A Study of the RPL Repair Process using ContikiRPL

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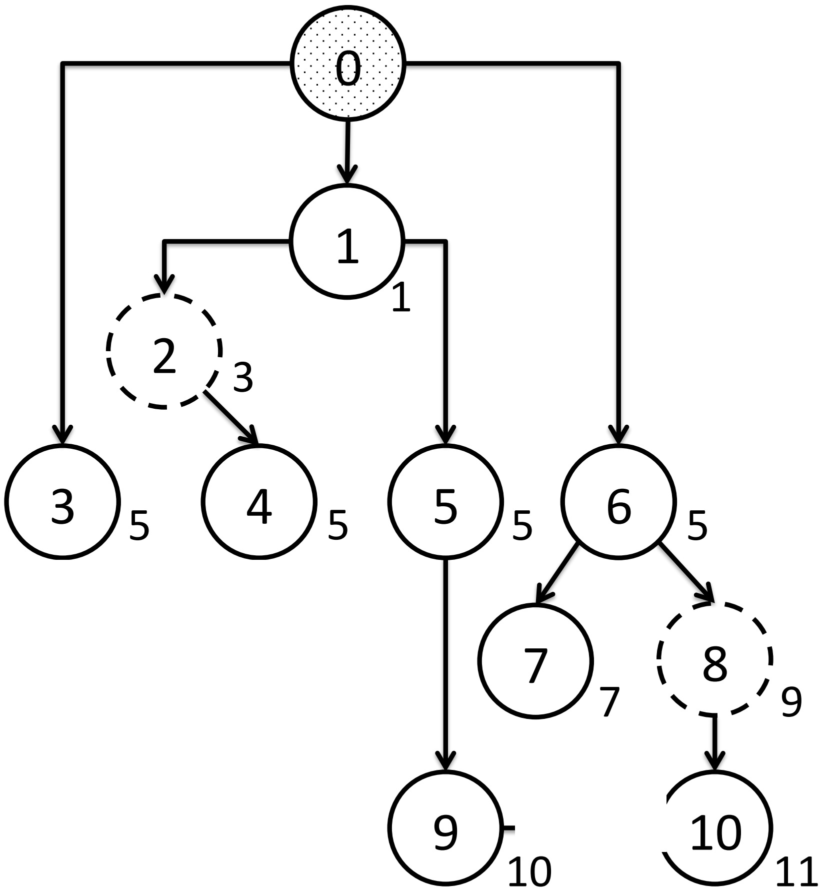
Outline

- Overview of RPL
- Motivation
- Contiki
- Experimental Setup
- Results
- Conclusion

Overview of RPL

- Developed by the IETF RoLL working group.
- Based on an analysis of the routing requirements in low-power and lossy networks.
- Supports point-to-point, point-to-multipoint and multipoint-to-point traffic patterns.
- Objective functions can target requirements of the routing tree, e.g. energy conservation or fastest delivery.

Overview of RPL



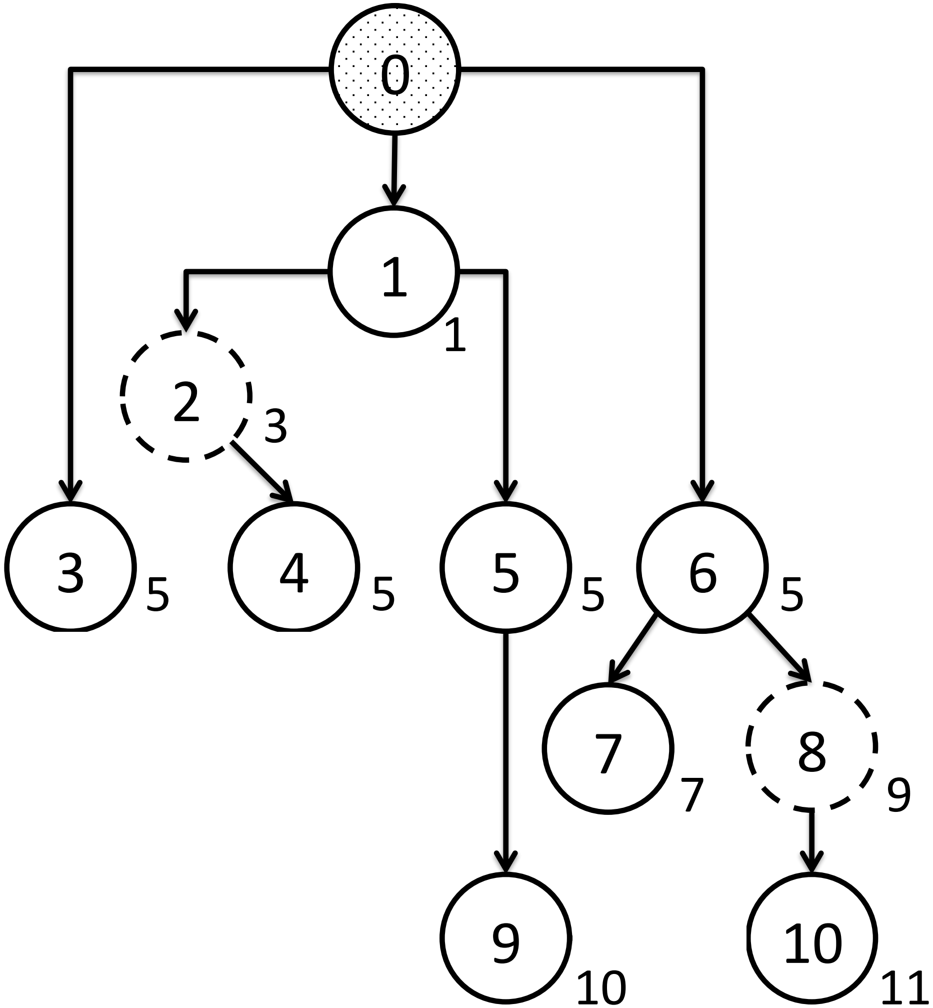
- Destination Oriented Directed Acyclic Graphs, called DODAGs.
- Root sends DODAG Information Object message.
  - Traffic pattern
  - Objective Function
  - Rebuild cycle information
- Receiving node decides action
  - If part of DODAG, but better rank, treat as join
  - If not part, compute rank, join DODAG and pass message

Overview of RPL

- Main problem in low-power lossy networks is nodes disappearing from network.
  - Loss of battery power; link degradation.
- RPL has two approaches to deal with this.
  - Global repair – increase DODAG version (costly, simple).
  - Local repair – do not rebuild, two approaches
    - *Route through siblings with same rank.*
    - *Switch parents.*

Overview of RPL

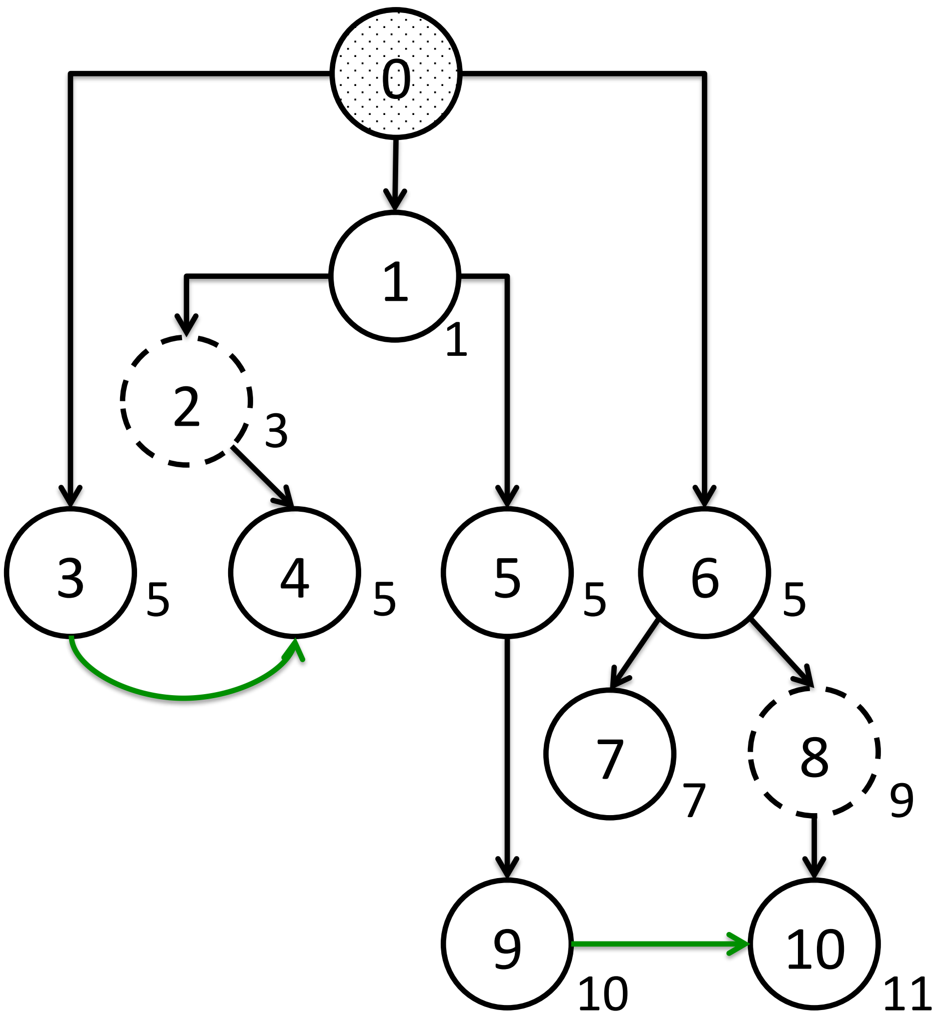
Local Repair



- Network with 11 nodes.
- Node 0 is root.
- Nodes 2 and 8 are failing.

Overview of RPL

Local Repair



- Node 4 routable through 3.
  - *Local repair, routing through sibling with same rank*
- Node 10 routable through 9.
  - *Local repair, switching parent*
- Works because
  - *Nodes 3 & 4 have same rank (5)*
  - *Node 10 switches parent to node 9*

Motivation

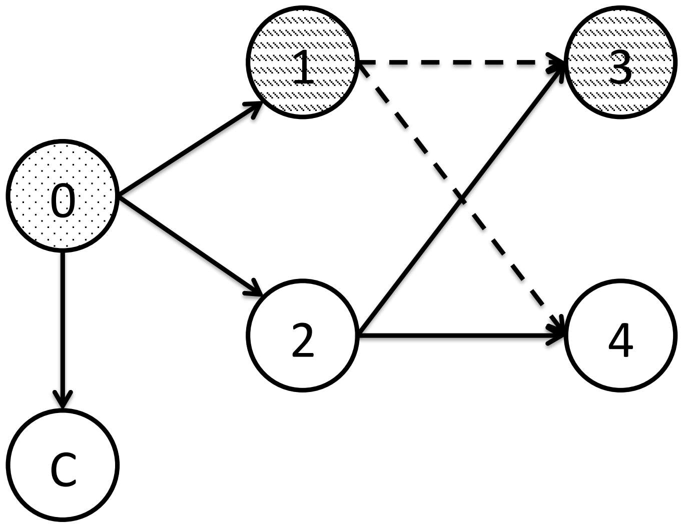
- Many research results on performance of RPL already available.
- Node failures in a low-power lossy medium likely.
  - Good to know the performance of RPL in such scenarios.
- ContikiRPL is one of the more popular implementation.
  - Evaluate effectiveness of the repair and recovery procedures.

Contiki

Platform	RAM	Flash	Clock Speed	Architecture
MICAz	4 kB	128 kB	8 MHz	8-Bit AVR
RZ-Raven	16 kB	128 kB	8 MHz	8-Bit AVR
RZ-Raven USB	8 kB	128 kB	8 MHz	8-Bit AVR
TelosB / TMote Sky	10 kB	16 kB	8 MHz	16-Bit MSP430
Econotag	**96 kB**	**128 kB**	**24 MHz**	**32-Bit ARM7**

- Contiki is an Embedded-OS
  - Supports 6LoWPAN and RPL
- Must choose appropriate platform.
  - Resources are limited
- Contiki and ContikiRPL quite heavy.
  - RPL - 50 kB flash on MSP430 & AVR
  - RPL - 6 kB RAM on AVR
  - Contiki services occupy most resources

Experimental Setup



- Network of six Econotags.
- Node C used to monitor other branches of the network.
  - Check no global repair occurs.
  - SNMP to monitor local and repair counters.
- Repeat experiments till σ is below one-tenth of average. (Min 20 values)

Results

Fallback Parent

Monitored Value	Average	σ
ICMP Runtime before disconnect	43.4 ms	0.8 ms
ICMP Runtime after disconnect	43.8 ms	1.0 ms
ICMP Timeouts	211 s	19.4 s

- Check time taken for a node to switch from failed parent.
- Nodes 2 and 4 were turned off to force 3 to pick 1 as parent.
- Node 3 contacted by ICMP echo continuously and counter for parent switch monitored.
- Used SNMP to ensure no rebuild took place.
  - DODAG version number, local and global repair counters.

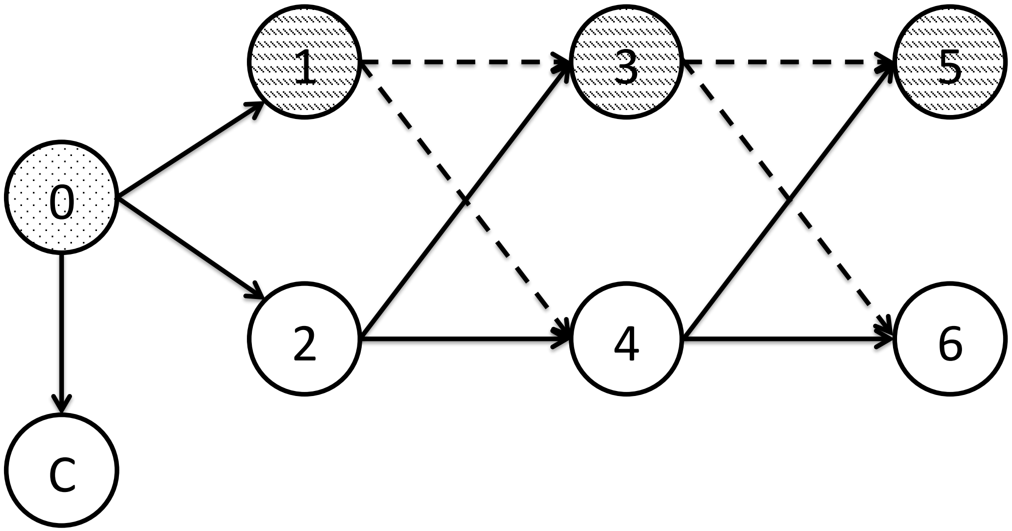
Results

Fallback Parent – Modified DIO Timer

DIO Timer	Average ICMP Timeouts
2^3	203 s
2^5	215 s
2^7	214 s
2^9	214 s
2^{12}	211 s

- Modified the DIO timer to check influence on nodes.
- Same experiment as Fallback Parent repeated.
- ICMP timeouts show that time between DIOs has no effect.

Experimental Setup



- Add 2 more nodes for remaining experiments.
- Rest of the experiment setup stays the same.

Results

Fallback Sibling

Monitored Value	Average	σ
ICMP Runtime before disconnect	43.5 ms	0.8 ms
ICMP Runtime after disconnect	43.6 ms	0.9 ms
ICMP Timeouts	236 s	13 s

- Check time taken for node 5 to switch failed parent to sibling.
- Nodes 2 and 3 were turned off, to force 4 to pick 1 as parent.
- Node 4 contacted by ICMP echo continuously.
- Used SNMP to ensure only local repair took place.
  - DODAG version number, local and global repair counters.

Results

Poised Tree

Monitored Value	Node 3	σ	Node 4	σ	Node 5	σ
Runtime before disconnect	44.3 ms	0.7 ms	44.8 ms	0.3 ms	63.4 ms	0.9 ms
Runtime after disconnect	44.2 ms	0.8 ms	44.9 ms	0.6 ms	62.3 ms	1.2 ms
Timeouts	235 s	12 s	234 s	6 s	265 s	18 s

- After local repair, routers must poison routes.
  - All nodes in RPL are routers.
- Node 1 turned on after network stable; ensured node 4 picks 2 as parent.
- Node 2 turned off, forcing nodes 3, 4 & 5 to change parents and trigger route poisoning.
- Used SNMP to ensure only local repair took place.

Conclusion

- Results show that while the repair process works as expected, it is slow.
- The ContikiRPL implementation correctly follows the path poisoning requirement.
- There is no discernable difference in time taken to switch parents or new sub-tree.

References

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