Wireless Sensor Networks
6. WSN Routing
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Routing Protocol for Low power and Lossy Networks (RPL)

- **Literature**

- **Designed for Low-power and Lossy Networks (LLN)**
  - limited processing power, memory, energy
  - interconnected by lossy links, low data rates
  - traffic patterns
    - Multipoint to point (convergecast)
    - Point to multipoint (multicast)
    - point to point (unicast)

- **Design Principles**
  - Routing Metric is variable
  - bidirectional links required
  - uses Trickle for data dissemination
  - uses DAG as basic topology

\[ ETX(a,b) = \frac{1}{d_f \cdot d_r} \]
DAG

directed acyclic graph

mon-cyclic

cycle

topological sorting

total order

partial ordering

set of nodes / vertices
set of edges / rays

knot nodes

undirected

vertex
RPL: Terms

- **DAG**: directed acyclic graph
  - routed towards root nodes
- **DAG root** = sink of a DAG = LBR (LLN Border Router)
- **DODAG**: destination-oriented DAG
  - DAG with single root
- **Rank**:
  - partial order in corresponding with the DODAG
- **Grounded DODAG**
  - DODAG where RPL can find the root
- **Floating DODAG**
  - A DODAG where there is no path to the root because wrong pointers
RPL: Ideas

- **Convergecast (MP2P)**
  - DAG with multiple successors if possible
  - DAG defined by specific metrics (e.g. ETX, latency, DAG rank/hop count)
  - Least expensive paths

- **Multicast**
  - DAG also used for P2MP flows

- **MP2P and P2MP for P2P (unicast)**

- **DAG**
  - Depth (aka. rank), i.e. cost towards the sink (root)
  - Rank defines position in the DAG
RPL: MP2P Forwarding

- Forward to nodes of lesser rank
  - avoids loops
  - loops may occur when the metric has changed or nodes leave due to rank inconsistency
  - use redundancy
- Forward to nodes of equal rank
  - not using DAG links
  - if forwarding to lesser rank (DAG-link) fails
- Do not forward to nodes of higher rank
  - causes loops
RPL: DAG Construction

- Given LLN with ETX
  - ETX should be stable enough for route computation
- Nodes are bidirectional and ETX is known at both ends
- Or use any other comparable metric, e.g. hop distance
- Minimize ETX
Sink broadcasts RA-DIO

- Router Advertisement (RA)
- DODAG Information Object (DIO)

Nodes A, B, C
- receive RA-DIO
- join DAG rooted to sink (LBR)
RPL: DAG Construction

- Nodes A, B, C
  - receive RA-DIO
  - join DAG rooted to sink (LBR)
  - compute rank
RPL: DAG Construction

- Nodes A, B, C
  - receive RA-DIO
  - join DAG rooted to sink (LBR)
  - compute rank

![Diagram of DAG with nodes A, B, C, D, E, F, G, I, H, and S (sink)]
RPL: DAG Construction

- Node C
  - send RA-DIO
- Nodes B, F receive it
  - recomputes rank
RPL: DAG Construction

- Nodes B and F
  - recompute rank
- Node B
  - redirects to C
- Node F
  - joins the DAG
RPL: DAG Construction

- Final network
- Rank is rounded
  - such that multiple paths exist
- Maintenance is continued
  - RA (router announcements) use Trickle algorithm
RPL: Convergecast (MP2P)

- MP2P traffic flows along DAG links
  - toward sink/DAG root/LBR
RPL: Multicast (P2MP)

- Destination advertisements object (DAO) message
  - build up routing state outwards from sink
  - toward sink/DAG root/LBR
- Two modes supported
  - Source routing (non storing case)
    - sink gathers information
  - Routing table (storing case)
RPL: Unicast (P2P)

- Unicast message
  - travel towards the sink (up)
  - and then towards the target node (down)
- Non-storing case
  - message travels to sink and is sent via source routing
- Storing case
  - message travels up until a node knows the target
RPL: Loop Avoidance

- Node A looses connection towards sink
  - with no alternatives
- A sends out RA-DIO
  - and becomes root of a floating DAG
- Successors of A flood RA-DIO to inform all dependent nodes
RPL: Floating DAG

- Floating DAG
  - does not need to satisfy the DAG constraint
- Nodes A becomes floating DAG
- Node B and D have alternate parents and remove links towards A
Node B will advertise with RA-DIO

A joins DAG again
Now link from E to B fails

Nodes E, D, G become floating DAG
  - informed by E

Nodes I, F
  - have alternative routes
- Assume A advertises link
- D links to A
  - and forwards info to E and G
- Nodes E, G now repair links
- Eventually, again the optimal network will be found
specified only for IPv6
based on Distance Vector
produces a stable DAG
  - well suited for traffic directions up and down
problematic for other traffic directions
Critical evaluation:
  - assumes bi-directional connections
  - not completely specified
  - Loops are in real experiments a big unresolved problem
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