A Passive and Multi-Neighbors Link Quality Estimator for 6TiSCH Networks
(to appear in EWSN 2018)

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18/01/2018
What is Industrial Internet of Things (IIoT)

Focus of this work: short range and multi-hop networks
Scenarios: smart building, smart factories, etc.

Best-effort protocols

Stable and reliable links

Flexibility (Wireless) + Reliability

Predictable performance

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The key role of the MAC layer in IIoT

**Problem**

Best Effort (CSMA-CA)

- Intermediate nodes need to keep their radio on → + Energy waste
- Collision and random backoff → No determinism

**Solution**

Deterministic MAC

- Scheduling
  - tx
  - rx
  - sleep

- No competition for medium access
- Deterministic performance
IPv6 Routing Protocol for Low-Power and Lossy Networks (RPL)

CoAP | RPL
---|---
IETF 6LoWPAN
6p
IEEE 802.15.4 MAC (TSCH)
IEEE 802.15.4 PHY

6TiSCH stack

Metric: Min hop

- Sink starts broadcasting DIO packets
- B and C join the network and they start broadcasting
- D and E join the network

Other metric → Expected Transmission Count (ETX)
How many transmissions until receive an ACK
802.15.4-TSCH

- **Synchronization**: beacons or ack
- **Slow channel hopping**
  - External interference mitigation
  - Some channels perform better than others
- **Scheduling algorithm**
  - When a node should wake-up?
  - How much resources to allocate?
  - How the resources should be allocated?
    - Priority: alternating slots (rx, tx), leaves nodes first, ...

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**TSCH slotframe**

- **Shared slot**: advertisement (beacon, DIO) + negotiation (6p requests) packets. All nodes turn their radio on when there is no dedicated slot.

- **Dedicated slot**: unicast (data) tx and rx only (radio)

**Diagram**:

- Synchronization
- Routing tree

- **Channel offset**
  - B-A
  - C-A
  - B-A
  - C-A

- **Timeslots**
  - Slotframe
Objective: identify good neighbors passively

Limit of the existing approach in 6TiSCH

Default value = 50%, metric = Expected Transmission Count (ETX)

- Over estimation (high default value)
  - Interactive probing → more parent changes → more renegotiation
- Under estimation (low default value)
  - Non exhaustively (good enough choice)
**Proposition & Challenges**

- **Proposition**: broadcast reception rate as *discriminator*
- **Assumption**: high broadcast rate $\rightarrow$ more likely to receive ACKs

- No need to add extra control packets

- Multi-neighbors *estimator* discriminator

- **Challenges**
  - Channel hopping $\rightarrow$ bias
  - Differentiate bad links and collisions

- Monitor the broadcast reception for a given period of time
Experiment 1: Measuring the correlation

Multipath topology with different link qualities
11 nodes deployed on IoT-LAB (Grenoble) for 24 hours

Send unicast packets (estimate link quality) → Target node → Record broadcast packets

>75%
>35% and <75%
<35%
Correlation for different window size

Mean Pearson Correlation
(Broadcast reception x Unicast PDR)

Collision impacts the correlation

Experiment 2: accuracy of getting the node with highest broadcast reception rate as best neighbor

Broadcast reception rate accuracy

Impact on the network density
(w = 4 minutes)
E2E PDR

- Average PDR
- Broadcast rate

E2E delay

- Path 1
- Path 2
- Path 3
- Path 4
- Path 5
- Path 6
- Path 7
- Path 8
- Path 9

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Experiment 4: 6TiSCH integration

Random topology (13 nodes)
6TiSCH default behavior
Updated RPL Objective Function

- **Blind selection** → default ETX (PDR = 50%)
- **Aware selection** → broadcast rate

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Conclusion & Perspectives

• **Using broadcast to select a good parent**
  • Energy efficient (no individual probe)
  • Discrimination is enough
  • Limited routing reconfigurations (more stability)
  • For both bootstrapping and operational phases

• **Future work**
  • Variable broadcast period
    • What is the impact of the Trickle algorithm?
  • Can we use only Enhanced Beacons?
Thank you!
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