

# Routing Protocol for LLNs (RPL)

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# Agenda

- Introduction
- Network Stack
- Directory Structure
- Cooja Simulator
- Hands On Excercise

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# Introduction

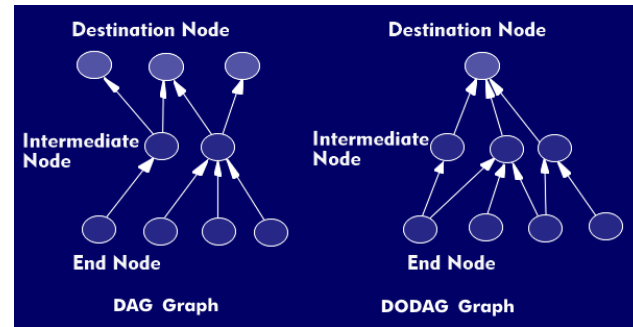
- Distance Vector IPv6 routing protocol for LLNs
- It constructs a Directed Acyclic Graph (DAG) to minimize path costs
- It defines a new IPv6 option to be added just after the main header called RPL Option
- RPL option adds routing information with each datagram that a router forwards

# Features

- To bind the subnet together with a common prefix and to route within that subnet
- RPL uses IPv6 Neighbour Discovery (ND), Prefix Information Option and Route Information Option
- RPL node often combines Host and Router behaviors
  - As a host it will process Route information options
  - As a router, it may advertise the information in ND Router Advertisement (RA) message

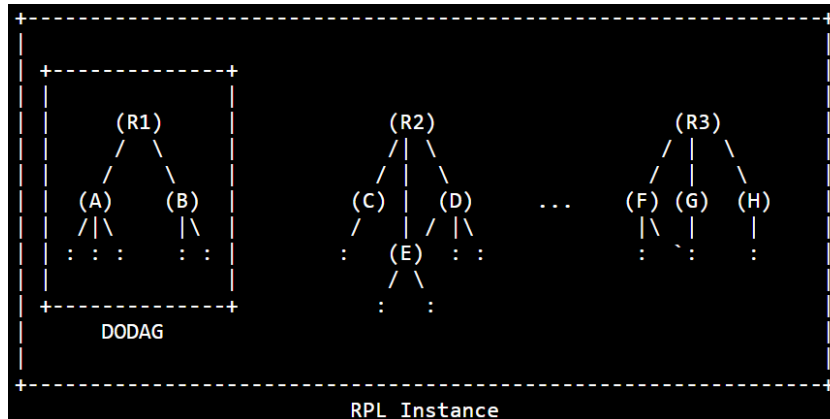
# Terminology

- Directed Acyclic Graph – A path-oriented connection of edges/nodes in such a way that no cycles exists. Each node has a direction Forward or Backward
- DAG root – A DAG root is a node within DAG with not outgoing edge i.e. sink of DAG; at least one root must be there
- Destination Oriented DAG: single root DAGs
- DODAG root – root of DAG of DODAG



# Terminology

- Rank – Position relative to other nodes with respect to DODAG root. Increases in Down direction and decreases in Up direction
- Objective Function (OF) – Compute the ranks in DODAG
- RPL Instance – It is a set of one or more DODAGs
- DODAGID- identifier of DODAG root. It is unique within RPL instance

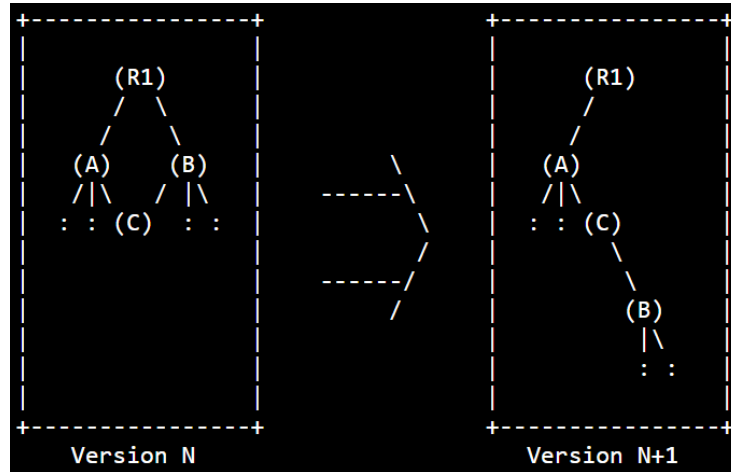


# Terminology

- **DODAG Information Object (DIO)**
  - The DODAG Information Object carries information that allows a node to discover a RPL Instance, learn its configuration parameters, select a DODAG parent and maintain DODAG
- **Destination Advertisement Object (DAO)**
  - The Destination Advertisement Object (DAO) is used to propagate destination information Upward along the DODAG
- **DODAG Information Solicitation (DIS)**
  - The DODAG Information Solicitation (DIS) message may be used to solicit a DODAG Information Object from a RPL node
  - A node may use DIS to probe its neighborhood for nearby DODAGs

# RPL identifiers

- Its uses four values to identify and maintain a topology
  - RPLInstanceId
  - DODAGID
  - DODAGVersionNumber
  - Rank





# Ranks

- A parent of a node within a DODAG is one of the immediate successors of the node on a path towards the DODAG root
- A DODAG parent's Rank is lower than the node's

# Rank Comparison

- It is thought of fixed point number
- MinHopRankIncrease is the minimum increase in Rank between a node and any of its DODAG parents
- It creates a trade-off between hop cost precision and maximum number of hops a network can support
- A large value allows precise characterization of a given hop's effect on Rank but not many supported
- Uses function like –  $\text{DAGRank}(\text{rank}) = \text{floor}(\text{rank} / \text{MinHopRankIncrease})$

# Rank Relationships

- $\text{DAGRank}(M)$  is less than  $\text{DAGRank}(N)$
- $\text{DAGRank}(M)$  is equal to  $\text{DAGRank}(N)$
- $\text{DAGRank}(M)$  is greater than  $\text{DAGRank}(N)$

# RPL Security

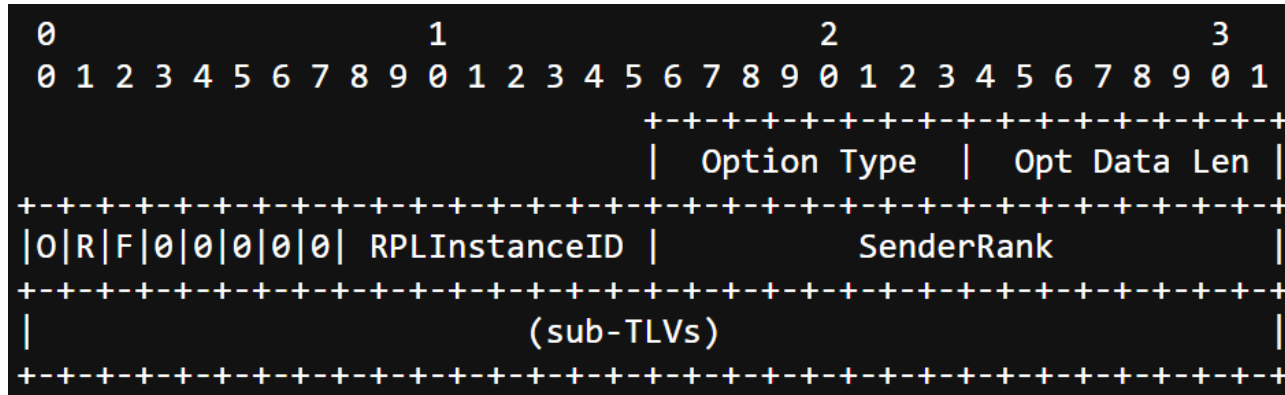
- **Unsecure Mode**
  - Messages sent without additional mechanism but Link Layer has option to use security
- **Preinstalled Mode**
  - Nodes joining RPL instance has preinstalled keys to generate secure messages
- **Authenticated Mode**
  - An authenticated RPL instance allows other nodes to join using preinstalled keys as leaf node

# Trickle Timers

- RPL uses a slow process to construct and maintain a routing topology
- If routing inconsistencies detected, then RPL temporarily increases beacon rate to quickly resolve that
- This dynamic rate control operation is governed by the use of dynamic timers called as “Trickle” (RFC 6206)

# Format of RPL Option

- IPv6 Hop-By-Hop Options header immediately follows RPL Option



# RPL Option

- Option Type
  - Define by IANA as 0x63
- Opt Data Len
  - The length of option header
- Down
  - 1-bit flag indicating whether the packet is expected to progress Up or Down. A router sets the 'O' flag when the packet is expected to progress Down (using DAO routes), and clears it when forwarding toward the DODAG root
- Rank Error
  - A Rank error is detected when there is a mismatch in the relative Ranks and the direction as indicated in the 'O' bit.

# RPL Option

- Forwarding Error
  - indicating that this node cannot forward the packet further towards the destination.
- RPL Instance ID
  - 8-bit field indicating the DODAG instance along which the packet is sent
- Sender Rank
  - 16-bit field set to zero by the source and to DAGRank(rank) by a router that forwards inside the RPL network



# Router Behaviour

- Router must use IPv6-in-IPv6 tunneling to send data frames
- Tunneling ensures delivered datagram remains unchanged and errors are sent back to the source
- Tunnel Exit points is the RPL router for which the original packet is destined to
- Single Tunnels
- Multiple Tunnels

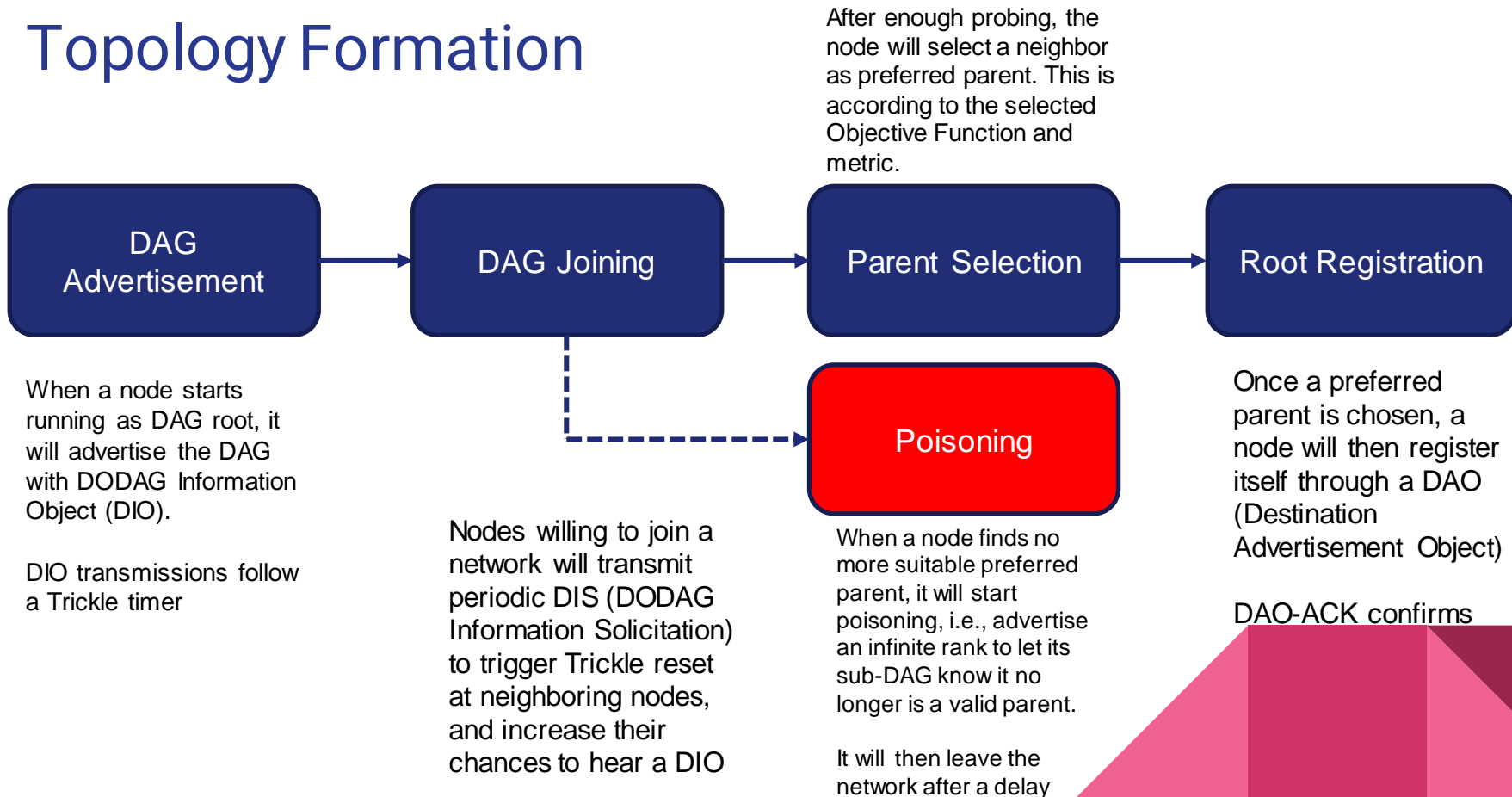
# Security Aspects

- **DAG Inconsistency Attacks**
  - Using Down and SenderRank field, an attacker can trick routers to start Trickle timer more often
- **Destination Advertisement Object (DAO) Inconsistency Attacks**
  - In Storing mode, RPL routers maintain Downward routing state, which is cleaned by Forwarding-Error flag
  - To avoid use MAX\_RPL\_OPTION\_FORWARD\_ERRORS to discard state per hour. Recommended value 20
  - In Non-storing mode, only LBR maintains Downward routing state, so no Option- involved

# Modes of Operation (MOP)

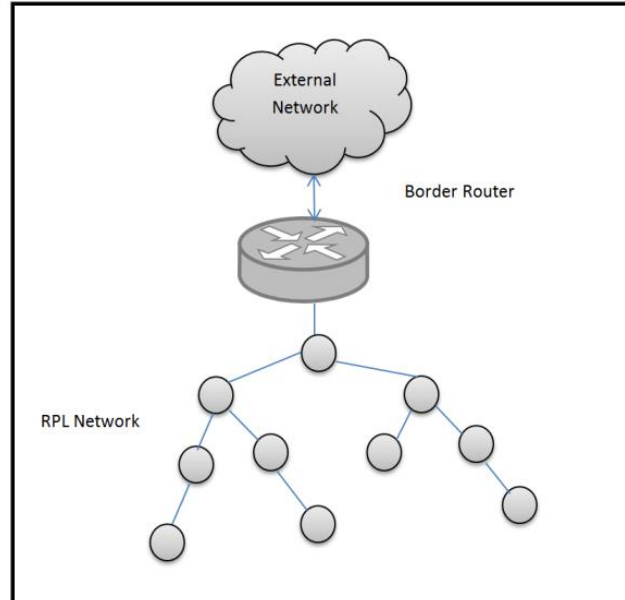
- The different modes of operation refer to the different ways downward routing is done
- Storing Mode
  - For storing mode, routing tables are stored on each node, which can impose a significant memory footprint in large networks and be hard to maintain consistently
- Non-Storing Mode
  - For non-storing mode, IPv6 source routing is employed, which means that nodes do not have to store routing tables for nodes below them in the DODAG

# Topology Formation



# RPL Border Router

- Border routers are routers that can be found at the edge of a network. Their function is to connect one network to another





# Thank You