Multipath Opportunistic RPL Routing over IEEE 802.15.4

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Motivation

- IPv6 vision of future WSN

  (The Internet of Things)
- Relying on two IETF standards:
  - 6LowPaN
  - **RPL**
- Majority of the devices running **802.15.4** standard at PHY and MAC level

- Why not combine them and additionally provide QoS? (not done so far)

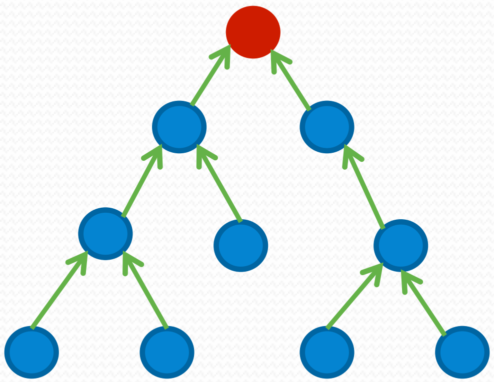
Copyright: Geoff Mulligan, IPSO Alliance

Emerging standards

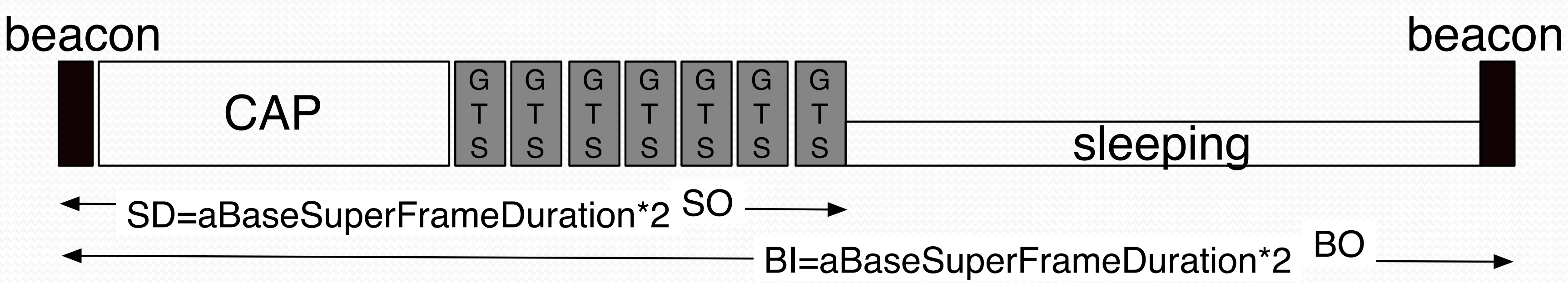
IEEE 802.15.4.

- **MAC**: beacon(less)
- Topology control:
  - Cluster tree(mesh), star, peer-to-peer

  1 parent
- Beacon **collisions** in basic version



Cluster tree

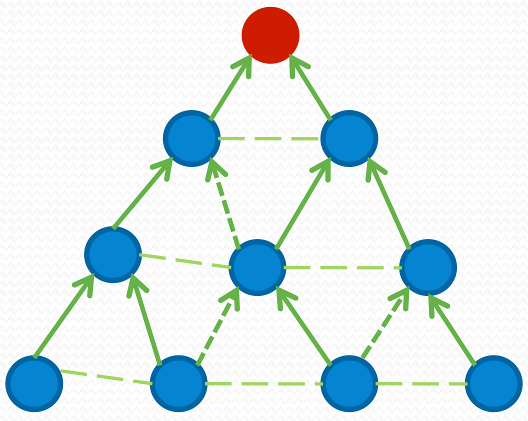


IETF RPL

- **Routing**: <u>Convergecast,</u> downlink traffic, P2P
- Topology control:

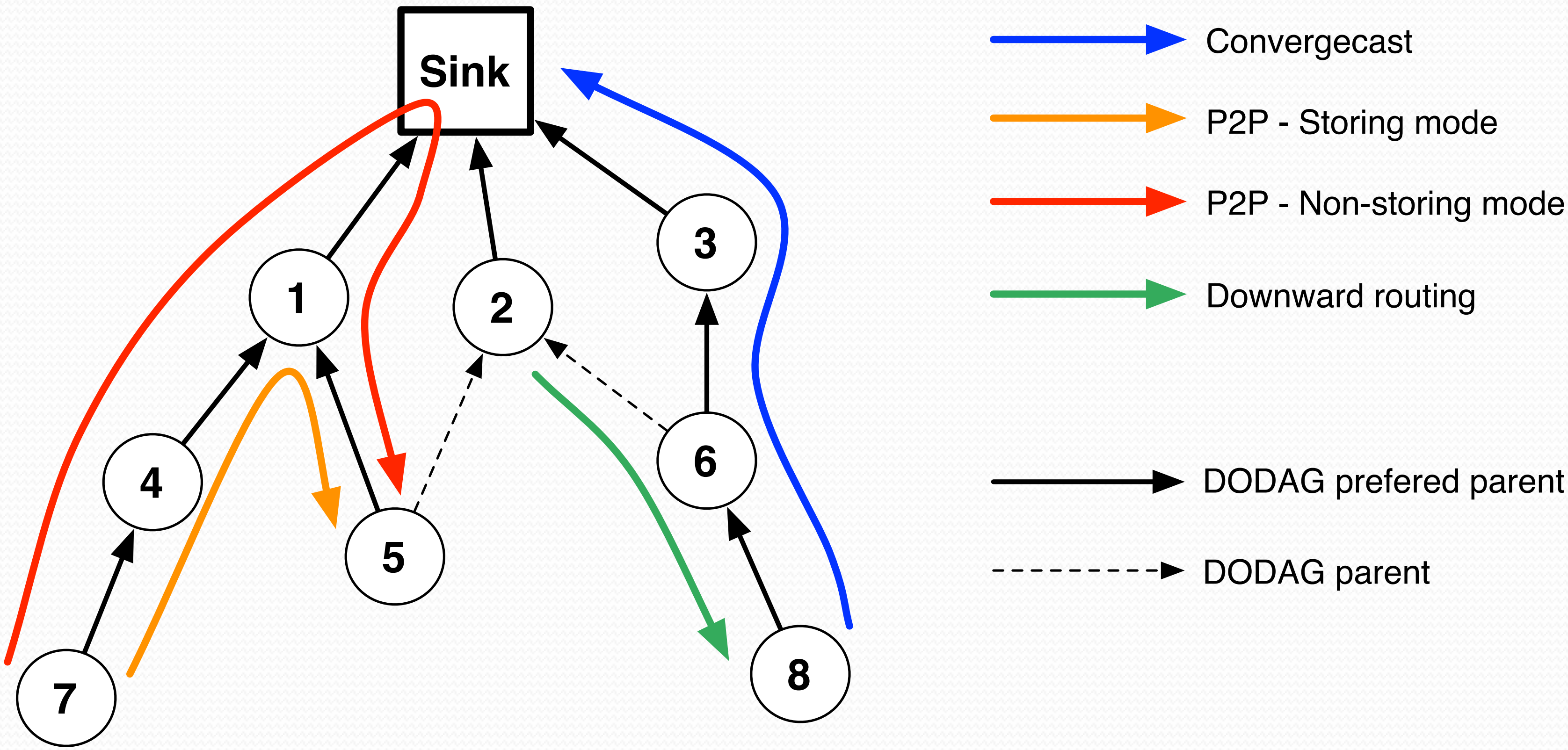
  Directed **A**cyclic **G**raph

  1 preferred parent + 2 backup
- DIO (DAG Information Object)
- Trickle Timer
- Supported different metrics: **ETX** (Expected Transmission Count), throughput, latency, …

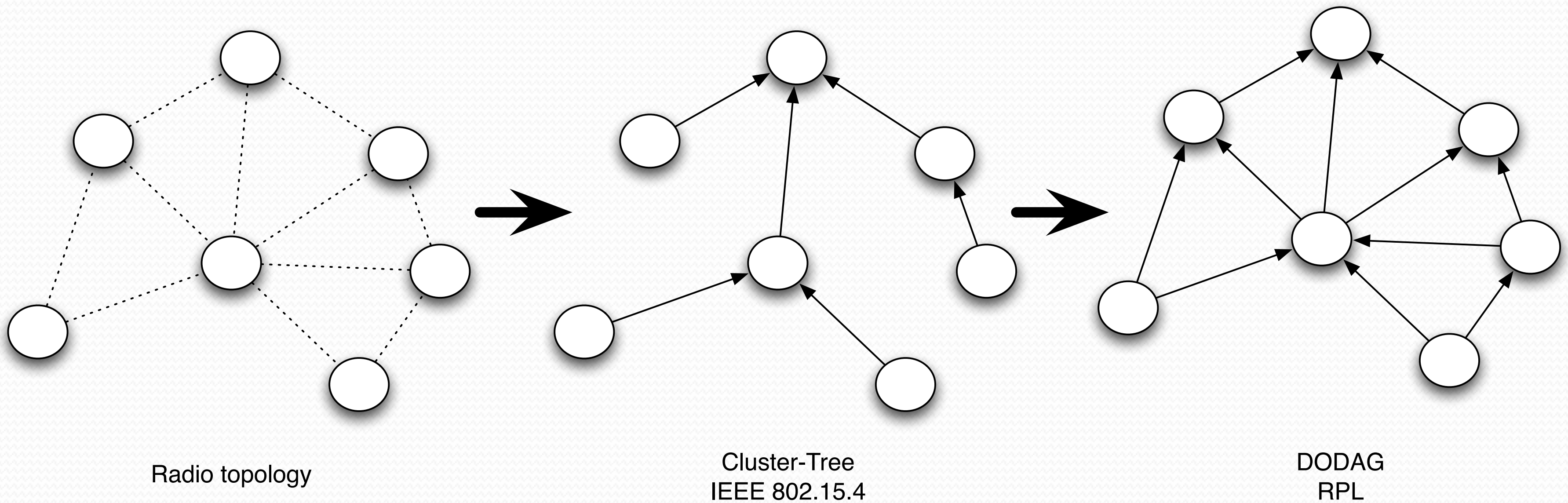


DAG

IETF RPL – traffic types



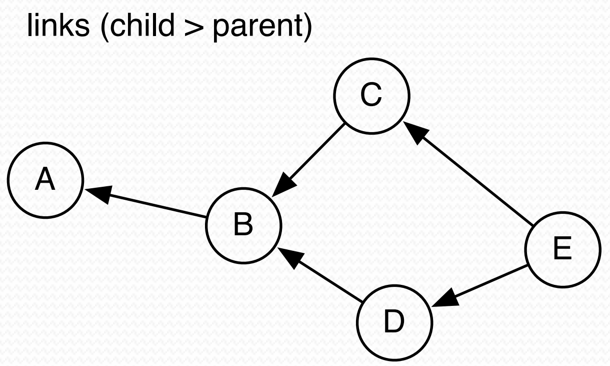
Topology difference

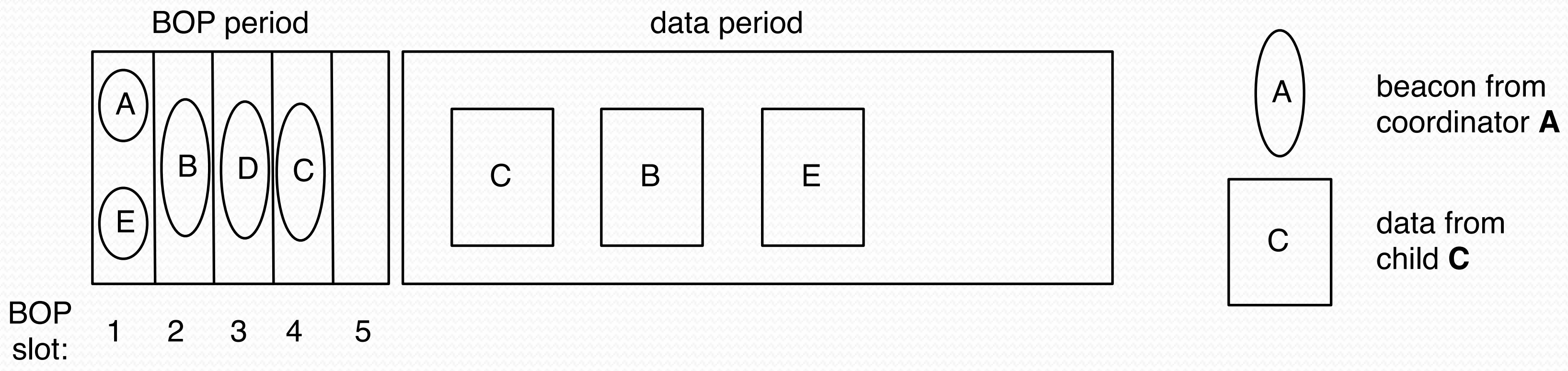


How to make them work together?

Superframe collision avoidance

- **Beacon-Only Period (BOP)**
- NO beacon, but data collision remains
- Lower PDR, higher end-to-end delay

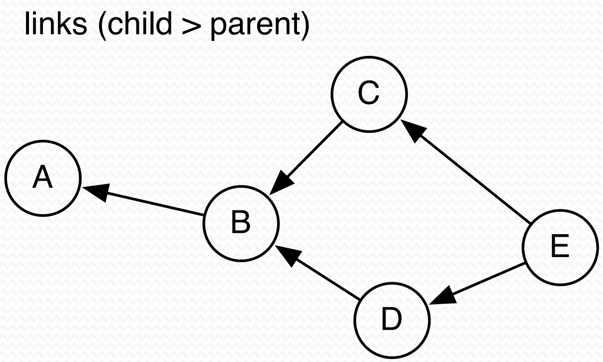


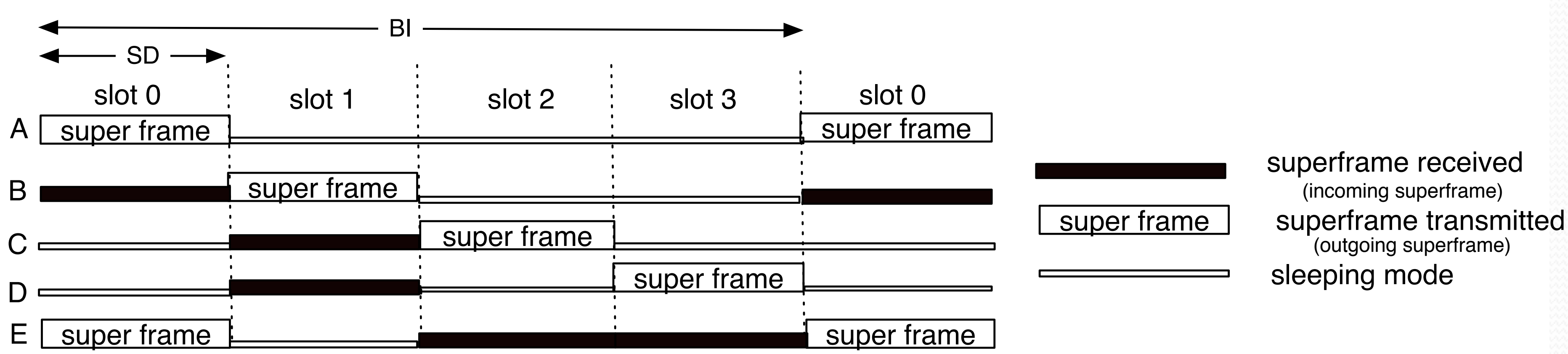


B.C. Villaverde, R. De Paz Alberola, S. Rea, and D. Pesch. Experimental evaluation of beacon scheduling mechanisms for multihop IEEE 802.15.4 wireless sensor networks. In International Conference on Sensor Technologies and Applications (SENSORCOMM), pages 226–231. IARIA, July 2010.

Superframe collision avoidance

- **Superframe Scheduling**
- NO beacon, NO data collision
- Higher PDR, lower end-to-end delay
- Less effected by num of neighbors / load





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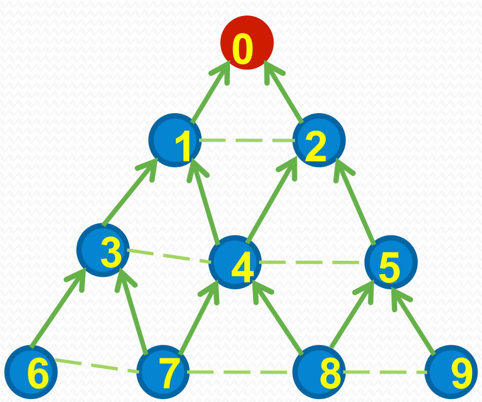
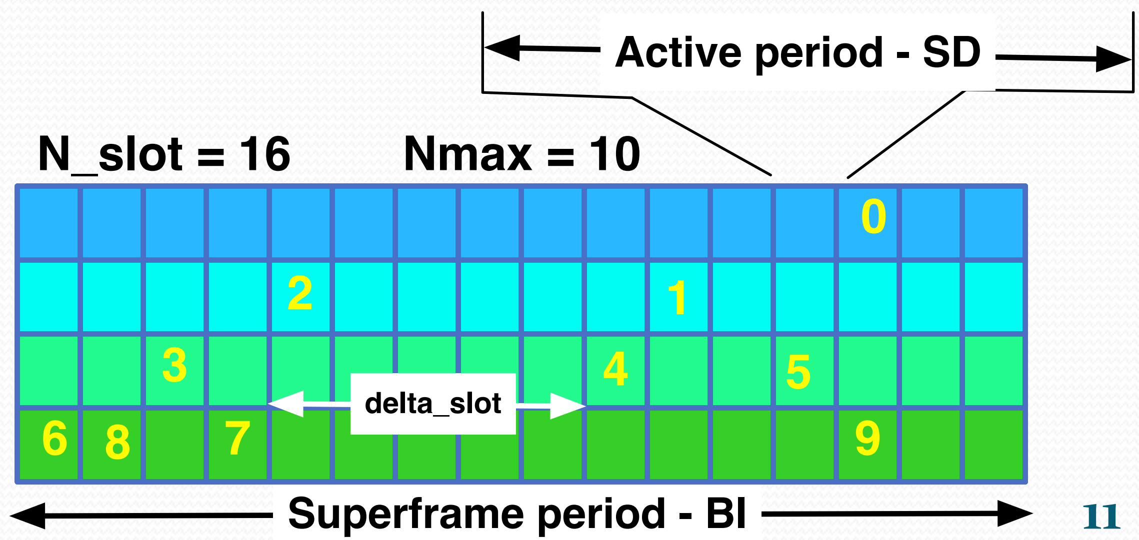
Our improvement

- Slot attribution: random – **accelerate convergence**
- Nmax a priori, same SO and BO

$$N\max + 1 \leq 2^k = N\_slot = 2^{BO-SO}$$

- 2-hop neighbor knowledge – *hello msg*
- Adaptable – min change, prudent, DAG consideration
- Example: N_slot = 16 & SD = 150ms => BI = 2.5s





Benefits vs. changes

Benefits

- Accelerate convergence
- Avoid beacon + DATA collisions
- Possibility to follow more parents
- Coexistence of RPL and 802.15.4.

Changes

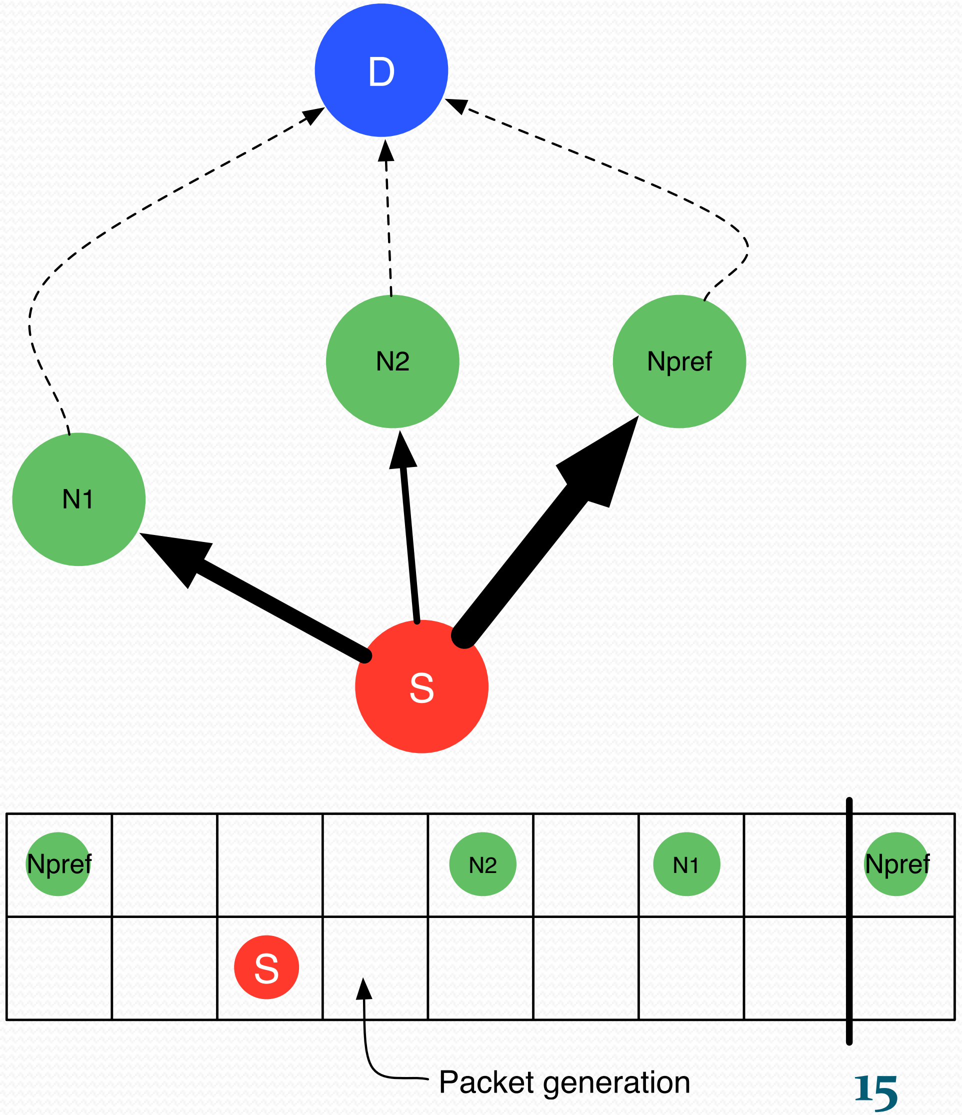
- DIO collated to beacon
- Trickle modification – follow beacon periods
- Clock drift neglected (sync) + OpenWSN Berkley

Opportunistic QoS routing

Basic principles

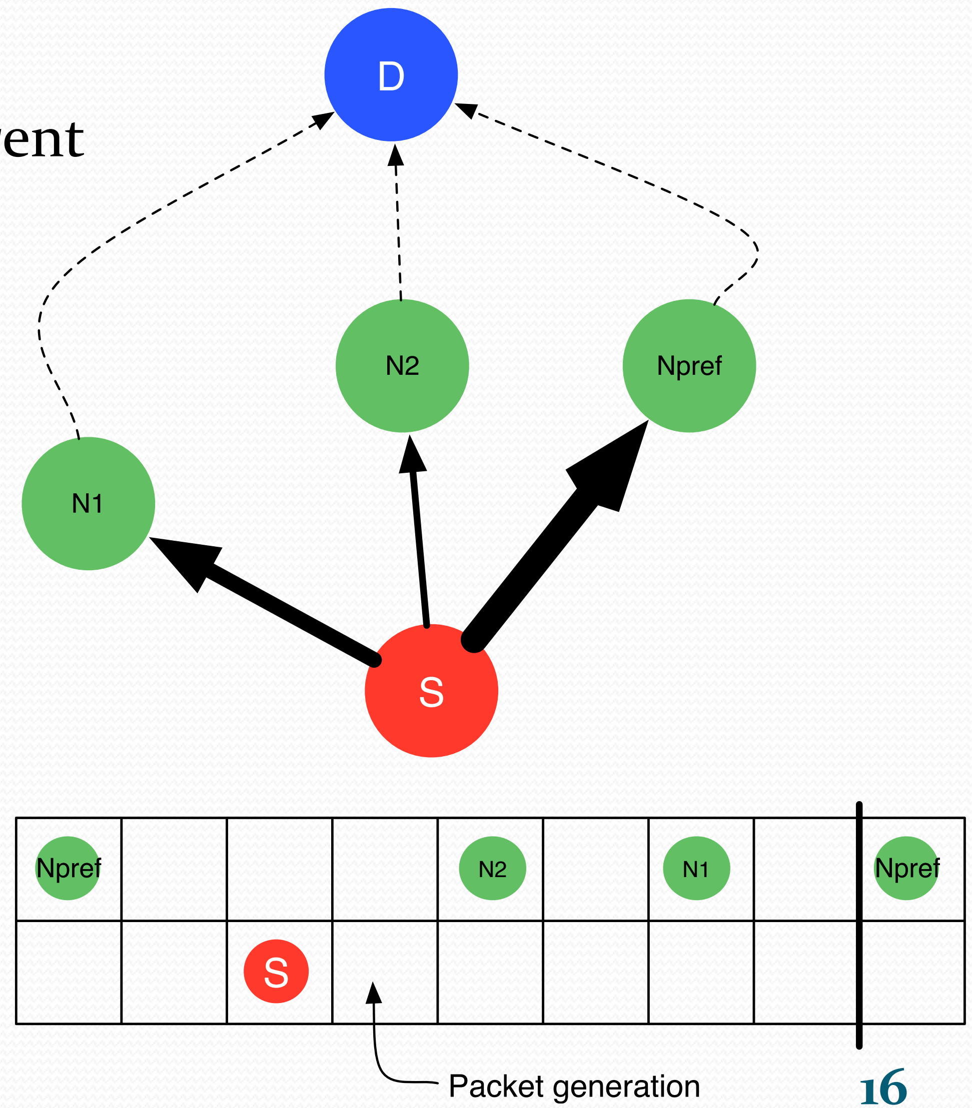
- **Opportunistic multipath routing**: MAC schedule coupled with routing decision, interchangeably use parents
- **QoS**: deadline and energy consumption
- **Packet priority**: best-effort, deadline, min-delay (70 – 20 – 10 %)
- **Queuing** - priority first, deadline first
- **Goals:** minimize overhead (packets / energy) while respecting a max delay
- **DAG metric**: ETX

Forwarding decision - example



Forwarding decision

- **min-delay** : first available parent



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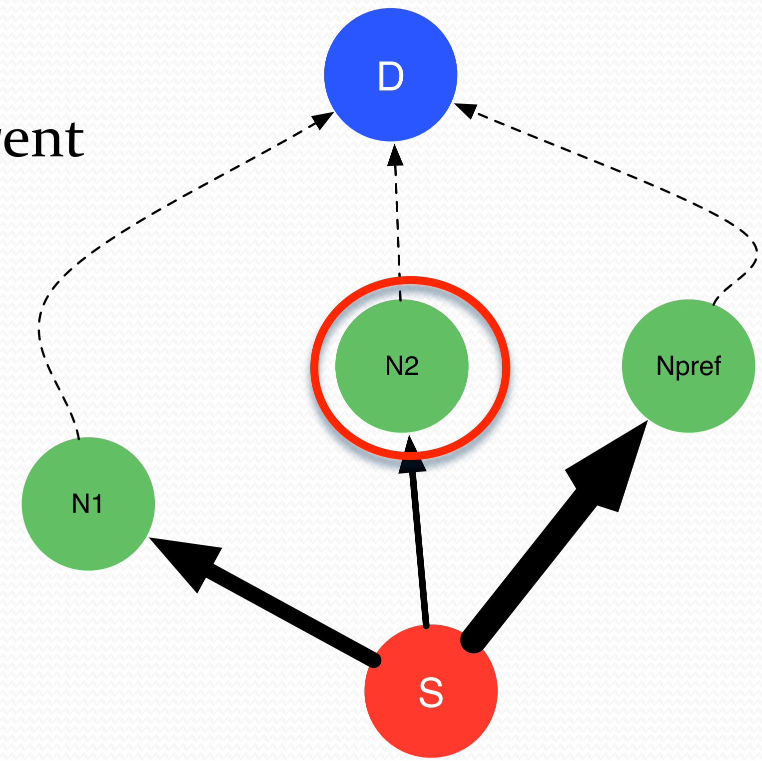
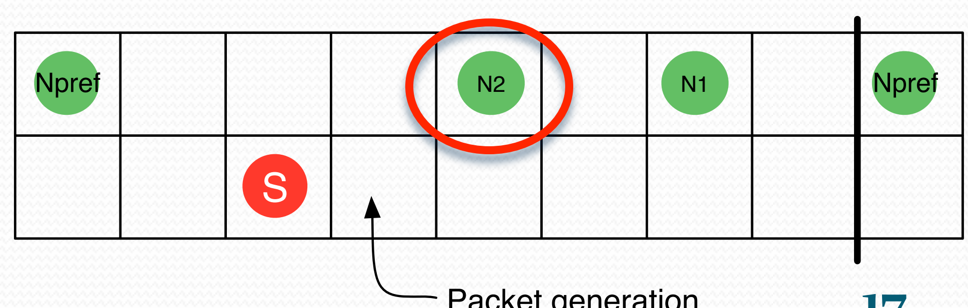
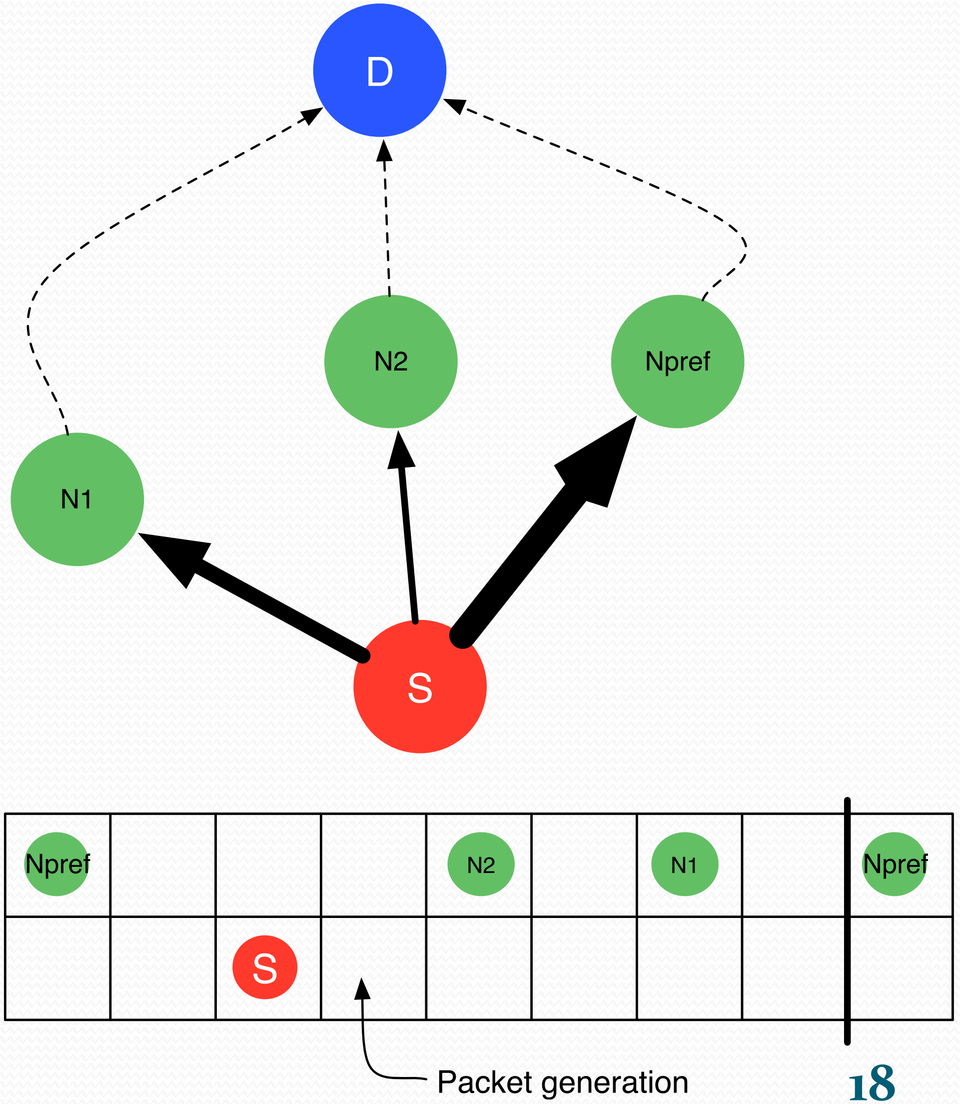




Forwarding decision

- **best effort** : preferred parent
  or
  parents with same ETX



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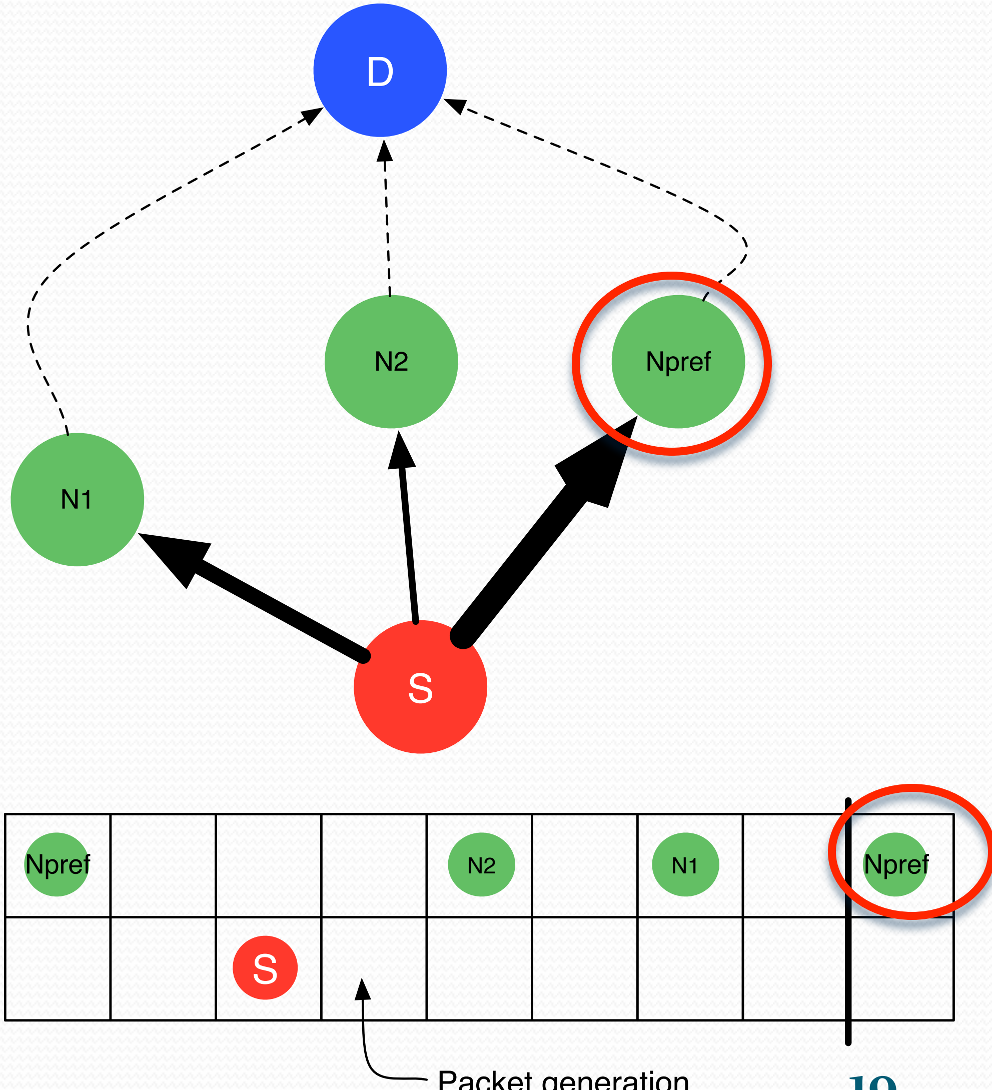

Forwarding decision

- **deadline** : respect delay budget and $\Delta ETX \leq 1$
- E2E deadline, step by step delay budget
- Possible candidates:

$$budget = \frac{deadline(p) - t}{d(V)} \geq SD \cdot \Delta_{slot} + BI \cdot \left(\frac{1}{PDR_{beacon}} - 1\right) + t_{packet} \cdot \frac{1}{PDR_{data}}$$

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due to beacon loss

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due to data loss

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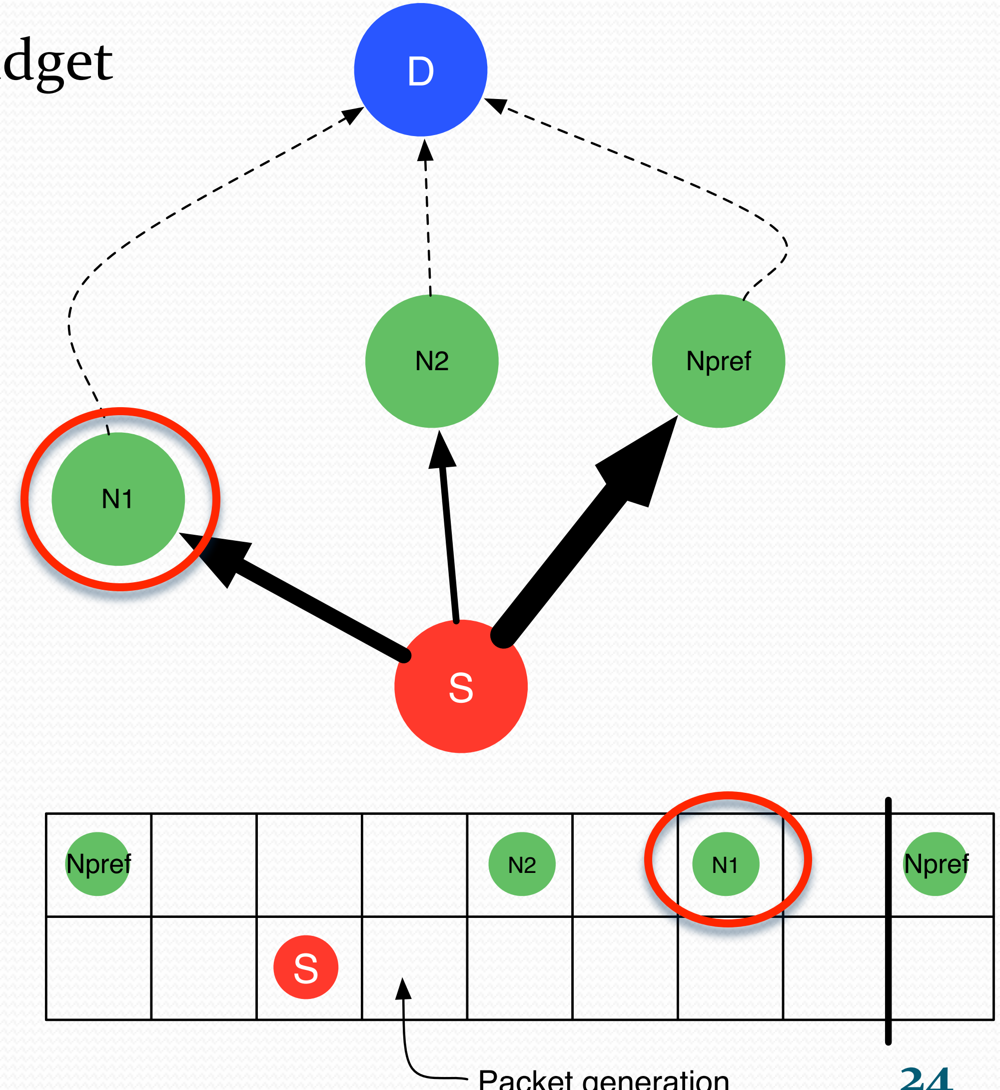


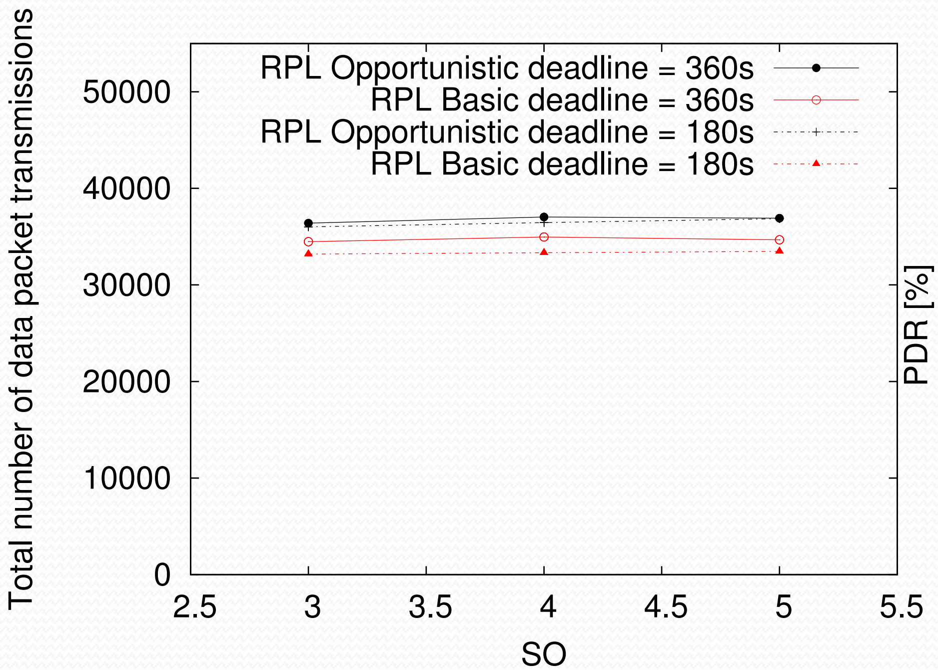
Simulation results

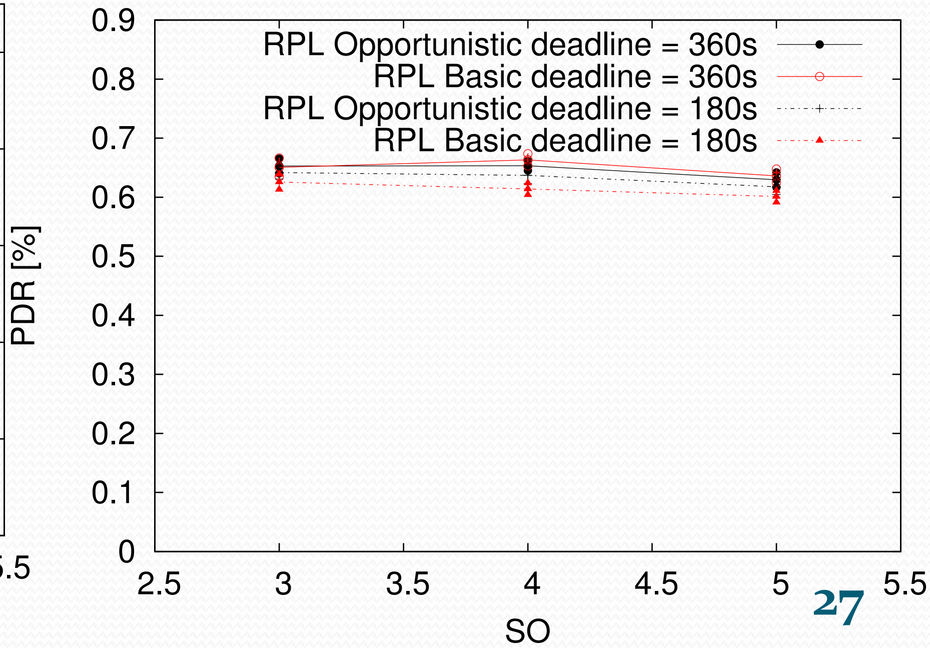
Simulation setup

- WSNet/Worldsens
- RPL (Contiki implem) & 802.15.4.(LIG – Nazim Abdeddaim)
- 10 random topologies: up to 256 nodes, 400x400 m
- Rayleigh propagation model (not UDG)
- Low intensity traffic: 7.5 min
- Three classes: best-effort, min-delay, deadline (70 – 20 – 10 %)
- SO between 3 and 5
- Duration: 50.000 s

Results – general behavior

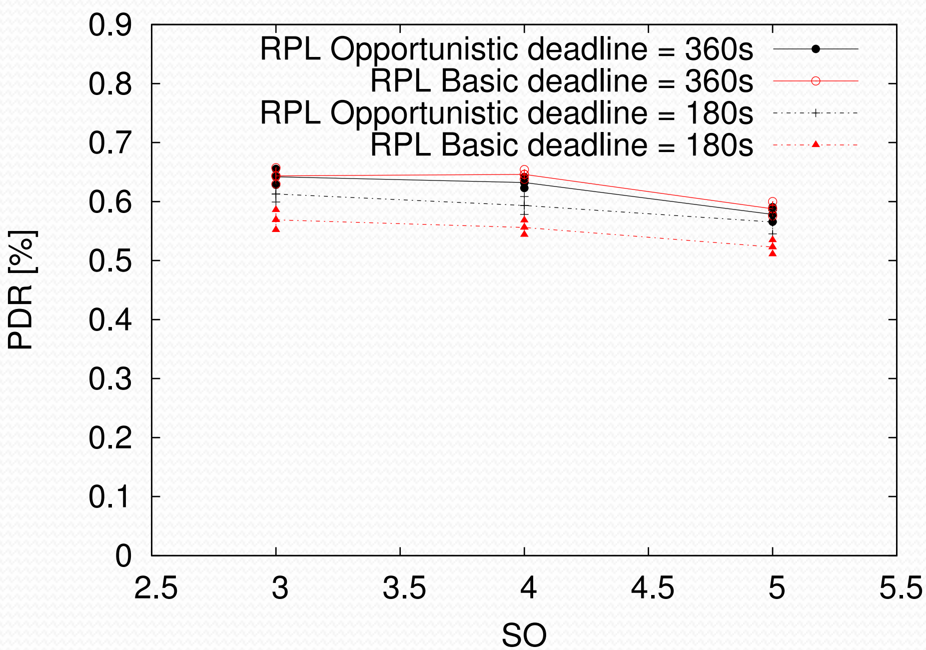
- Similar PDR behavior in general, better with shorter deadline criterion
- Slightly greater total number of transmitted packets (+9%)
- Reasonable price for distributing the charge over all possible parents

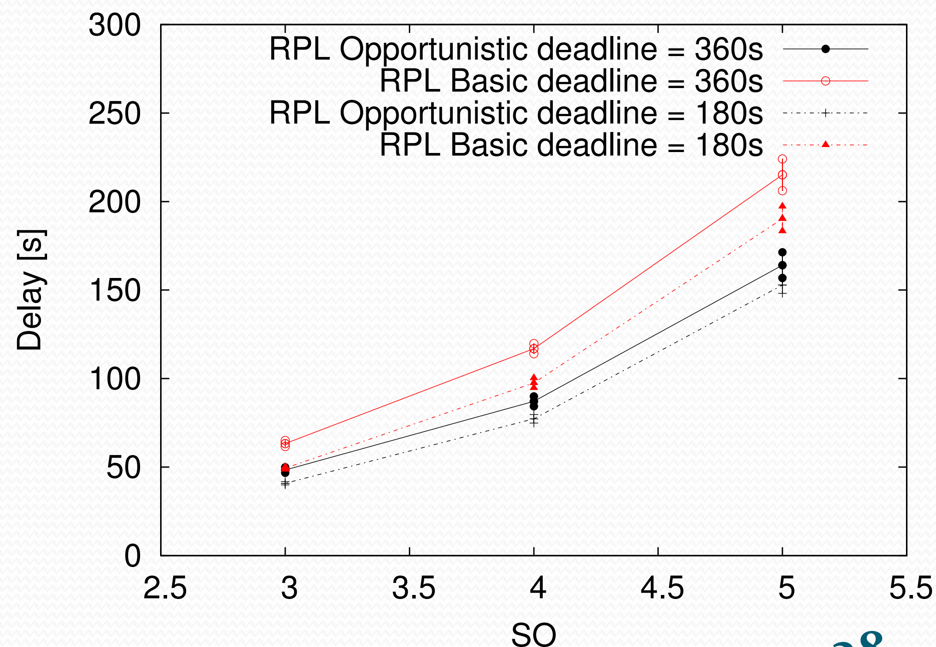




Results – "min-delay" type

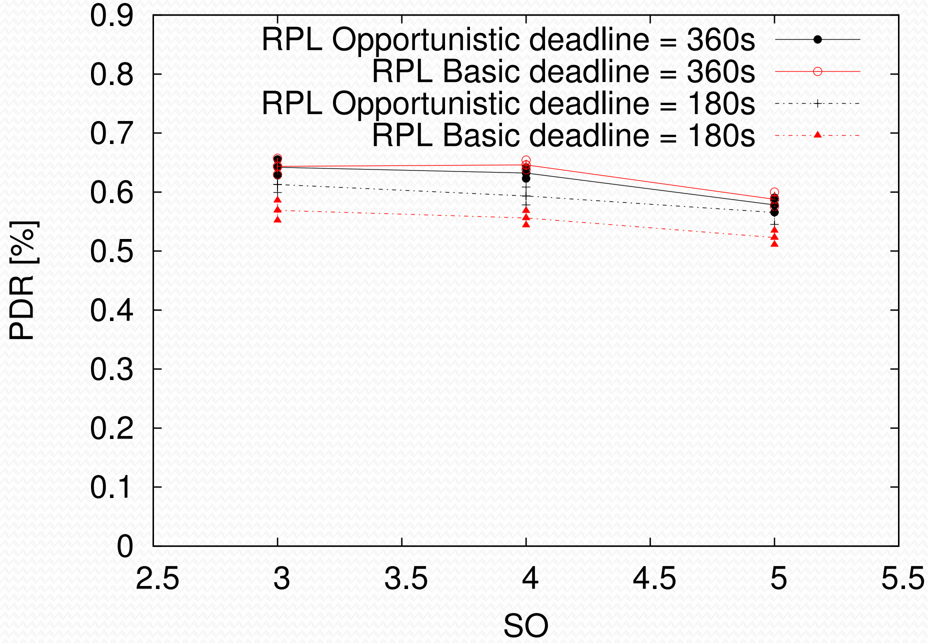
- Notable gain in PDR performance with harsh deadline constraints
- Real performance contribution : lower end-to-end delay

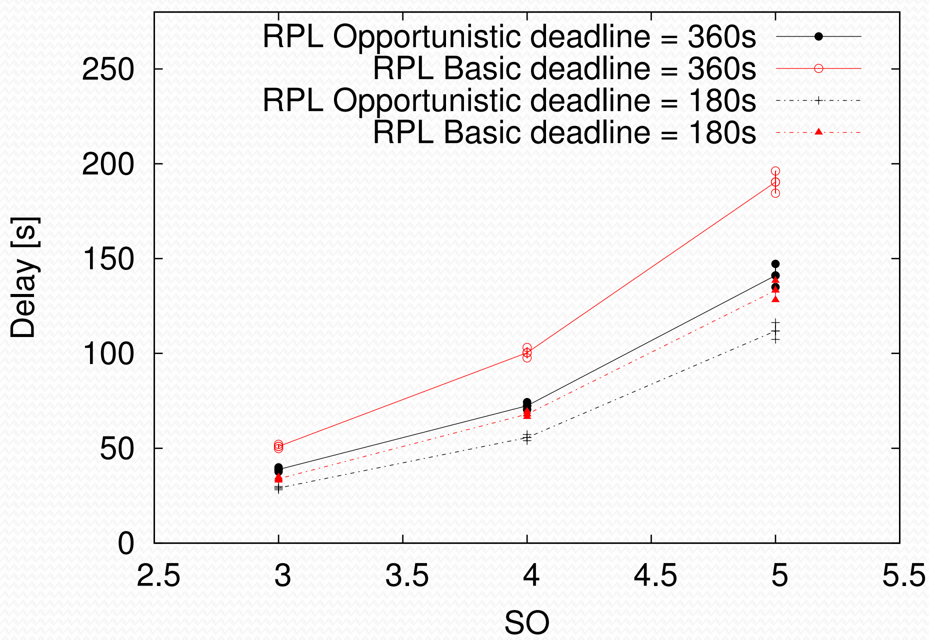




Results – "deadline" type

- Similar results – proof of concept





Contributions

- Coexistence of RPL with IEEE 802.15.4. MAC
- Cluster tree adapted to support DAG - multiple parents
- Slightly better PDR and delay results
- Keeping almost the same amount of the generated traffic
- Lower delay incurred even for harsher constraints
- Believe: charge distributed evenly => prolong network lifetime

Future work

- Refine simulation:
  - Verification of charge distribution
  - Limit the packet buffer size
  - Energy consummation (battery level)
  - Tweak MAC parameters to accommodate higher traffic rates
- SensLab experimentations: Contiki RPL + Opportunistic

Questions?

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