IoT NETWORK ROUTING

A New Routing Objective Function for IETF 6TiSCH Protocol

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Introduction & Motivation

- Industrial IoT (IIoT) demands high reliability against interference and multipath fading, plus predictable, low latency.
- IEEE 802.15.4e / 6TiSCH combine TSCH scheduling with IPv6 to meet these needs in low-power, lossy networks.
- RPL builds the routing topology, but its default Objective Functions cause frequent, costly parent switches — degrading reliability and increasing delay.
- This study proposes a new parent-selection function that accounts for a node's neighbor count and traffic load to stabilize the network topology.

WHY IT MATTERS

21 nodes in the simulated topology

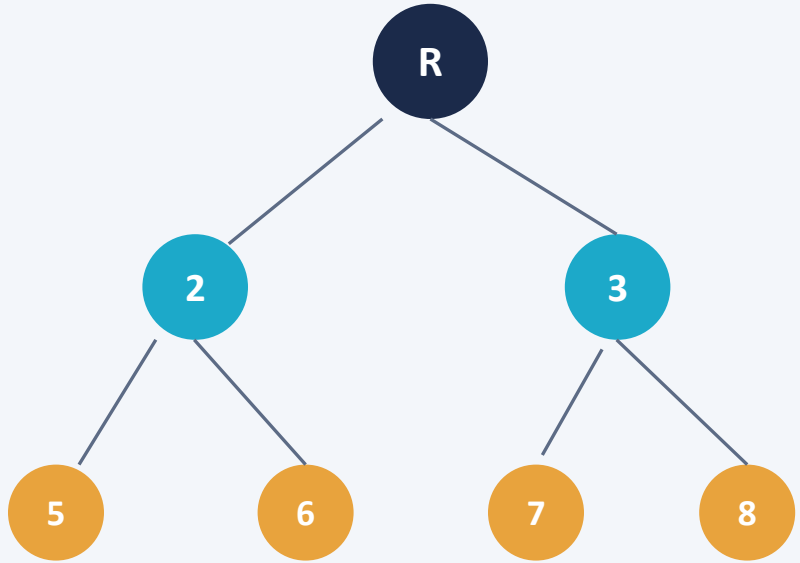
2 new objective functions proposed

50% improvement in packet delivery under weak links

Background: RPL over 6TiSCH

- RPL organizes the network as a Destination-Oriented Directed Acyclic Graph (DODAG), rooted at a sink node.
- Each node computes a rank (distance from the root) and advertises routing metrics via DIO messages.
- An Objective Function (OF) — e.g., MRHOF — defines how rank is computed and how the preferred parent is chosen.
- 6TiSCH allocates TSCH time-slot (cell) resources for each parent-child link — resources that must be fully reallocated on every parent switch.
- Frequent or poorly chosen parent switches waste this allocation effort and cause packet loss and delay.

DODAG Formation

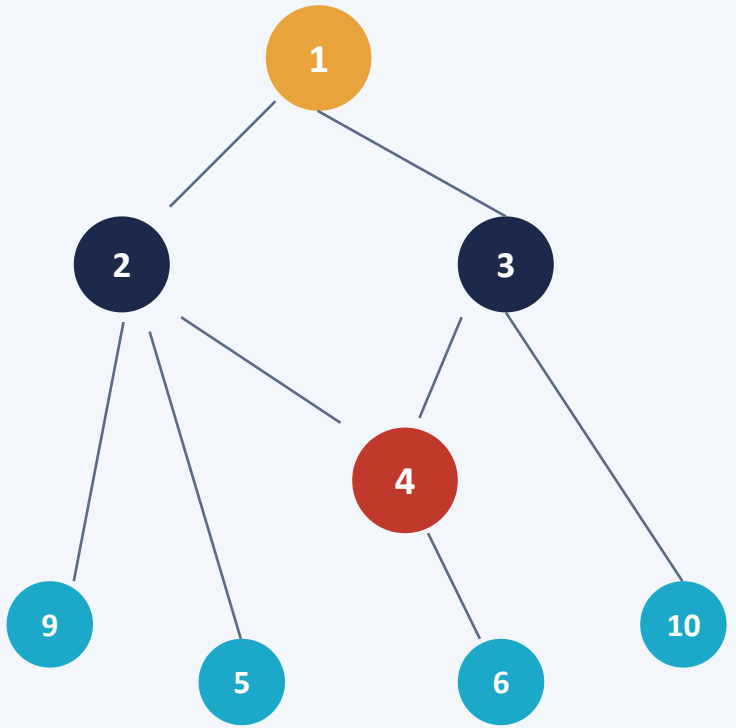


Root broadcasts DIO → nodes select a parent based on the Objective Function → tree topology emerges.

The Problem: Unstable Parent Switching

- Default RPL compares a candidate parent's rank to the current parent's rank using a fixed hysteresis threshold (MRHOF: 96 / 0.75 ETX; RFC 6719: 192 / 1.5 ETX).
- A low, fixed threshold causes continuous parent switching — halting traffic, releasing and re-negotiating TSCH cells each time.
- Switching cost is especially severe at critical relay nodes that serve many downstream nodes.
- A relay node's parent switch forces traffic from all its dependents to buffer temporarily — risking buffer overflow and dropped packets.

Critical Relay Node Scenario



Node 4 (red) relays traffic for nodes 5, 6, 9, 10. If node 4 switches parent, all their traffic buffers temporarily — risking loss.

Proposed Mechanism

- Goal: optimize the parent-switching threshold using real-time node state, avoiding unnecessary resource-allocation cost.
- Two new Objective Functions dynamically scale MRHOF's switching threshold:

SR1 — Neighbor-Count-Based

Scales the switching threshold by the node's neighbor count (bounded between 2 and 6 neighbors), making well-connected nodes more resistant to unnecessary switches.

SR2 — Cell-Count-Based

Scales the threshold by the number of allocated transmission cells, protecting nodes that already carry significant scheduled traffic.

If a node has no allocated transmission cell, the maximum link metric is added to its parent's cost — keeping it from being preferred until it establishes cells.

Objective Function Logic

1

Check Cells

If a node has 0 allocated transmission cells, add the maximum link metric to its cost — deprioritize it.

2

Compute Threshold

Otherwise, scale the switching threshold by neighbor count (SR1) or cell count (SR2), bounded to avoid runaway values.

3

Compare Costs

Compare candidate parent cost against current parent cost ± the dynamic threshold.

4

Select Parent

Keep the current parent if within threshold; otherwise select the lower-cost candidate.

This logic runs at every RPL parent-comparison event, keeping well-connected or heavily-loaded relay nodes stable.

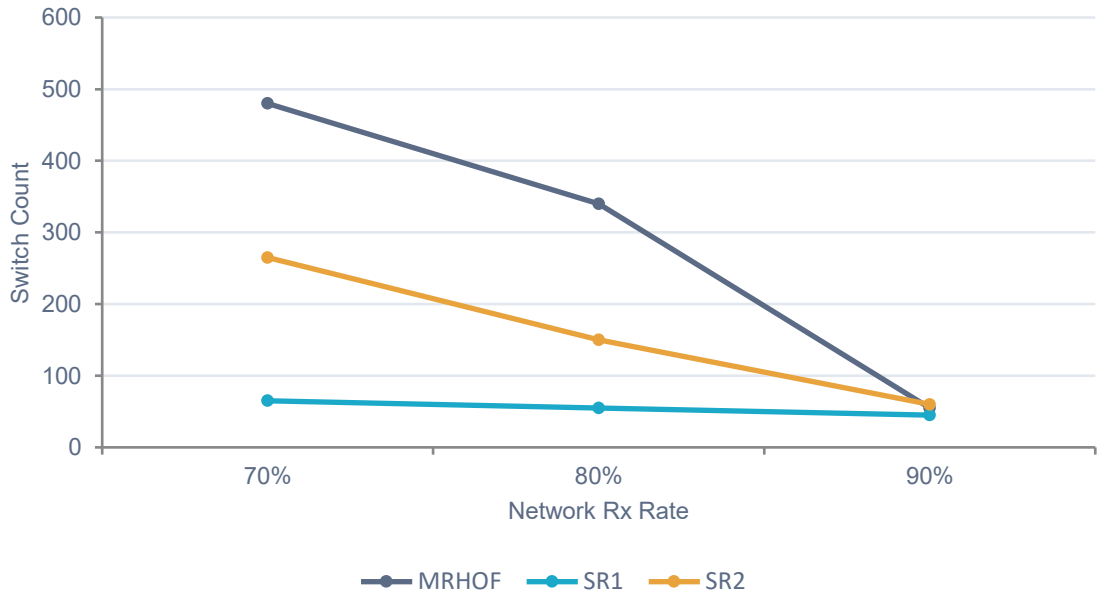
Experimental Setup

Simulator	Cooja, on Contiki-NG
Topology	21 nodes (1 server + 20 client), Exp5438 modules, randomly placed
MAC Model	6TiSCH
Propagation	Cooja UDGM
Objective Functions	MRHOF (baseline), SR1, SR2 (proposed)
Rx Success Rate	70%, 80%, 90% (tested separately)
Transmission Range	50 m
Test Duration	1 hour, 5 repetitions per configuration, averaged

Results: Delivery Rate & Parent Switches

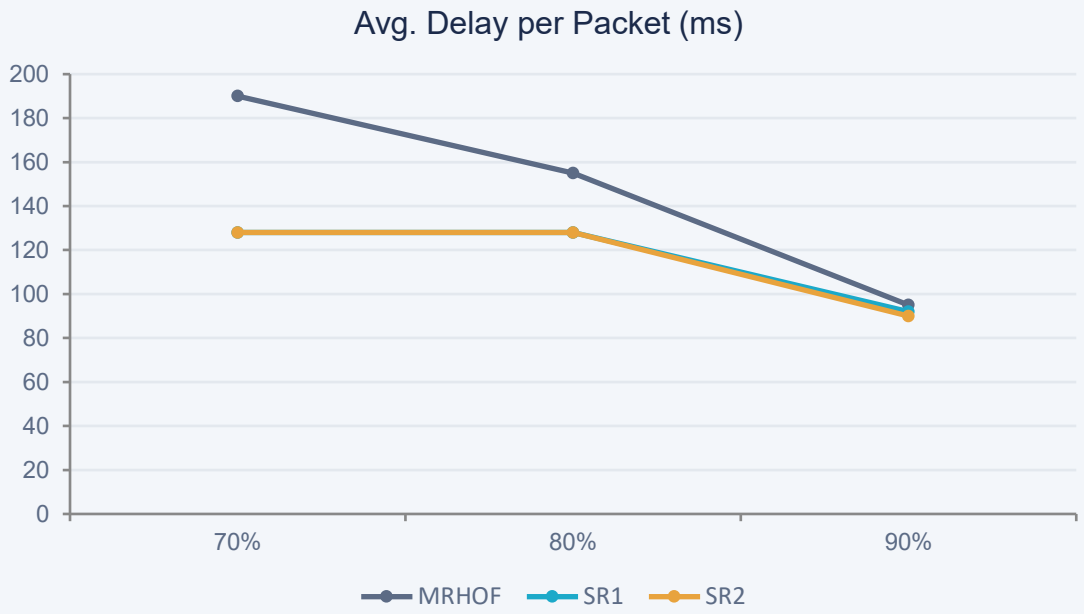
Packet Delivery Ratio (%)

Total Parent Switches



Both SR1 and SR2 improve packet delivery over baseline MRHOF, especially at lower Rx rates (weaker links) — and dramatically reduce parent-switch counts, most notably SR1.

Results: Latency & Discussion



1

Up to 50% Faster Delivery

Under weak-link conditions (low Rx rate), SR1/SR2 reduce delay by up to 50% versus MRHOF.

2

Fewer Buffer Overflows

Fewer parent switches mean fewer packets stuck in limited node buffers awaiting new-parent cell allocation.

3

Trade-off Is Minimal

Gains in stability and delivery come at negligible cost to rank-computation complexity.

Conclusion

- Two new Objective Functions (SR1, SR2) dynamically scale RPL's parent-switching threshold using neighbor count or allocated-cell count.
- Both significantly reduce unnecessary parent switches versus standard MRHOF — SR1 shows the strongest stability gains.
- Packet delivery time improves by up to 50% under weak-link conditions, where stability matters most.
- Future work: enhance these objective functions with reinforcement-learning-based approaches for adaptive, data-driven parent selection.

50%

Faster packet delivery under weak links

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21 nodes simulated topology

2 new objective functions

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