IPSO Webinar

Overview of the RPL protocol (routing for IP Smart Object networks)

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Welcome

- **Brought to you by the IPSO Alliance**
  - An Alliance of 50+ companies
  - Working to market, educate and enable the use of IP for the Internet Of Things
  - Create awareness of available products and technology
  - Current committees:
    - » Interop, Marcom, Security and Smart Buildings
  - http://www.ipso-alliance.org
- **Second webinar in our technical series**
  - First webinar – “6lowpan” – is available for download
- **Also available – “Why IP” - high level overview of benefits of IP to embedded networks**

Routing Over Low power and Lossy Link (ROLL) WG

Working Group Formed in Jan 2008

http://www.ietf.org/html.charters/roll-charter.html

Co-chairs: JP Vasseur (Cisco), David Culler (UC Berkeley)

Mission: define Routing Solutions for LLN (Low power and Lossy Networks)

Very active work with a good variety of participants with at first little IETF background

Rechartered to specify the routing protocol for smart objects networks (after protocol survey discussed within the WG, not published)

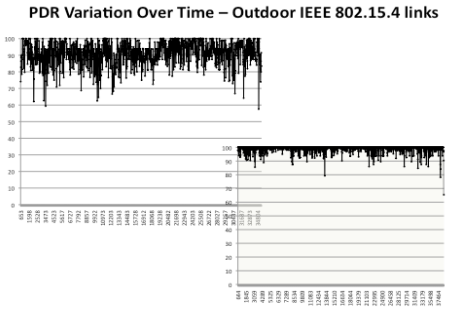
Several proposals: one of them adopted as WG document: RPL

Routing in Sensor Networks: *not technically trivial problem …*

Two decades of experience in routing …

But very different challenges

- Constrained devices ! (few Kbytes of RAM, dozens of Kbytes of Flash, 8/16-bit micro-controller)
- Low-speed highly unstable lossy links

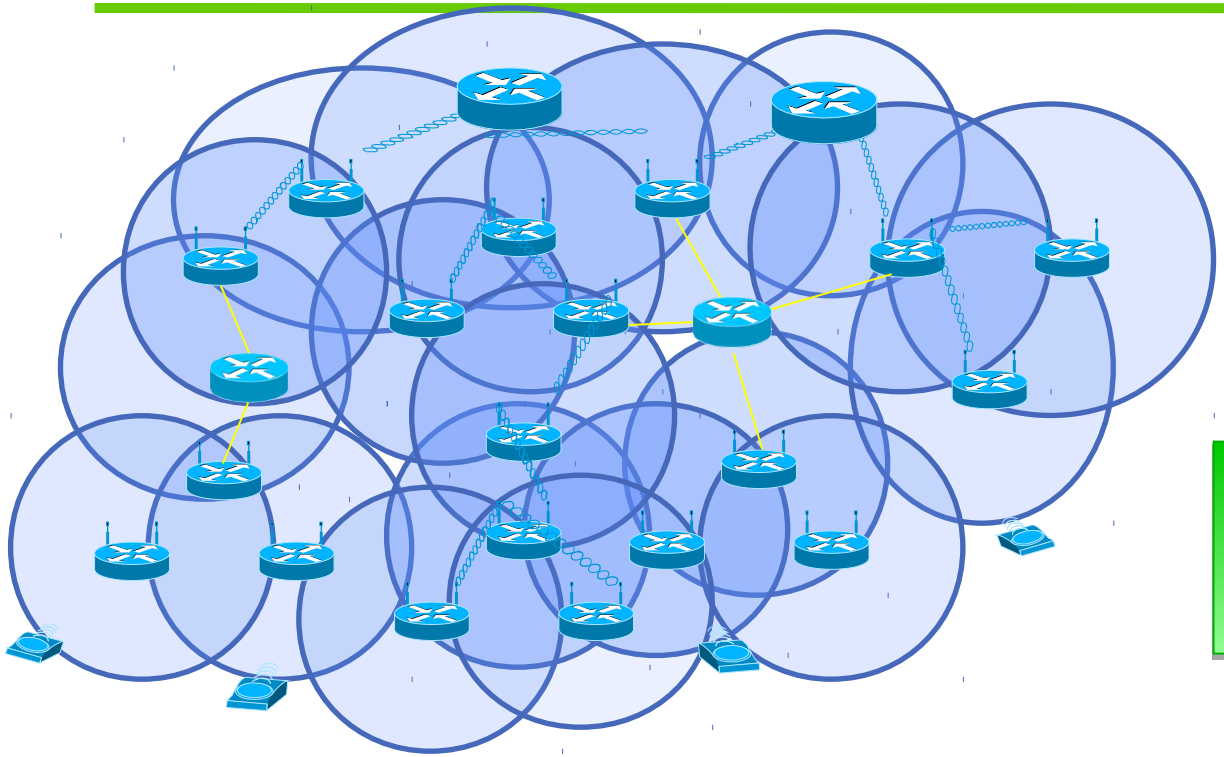


(oscillation avoidance is a key)

- Potentially very large scale (10-100sK nodes)
- Unattended devices in harsh environments

Required a deep understanding of the requirements, which led to 4 RFCs

RPL: a DV routing protocol building a colored DAG



RPL is specified in draft-ietf-roll-rpl

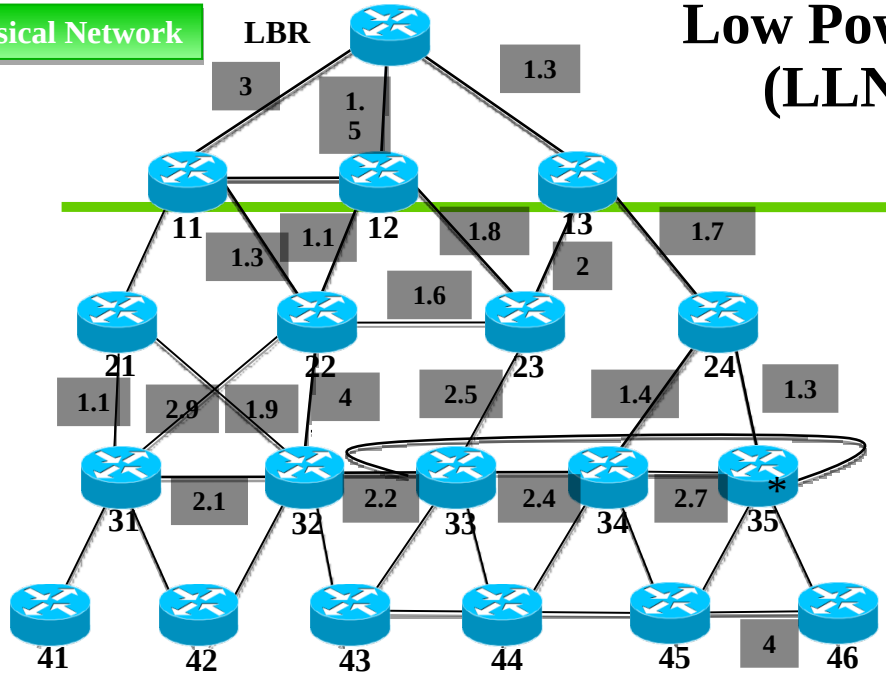
Not a WSN routing protocol (support multiple PHY/MAC) !

- RPL: DV Based Routing Protocol – DAG Formation - Proactive
- The DAG is colored (Constraint-Based Routing)
- Rules for parent selection based on metric, OF and loop avoidance
- Under-react is the rule !! (local versus global reroutes) to cope with transient failures
- Governed by Trickle Timers
- Control load

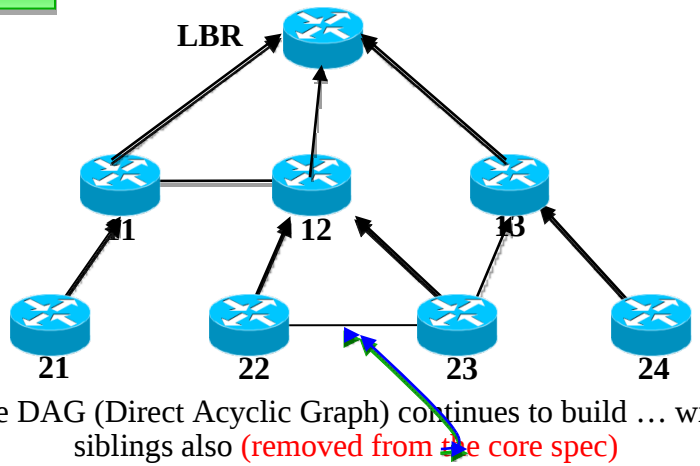
Low Power and Lossy (LLN) Network

X ETX (=1 when not indicated)
=> reflect the link quality

Physical Network

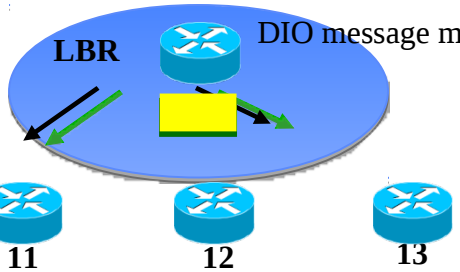


Step 3



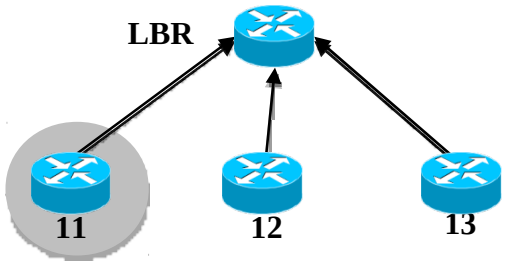
The DAG (Direct Acyclic Graph) continues to build … with siblings also (removed from the core spec)

Step 1



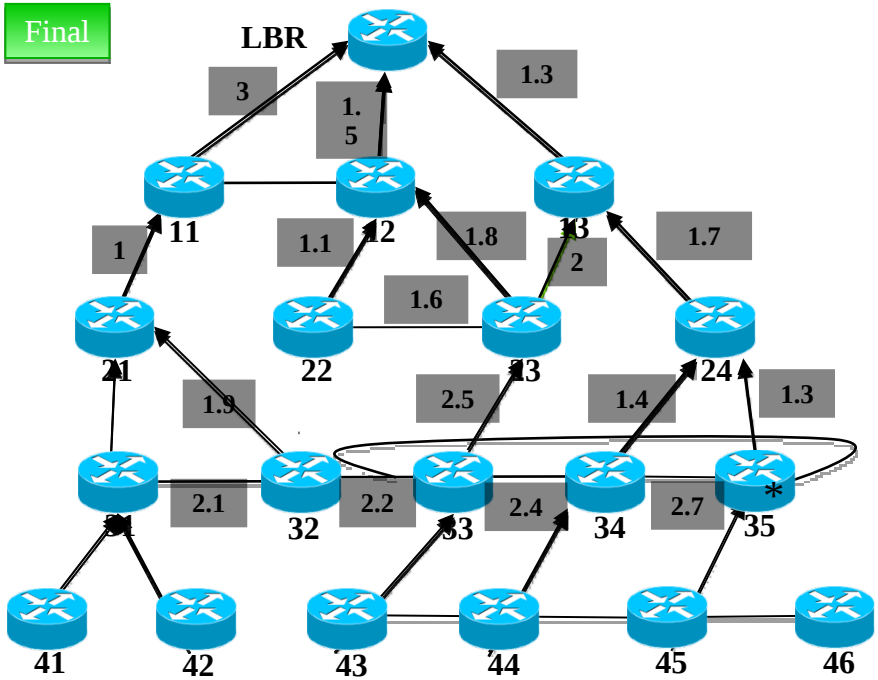
DIO message multicast by the root

Step 2



Every router runs an algorithm to choose a parent based on an objective (best quality path, highest bandwidth link,….)

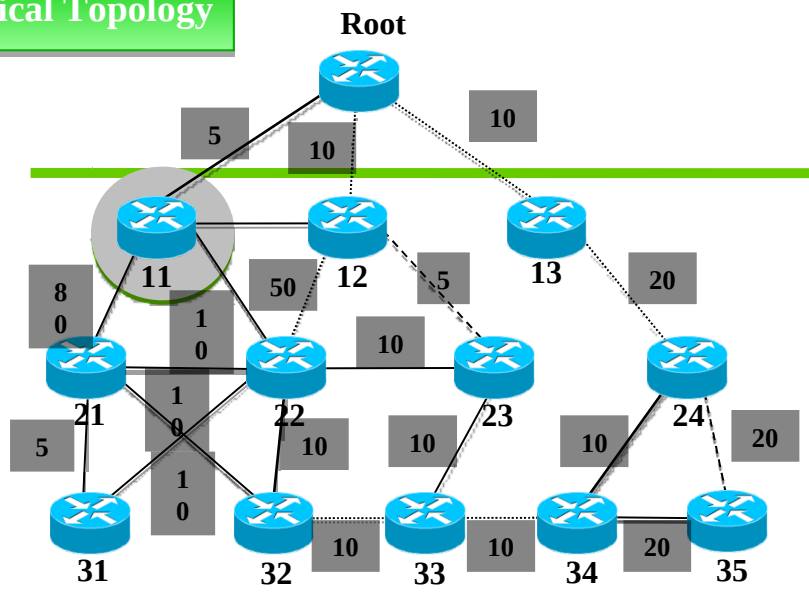
Final

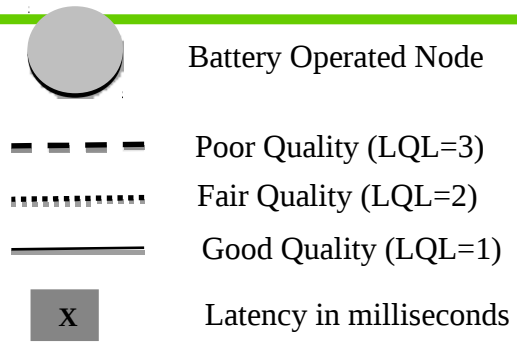


Enabling the INTERNET OF THINGS

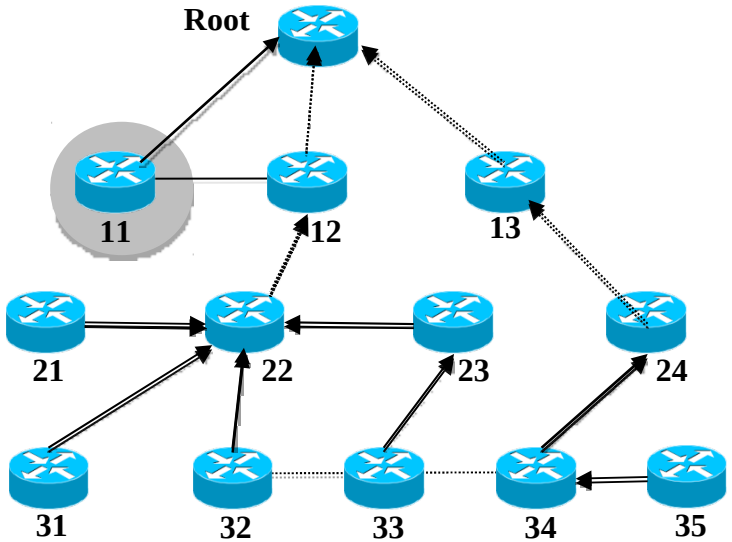
Support of QoS Aware Routing:
A multi-servive IP core

Physical Topology

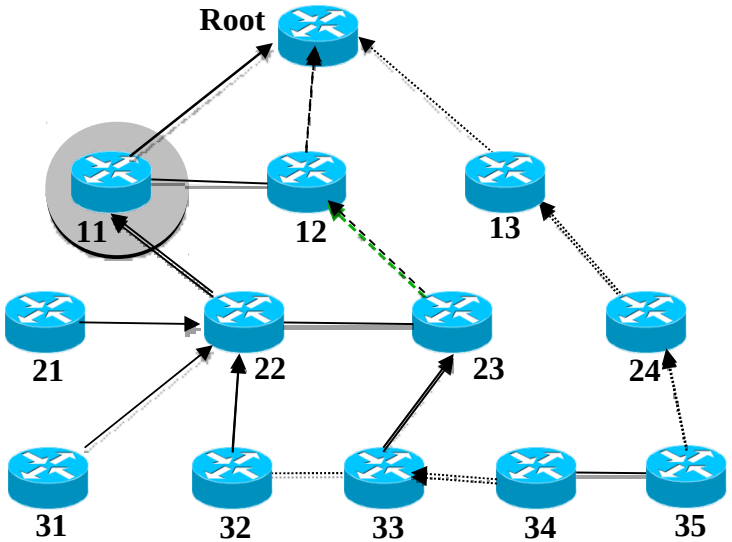




DAG Instance 1: high quality – no battery operated nodes
DAG Instance 2: low latency



DAG 1 is is optimized for Smart Metering readouts: not time sensitive, avoid battery operated node

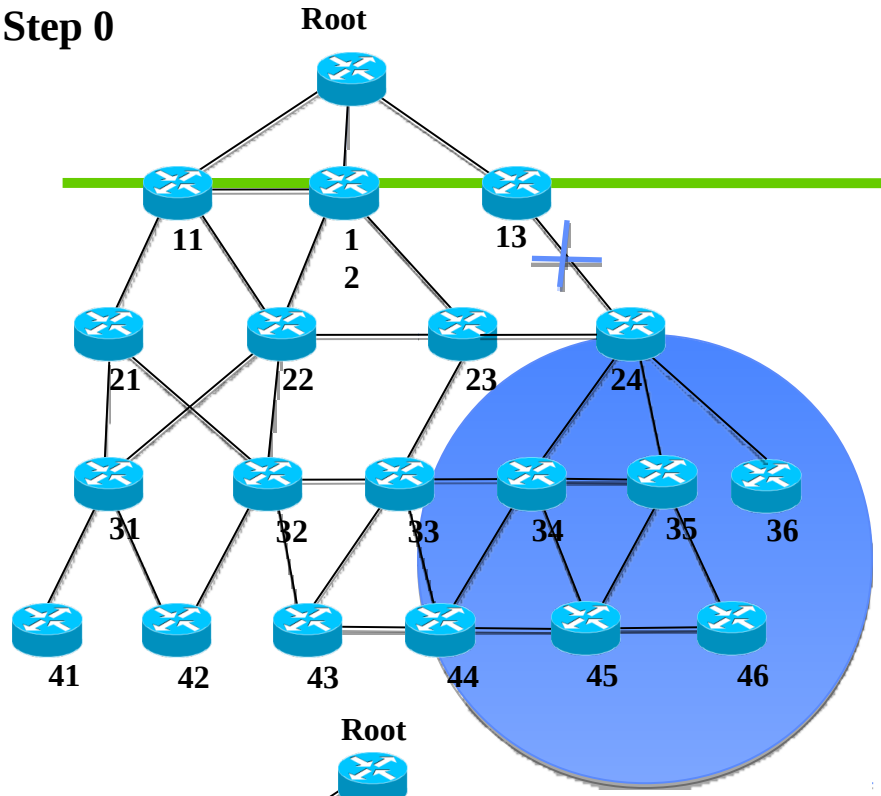


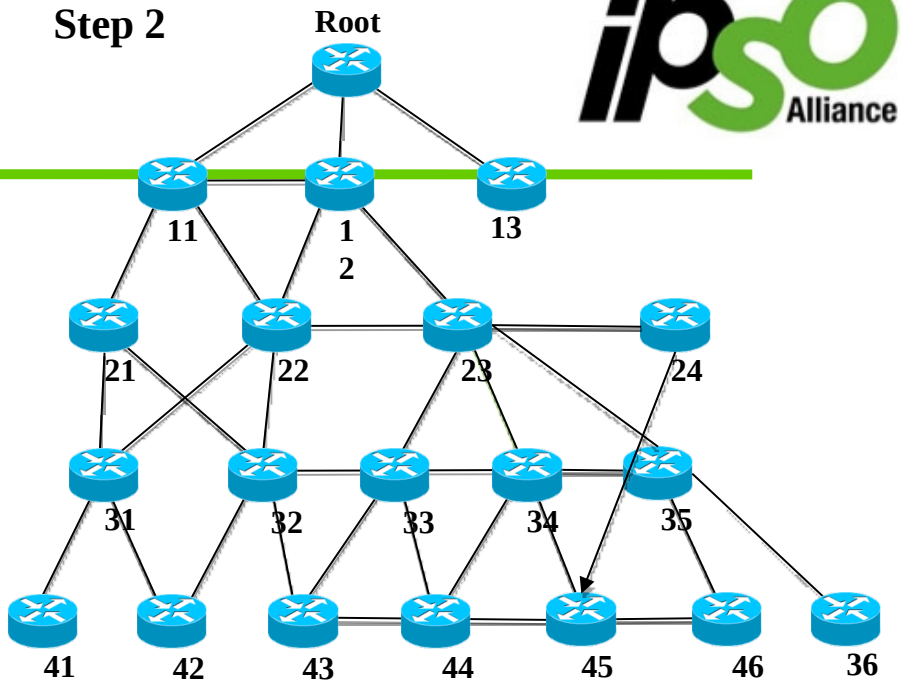
DAG 2 is optimized for real-time delay sensitive traffic (alarms, distribution automation, …)

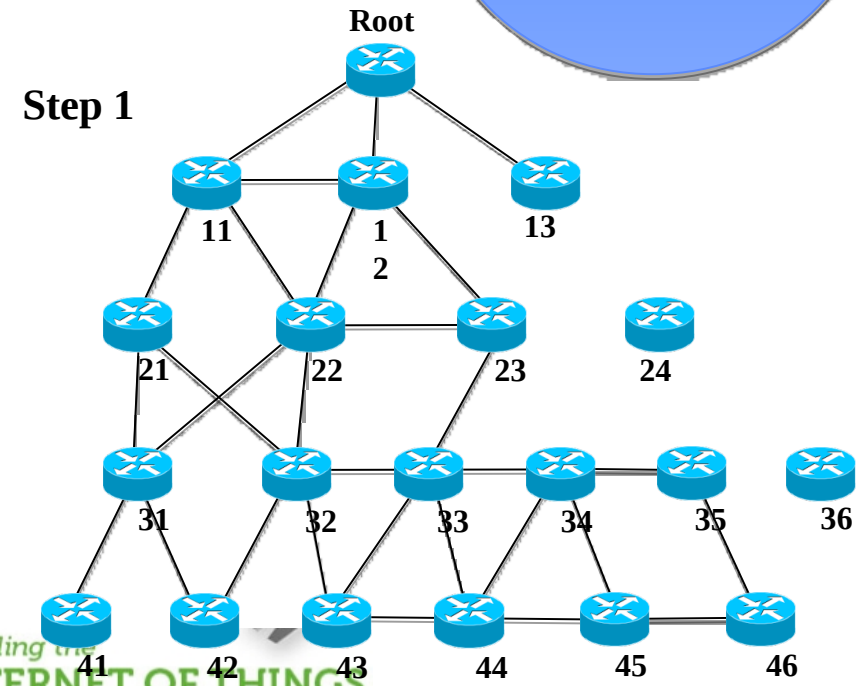
Enabling the
INTERNET OF THINGS

Global versus Local Repair

- **Global repair:** rebuild the DAG … requires a new DAG Sequence number generated by the root
  - Triggered by the root
  - Potentially signaled to the root (under investigation)
- **Local Repair:** find a "quick" local repair path
  - Only requiring local changes !
  - May not be optimal according to the Objective Function and overall DAG shape, which is fine
- Complementary approaches







Enabling the
INTERNET OF THINGS

New set of metrics

- Requirement for both link and node metrics and constraints in LLNs
- Routing objects can be used as a metric or as constraint
- Constraints used for constraint-based routing
- Some metrics are dynamic => use of low pass filters and multi thresholds to avoid oscillations
- Min, max and cumulative metrics
- Reliability metrics: ETX (mono-dimensional but Link layer independent) + Link Quality Level

Defined in draft-ietf-roll-routing-metrics (node state/attribute, energy, Hopcount, Throughput, Latency
Link Reliability, Link Colors: can be used as a constraint or a metric
=> Passed WG Last Call

Forwarding

- **Two related drafts (Passed Working Last Call):**

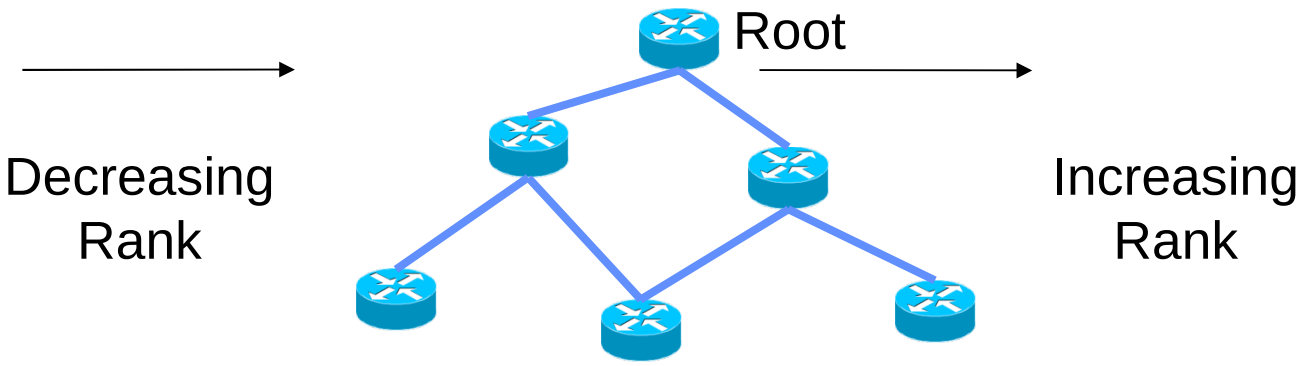
- **draft-ietf-6man-rpl-option**
  - **RPL information in data-plane with IPv6 Hop-by-Hop Option**
- **draft-ietf-6man-rpl-routing-header**
  - **Source routes for non-storing mode with IPv6 Routing Header**

Hop-by-Hop Option

- **Carry RPL information in data-plane:**
  - **Instance ID: which DAG to forward along?**
  - **Direction: is the packet going up or down the DAG?**
  - **Sender Rank: what Rank is the sender currently at?**
  - **Rank-Error Flag: indicates of rank-error was detected before**
  - **Forwarding-Error Flag: indicates if forwarding-error occurred**
  - **Arbitrary TLVs (for future definitions)**

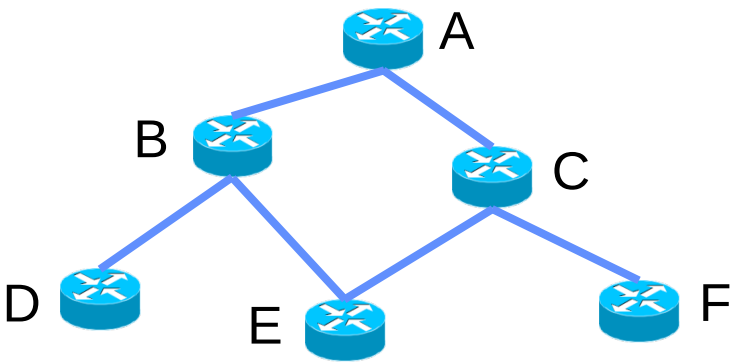
Hop-by-Hop Option: Data-Path Validation

- **Rank Properties when Forwarding**
  - **Towards root ➔ Rank should decrease**
  - **Away from root ➔ Rank should increase**
- **When forwarding, inspect Rank in datagram**
  - **If Rank is inconsistent, trigger local repair**
  - **May tolerate some error by using the Rank-error flag**



Hop-by-Hop Option: Backtracking

- **If node has no downward route, set forwarding-error flag and send back to parent**
- **Example:**
  - **1) A has downward route to E through B and C, try B**
  - **2) B sets forwarding-error flat, sends back to A**
  - **3) B removes route to E through B**
  - **4) A has downward route to E through C**

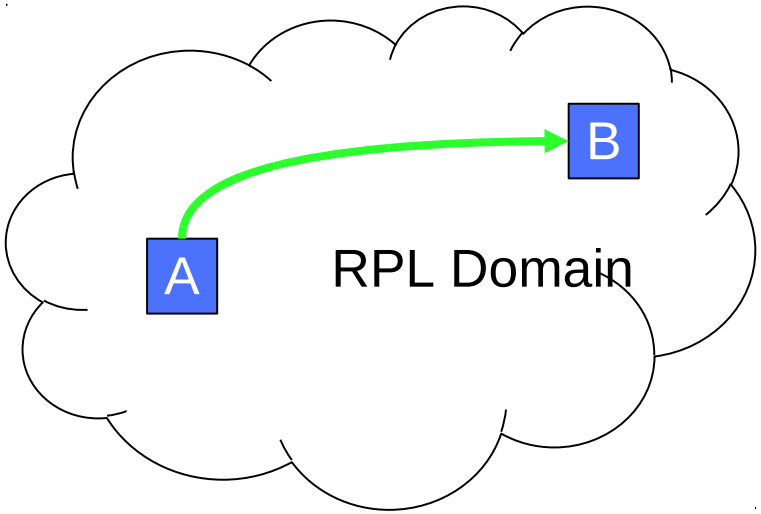


Routing Header

- Include list of addresses within IPv6 Routing Header
  - Elide prefix bytes when they match the destination address
  - Special processing to address security concerns raised with RH0
- Hop-by-Hop Option not required with Routing Header
  - Loops cannot occur if route is formed properly
  - Packet routed according to a path, not an instance

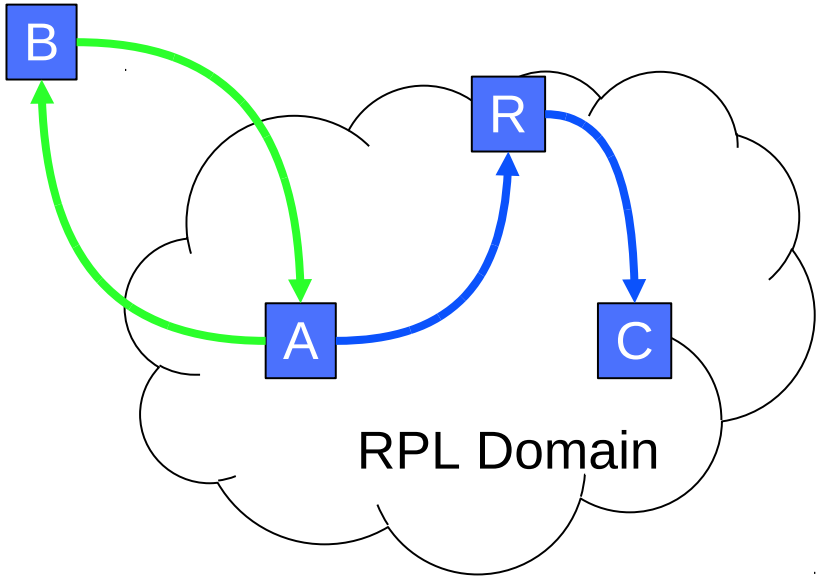
Including Hop-by-Hop and Routing Headers

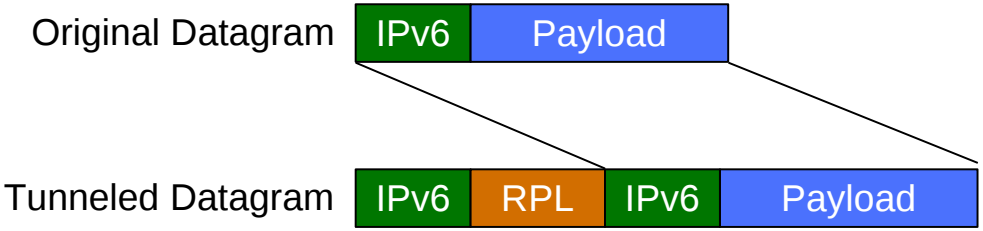
- **When RPL info is only inserted/removed by source/destination: *transport mode***
  - **Include directly within datagram (between IPv6 and payload)**



Including Hop-by-Hop and Routing Headers

- ***Tunnel Mode*** **when RPL info is inserted/removed along a path**
  - **Insert: encapsulate original IPv6 datagram within another IPv6 datagram and include RPL headers outside**
  - **Remove: strip off outer RPL header**





- Insert/Remove when:

  Entering/Exiting RPL domain

  Removing Hop-by-Hop and adding RPL routing header (non-storing mode)

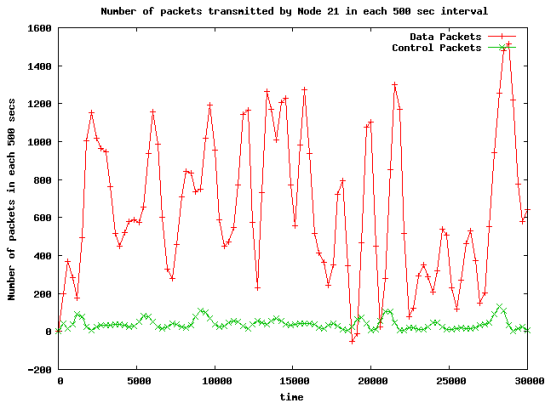
- Why tunnel mode?

  IPv6 min MTU is 1280 bytes, must support that along the path!

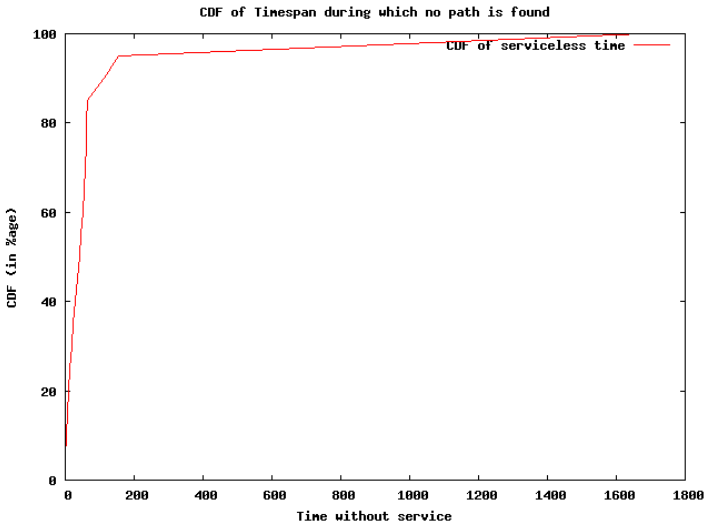
  Adding RPL information expands datagram along the path

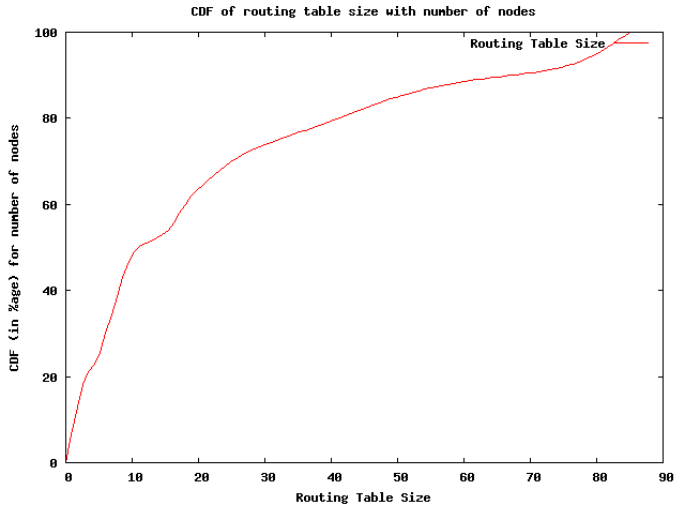
Simulation Results

Traffic Control



Traffic Holes – Global Repair only





Routing Table Sizes

Is RPL Ready for "prime time" ?

- More than 15 implementations
- Stable specification (Passed IETF Last Call, Working Group Last Call, IESG review almost done, …)
- Two interoperability test events took place:
  - IPSO (Storing mode)
  - Zigbee/IP (Non-Storing modes)

–Industry alliances: Zigbee/IP, Wavenis, IEEE P1901.2, …

Conclusion

- **RPL is a core piece of the Internet of Things, an open standard designed to meet challenging unique requirements IP end-to-end is not just a vision but a reality**
- **A new very promising technology and differentiator enabling IPv6 on trillions of smart objects (Smart Grid, Smart Cities, Building/Home Automation)**
- **Very compact code w/o compromising layering ☺**
  - **⇒ Support of a wide variety of media (as opposed to L2 routing approaches)**
  - **⇒ Support of a wide set of devices (from micro-controllers to routers)**
- **Standardization status:**
  - **–Passed WG and IETF Last Call**
  - **–More than 15 existing implementations**
  - **–Adopted by a number of alliances: Zigbee/IP, Zwave, Wavenis, IEEE P1901.2**

Q&A

THANK YOU

- Thank you for joining us
- Stay tuned for future webinars both Business and Technical
- Webinar will be available for download
- Comments and suggestions - info@ipso-alliance.org
- More information about IPSO
  - http://www.ipso-alliance.org
  - White papers and other resources
- Consider joining us to help define, promote and enable and demonstrate embedded IP and the Internet of Things