# Transmission Power Control in IPv6 Routing Protocol for Low-Power Wireless Network


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## Introduction – Adaptive Multihop Topology and Tx. Power Control for Not Losing Bandwidth!

### Background 0: Low-power and Lossy Network (LLN)

- Network comprised of many resource constrained devices, which usually requires a routing protocol to overcome limited transmission range

### Background 1: Multihop Topology Formation in LLNs

- **RPL**: IETF IPv6 Routing Protocol for Low-power Lossy Networks (RFC6550)
- Main goal: Reliable packet delivery over dynamic and lossy links
- Routing metric: Link quality (ETX) and hop distance

### Background 2: Transmission Power Setting in LLNs

- **Highest** transmission power for minimizing hop distance
- **Uniform** transmission power for all nodes for easy deployment

### Problem: How about Bandwidth??

- There has been no bandwidth consideration for RPL and transmission power setting
- We experimentally observed that the current strategy (RPL with uniform transmission power) loses significant bandwidth due to **hidden terminal** and **load imbalance** problems

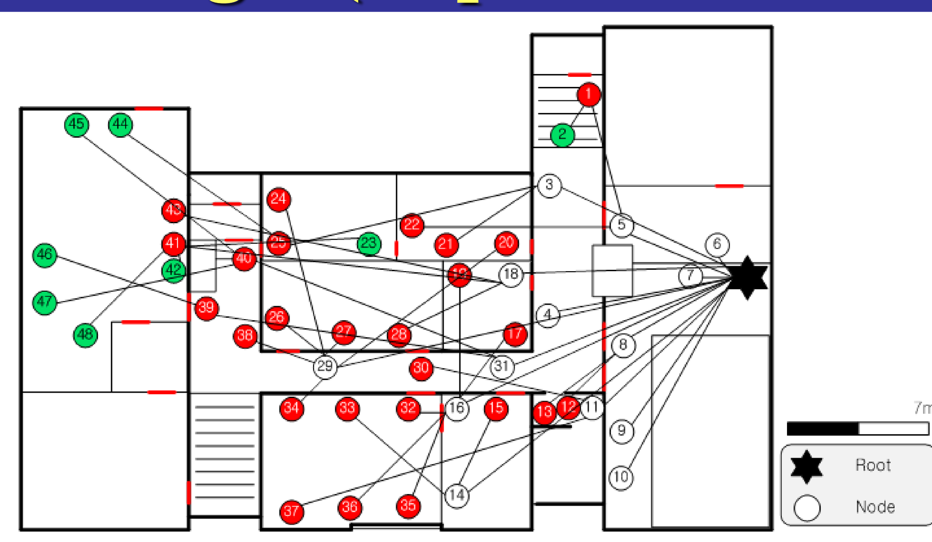
### Our Proposal: PC-RPL (Power-Controlled RPL)

- **Key feature: Adaptive/non-uniform/distributed** transmission power control tightly coupled with **load balancing/hidden terminal-aware** multihop topology control
- **Improvement**: 1) Better aggregate bandwidth, PRR fairness among nodes, and routing stability without increasing hop distance 2) With non-uniform and less-average tx. power usage without manual configuration

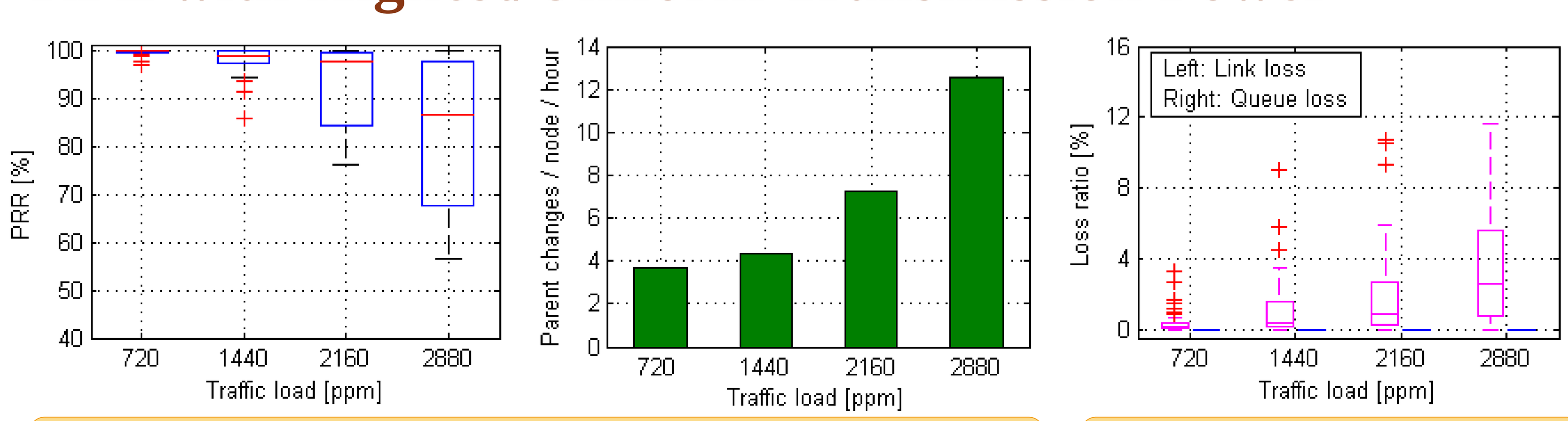
## Observations and Challenges (Experimental Study)

### Testbed Environment

- 48 nodes and 1 root (telosB)
- 3-hop network with highest transmission power (0dBm)
- TinyOS (BLIP + TinyRPL)
- Upstream traffic only, with reasonable traffic load
- No duty-cycling mechanism



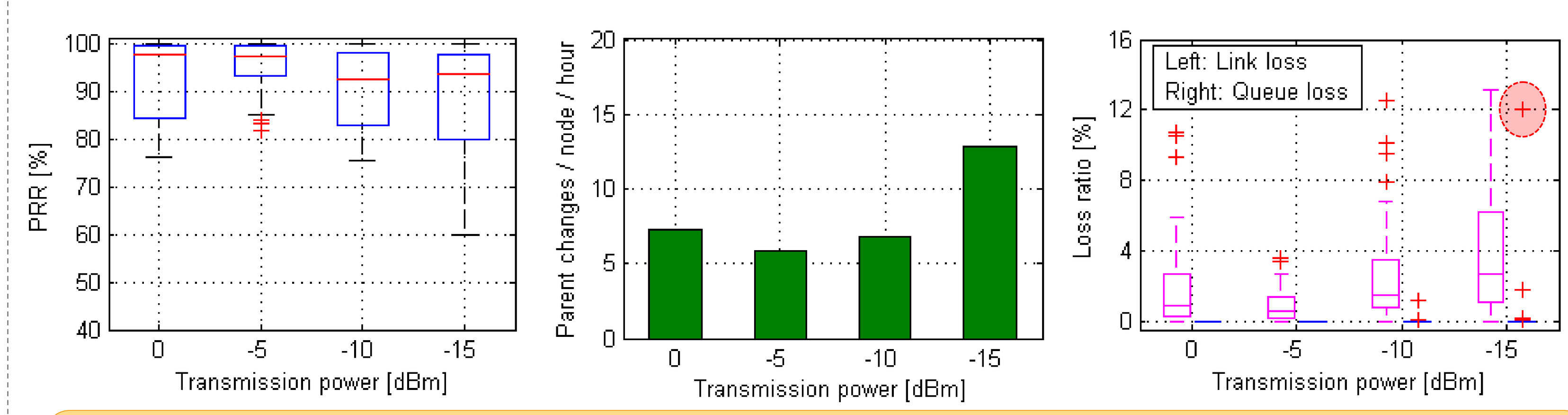

### RPL with Highest/Uniform Transmission Power



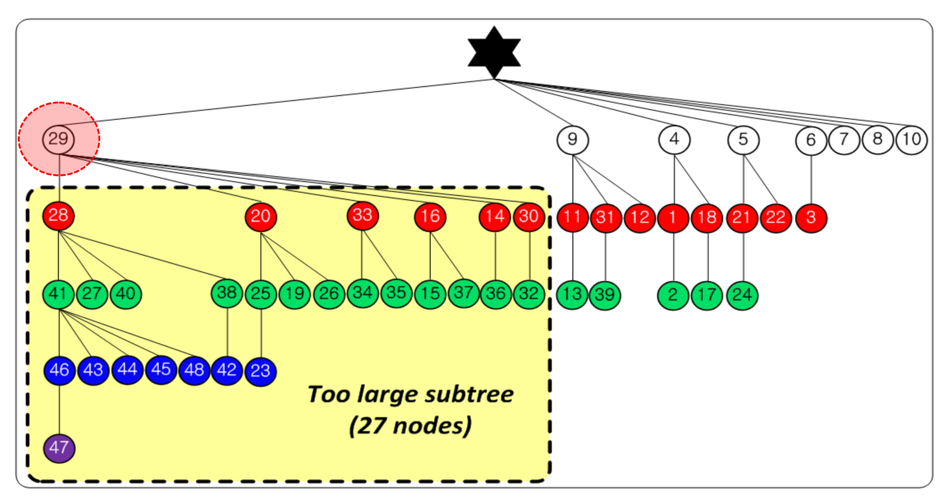

**Unfair/Low PRR and Topology churn**

**Hidden terminal!**

### RPL with Uniform Transmission Power Control




**Tx. power control has the potential, but causes severe queue loss at a few nodes when tx. power is too small**



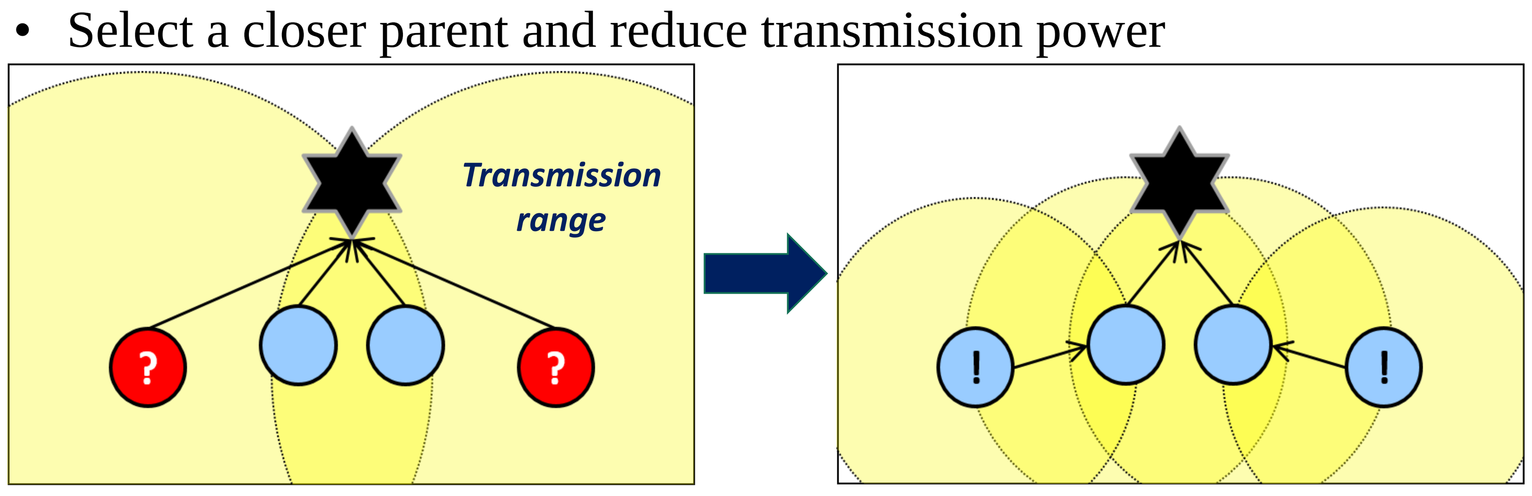

**Queue loss comes from load imbalance due to non-uniform node density!**

**Non-uniform tx. power control has the potential**

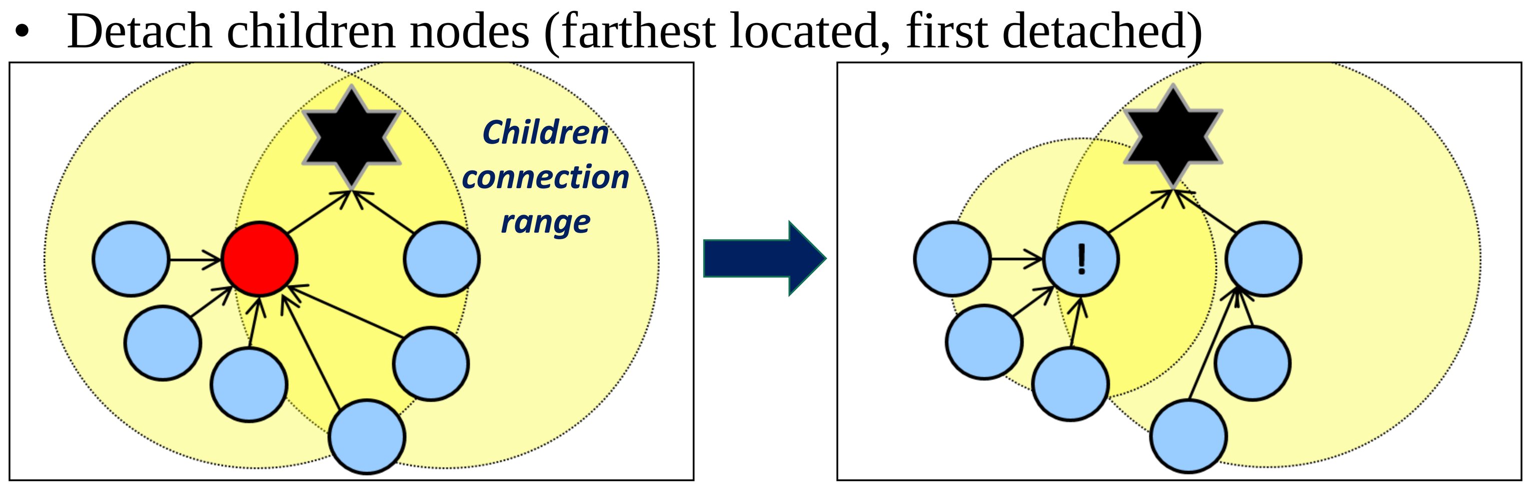
## Design and Evaluation – "PC-RPL : Power-controlled IPv6 Routing Protocol for LLN"

### Design and Approach

- **Problem self-detection**
  - Link loss ➡ hidden terminal. Queue loss ➡ load imbalance
- **PC-RPL structure**
  - Reference RSSI value measurement through DIO with max. tx. power
  - Parent selection by comparing 'reference RSSI' value with 'Children control RSSI threshold' and 'Parent selection RSSI threshold'.
- **Distributed problem resolution 1: Hidden terminal mitigation**
  - Select a closer parent and reduce transmission power

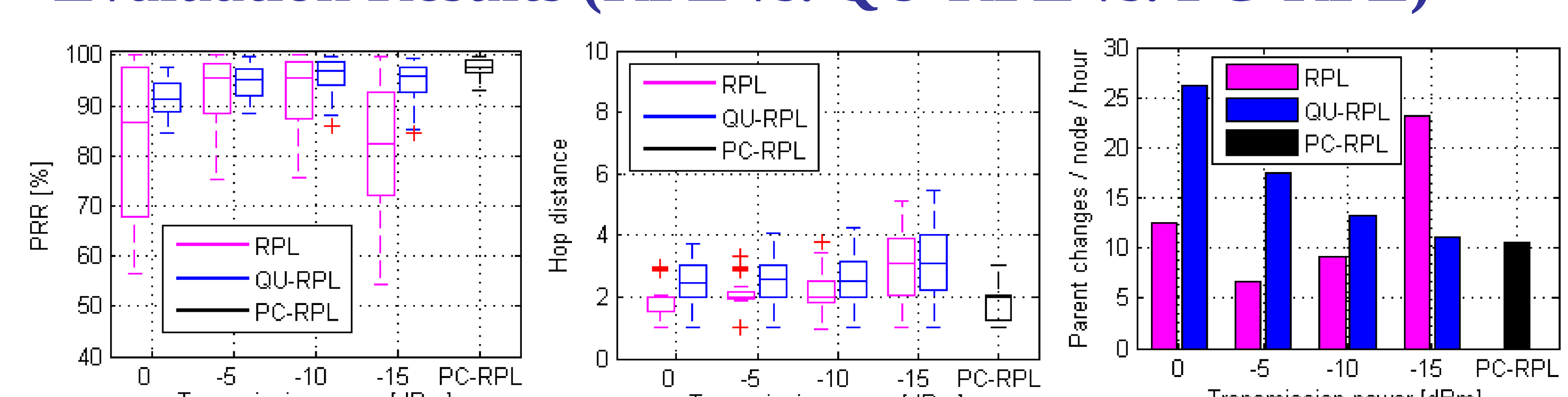



- **Distributed problem resolution 2: Load balancing**
  - Detach children nodes (farthest located, first detached)

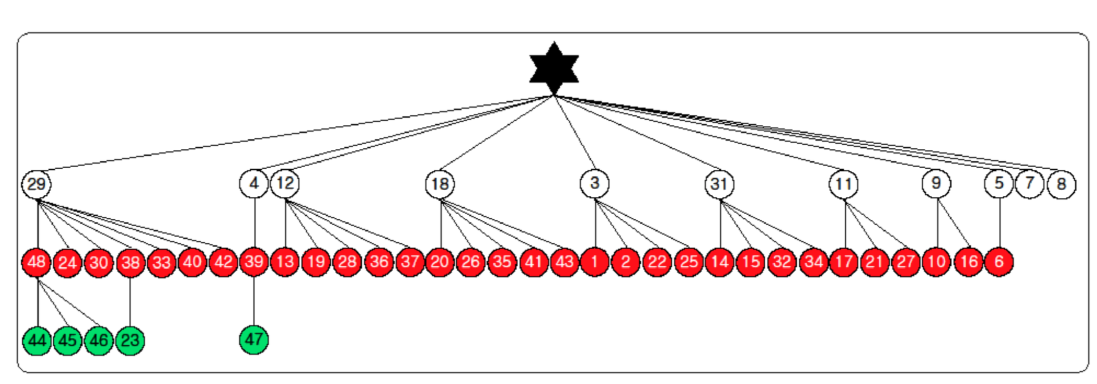



- **Data transmission power control ('just enough' transmission power)**
  - 1) RSSI margin-based fast adaptation
  - 2) Transmission experience-based gradual adaptation

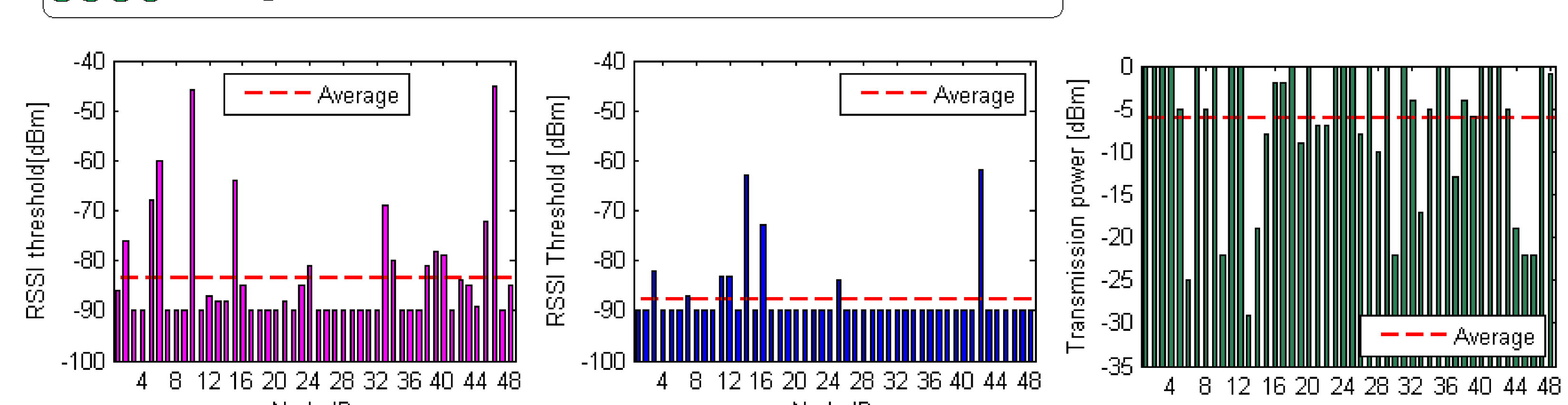
### Evaluation Results (RPL vs. QU-RPL vs. PC-RPL)




**1) 17% more aggregate bandwidth, 2) 64% higher PRR for the worst-case node, 3) Better routing stability, 4) Similar stretch**



**Load balancing effect of PC-RPL**




**Non-uniform transmission power and RSSI thresholds via distributed control, -6.21dBm transmission power on average**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