RPL Applicability in Industrial Networks IETF 82

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Culprits and Status

- Tom Phinney, editor
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- Robert Assimiti, co-author
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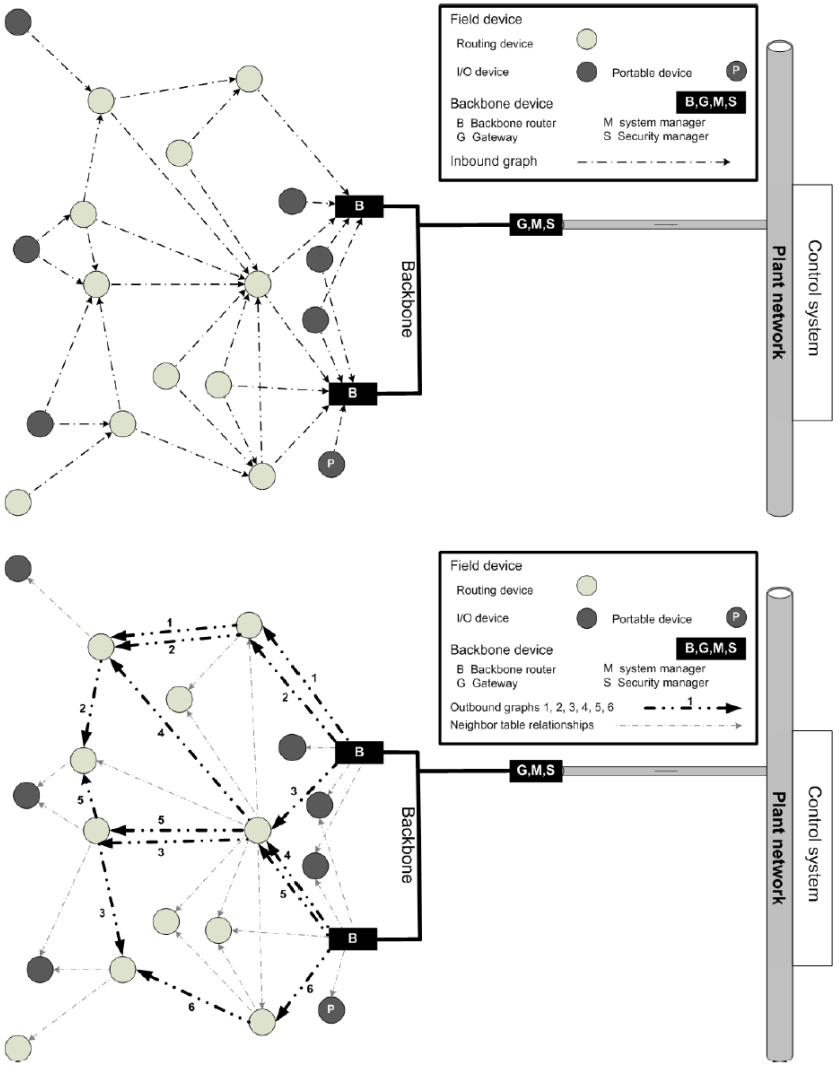
- Pascal Thubert, co-author
  - ISA100.11a co-editor
  - ROLL/RPL co-editor

Process Automation Requirements Primer

- Typically utilize deterministic and centralized networks
- Scalability:
  - –Hundreds per network
  - –Tens per backbone router
- Extremely high reliability -> dire consequences associated with communication failure
- Path diversity a must
- Typically tightly time synchronized (within uSeconds)
- "Shallow" wireless networks – typically up to 3 hops
- Must meet latency bounds: sub-second
- Relies heavily on publication/subscription (push) model for periodic data collection: as frequent as every 100 ms
- Need to support for P2P control loops
- Long battery life: 5 -10 years

Wireless Industrial standards

- Communication reliability requirements implicitly mandate path diversity for MP2P, P2MP and P2P traffic flows
- Current routing paradigm in ISA100.11a and WiHART standards is DODAG based but takes place at the link-layer (mesh-under)
- Graphs are computed by a system manager (centralized PCE with high degree of determinism)



Traffic Classes

Safety	0	Emergency action	Always critical
Control	1	Closed loop Regulatory control	Often critical
	2	Closed loop Supervisory control	Usually non-critical
	3	Open loop control	Human in the loop
Monitoring	4	Alerting	Short-term consequences
	5	Logging Downloading/uploading	No immediate consequences

Data Flows

- Publish/subscribe (push)
  - One way, periodic communication
  - Not acknowledged end-to-end
- Source/sink
  - Devices in set 1 send messages to devices in set 2 (alerts, alarms, etc)
  - Infrequent, intermittent and bursty traffic
- Peer-to-multipeer (P2MP)
- Peer-to-peer (P2P)
  - Device A sends data directly to devices B with high periodicity
  - Allows for control-loops
- Duo-cast (or N-cast)

RPL MOPs versus Data Flows

Paradigm\RPL MOP	RPL spec	Mode of operation
Peer-to-peer	RPL P2P	reactive (on-demand)
P2P line-of-sight	RPL base	2 (storing) with multicast DAO
P2MP distribution	RPL base	3 (storing with multicast)
Publish-subscribe	RPL base	1 or 2 (storing or not-storing)
Source-sink	RPL base	0 (no downward route)
N-cast publish	RPL base	0 (no downward route)

RPL Instances

- Nodes to participate in potentially multiple RPL instances that meet different optimization goals
  - Minimize and guarantee latency
  - Maximize reliability
  - Minimize aggregate power consumption
  - Some of these optimization goals have to be met concurrently through constraints
- Nodes to participate in at least one instance that has a virtual root -> allowing communications over the backbone infrastructure (subnet to subnet)

Objective Functions

- OF0:
  - Wireless industrial communications are subject to swift and temporary variations due to the nature of the environment (metal pipe jungles) causing link related metrics to vary
  - Hysteresis is needed in order to ensure stability
- MRHOF
  - A step in the right direction for industrial networks
  - Not all metrics that need to be balanced are additive
    - Example: packet success rate (ETX) for a device with rank=1 versus packet success rate (ETX) for a device with rank=3
    - Look into multiplicative metrics
- Need a more complex OF that:
  - Takes in consideration multiple constraints
  - Balances (weighted sum) multiple additive and multiplicative metrics

Storing versus Non-storing Mode

- Support for storing mode is imperative in wireless process automation networks
- Maintaining state does not cost too much
  - Typically <100 nodes per backbone router
  - Shallow multi-hop networks
  - Lots of devices with low rank (networks are planned and deployed that way)

Food for Thought

- How well does RPL interact with a centralized and deterministic paradigm?
- Clock synch packets (currently link layer advertisements) need to be synched with DIO transmissions
- Trickle timer considerations
- DODAG repair
  - Global repair – increasing the DODAG version must be subject to explicit consent from plant administrator since it could potentially result in plant shutdown
  - Local repair actions need to be communicated and approved by PCE (system manager)