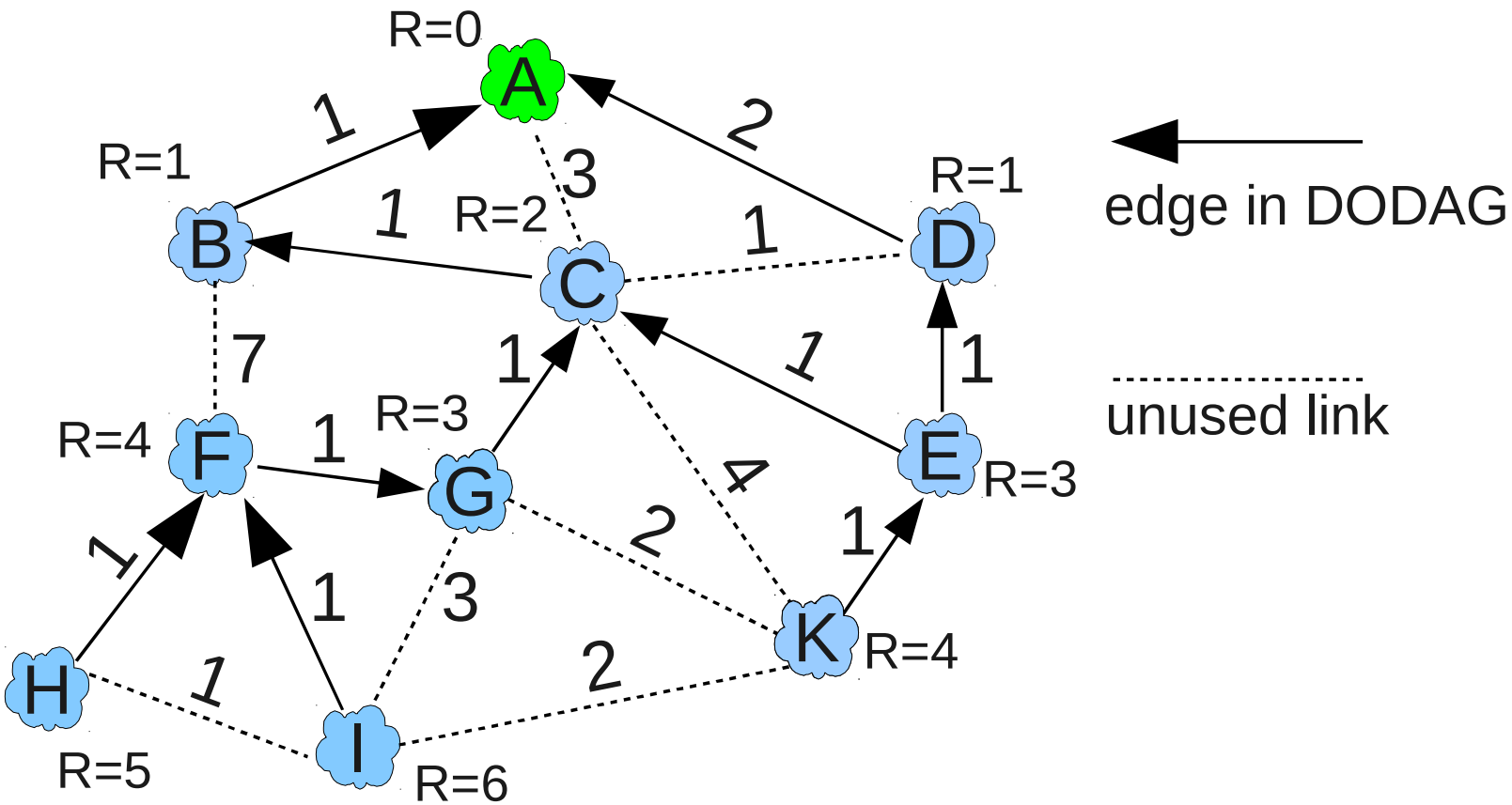
DODAG Construction

- Nodes periodically send link-local multicast DIO messages
- Stability or detection of routing inconsistencies influence the rate of DIO messages
- Nodes listen for DIOs and use their information to join a new DODAG, or to maintain an existing DODAG
- Nodes may use a DIS message to solicit a DIO
- Based on information in the DIOs the node chooses parents that minimize path cost to the DODAG root

Result: Upward routes towards the DODAG root

DODAG Example

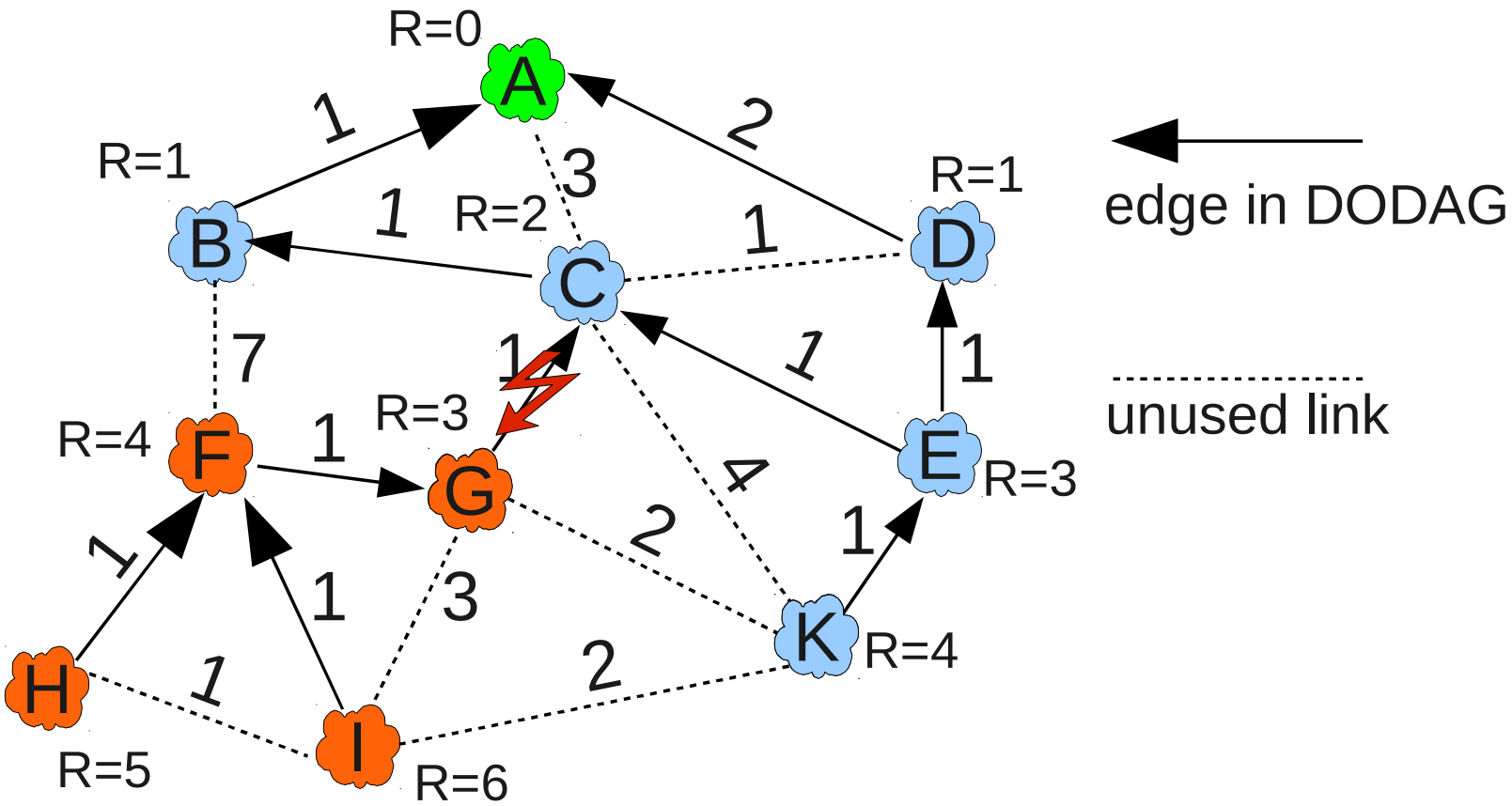
- Each node has a set of parent nodes
- A node has no knowledge about children → ONLY upward routes



DODAG Repair

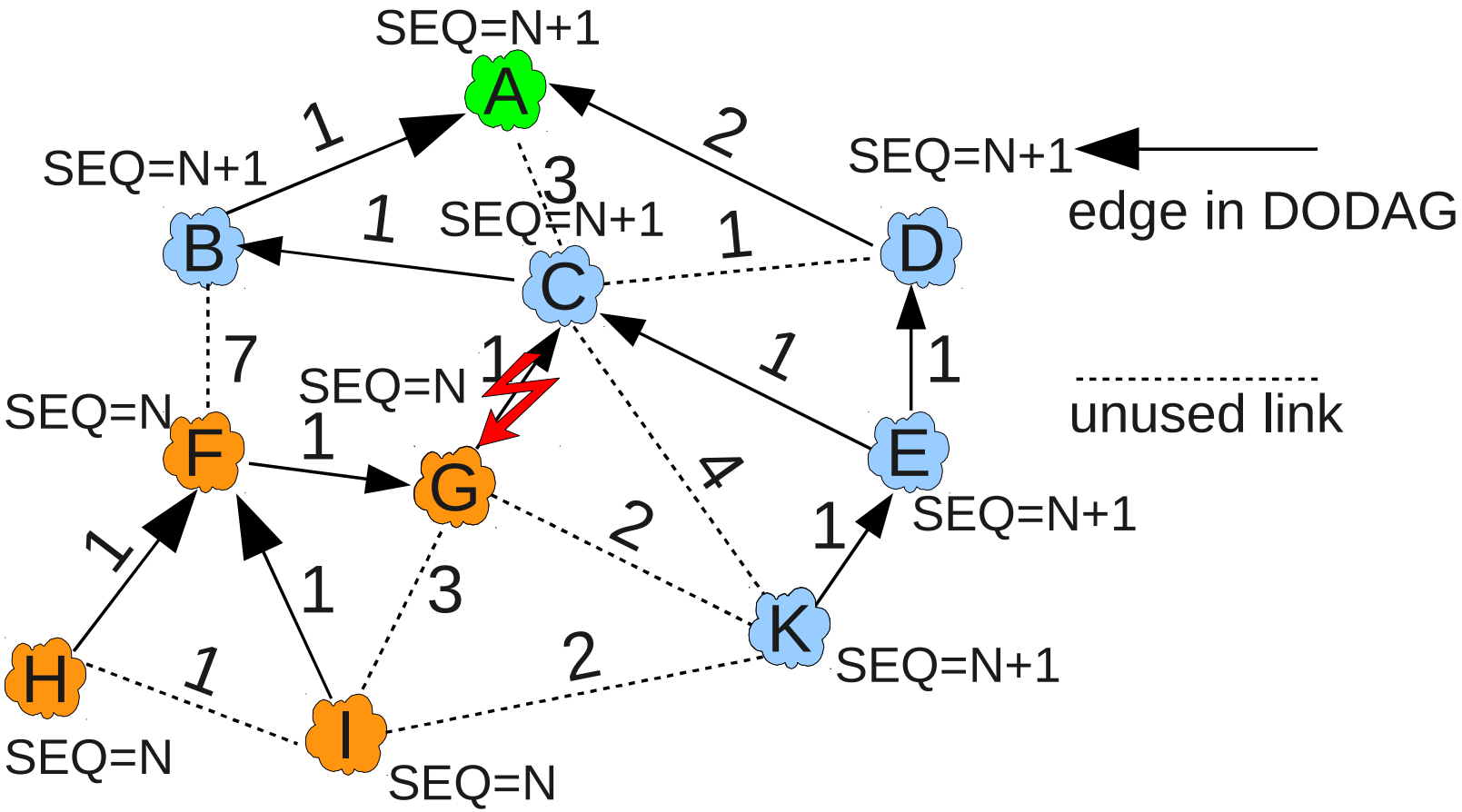
Link between G and C fails:

- Choose another parent with a lower rank



DODAG Repair

- Global repair- makes use of DODAG Sequence Numbers
- Local repair - poison the sub-DODAG by advertising the rank of INFINITY

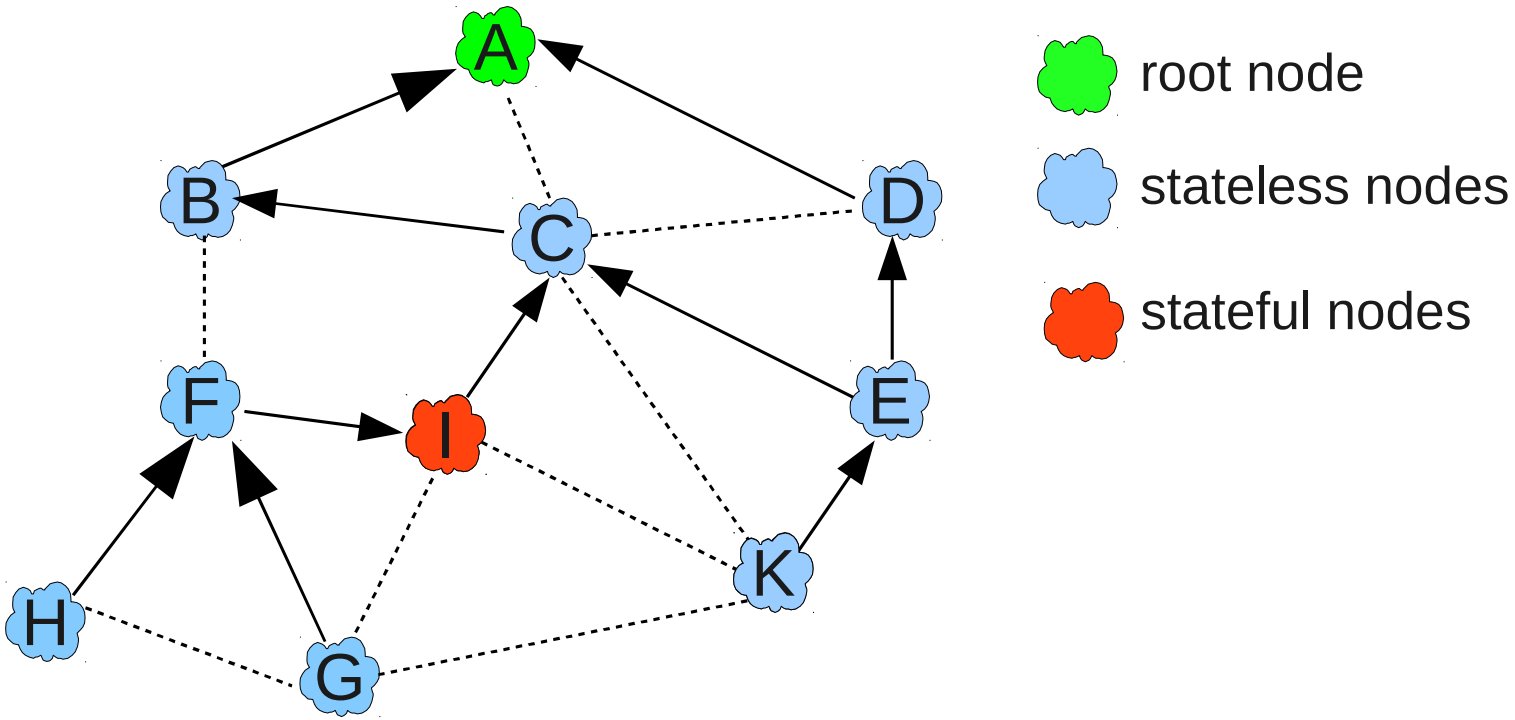


Downward Routes and Destination Advertisement

- Nodes inform parents of their presence and reachability to descendants by sending a DAO message
- Node capable of maintaining routing state $\longrightarrow$ aggregate routes
- Node incapable of maintaining routing state $\longrightarrow$ attach a next-hop address to the reverse route stack contained within the DAO message

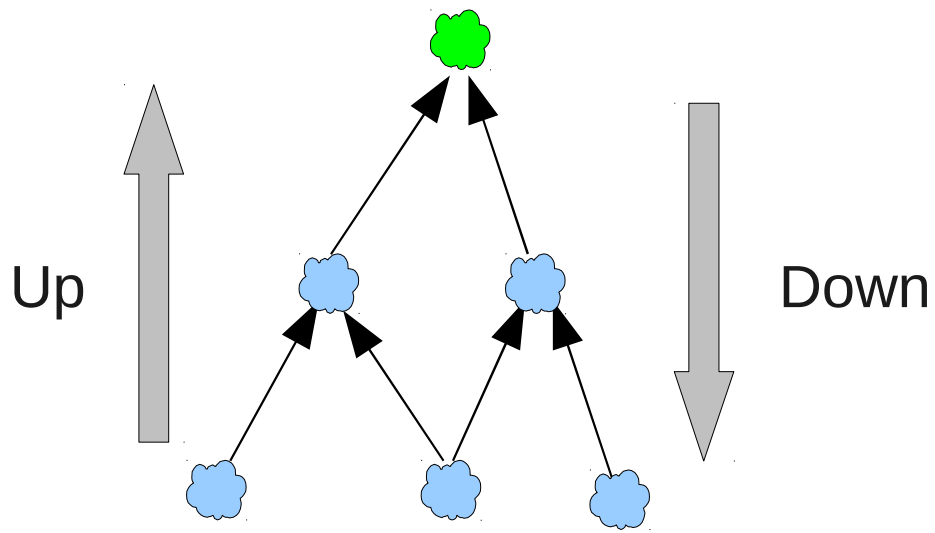
Destination Advertisement - Example

- H sends a DAO message to F indication the availability of H, F adds the next-hop and forwards the message to I
- G sends a DAO message to F indication the availability of G, F adds the next-hop and forwards the message to I
- F sends a DAO message to I indication the availability of F
- I aggregates the routes and sends a DAO advertising (F-I)



RPL Traffic Flows

- Up towards the DAG root for many-to-one
- Down away from the DAG root for one-to-many
- Point-to-point via up*down*



RPL Summary

- Optimized for many-to-one and one-to-many traffic patterns
- Routing state is minimized: stateless nodes have to store only instance(s) configuration parameters and a list of parent nodes
- Takes into account both link and node properties when choosing paths
- Link failures does not trigger global network re-optimization

References

- P. Thubert. RPL: IPv6 Routing Protocol for Low power and Lossy Networks. IETF, Internet-Draft draft-ietf-roll-rpl-05, December 2009.
- A. Brandt. RPL Routing Protocol for Low Power and Lossy Networks. http://cabernet.verkstad.net/agenda/75/slides/roll-2/roll-2_files/v3_document.htm, February 2010.
- J. Hui. RPL: IPv6 Routing Protocol for Low Power and Lossy Networks. ROLL WG Meeting, 76th IETF Meeting, Hiroshima, Japan.

Thank you for attention!