RPL industrial applicability statement

IETF 81 status

`draft-phinney-rpl-industrial-applicability-statement`

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draft Status

- Started early June.
- Missed 00 date
- Tom Phinney, editor
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What’s specific

- Industrial networks evolved concurrent with IP
- Process Control and Factory Automation goals differ from those of IT – schism
- Need low latency and high cyclic determinism
- e.g. ExxonMobil Baytown refinery near Houston (Texas), 100 hectares (40 sq. miles) with 12 control rooms (CRs):
  10 refining CRs localized to a few hectares each,
  2 CRs that span the plant and interact with the other 10;
  large chemical plant adjacent to refinery
- Largest plants potentially reap the most profit from small productivity improvements, thus are more willing to innovate (in stages) and to fund proven new technology

Process control example: a refinery

- Sensors and actuator usually close: <100m
  - Elements of critical loops can be wire-interconnected
  - Low-quality (noisy, intermittent) field power often available
- Control room typically 500m to 2km distant
  - Wired: power + signal carried together on one twisted pair
    - Designed to meet intrinsic safety regulations: ~40mW/pair
    - Typically 25-pair to 100-pair wire bundles in buried conduit
  - Wireless is most attractive for this long, costly link
    - Primary requirement is ≥ 5yr battery life for field devices
    - Battery replacement is often very costly or impractical
    - Environmental power harvesting strongly desired

Time-critical process control messaging

- Real-time process measurements (value+status): publish/subscribe, published by device on fixed period, subscribed by assigned loop controller(s), which may be local, and by managing devices in remote control room(s)
- Real-time loop controller outputs (value+status): also pub/sub, similar to process measurements
  - Together these last two imply that controllers drive actuators while actuators report their state back to the same controllers
- Process alarms, network and device alerts: source/sink, multicast to managing devices in remote control room(s)
- Control room commands to field devices: peer/peer

Publish/subscribe communications

- Used as interconnect for closed-loop control
- Control algorithms are designed to ride through loss of 1-3 successive periodic pub/sub reports
- Loss of four successive periodic pub/sub reports not acceptable:
  - Causes actuator to go into a fallback control mode
  - Considered a system failure by the plant operator
  - For the Baytown example, should happen less than once/year across the entire refinery

Loss mitigation strategies for wireless

- For wireless pub/sub:
  - Use peer/peer to line-powered router (usually a BR), which takes over any pub/sub multi-destination needs
  - Keep devices 1 hop from BR except under failure
  - Retry: Wireless 95% per-message success rate implies up to 7 retries needed for any given message
  - Use duocast (send once, two scheduled receivers):
    - Changes per-xmt success statistic from 95% to 99.75%
    - Reduces the above to 3 retries max, easing scheduling
  - As a last resort, use wire for critical local interconnect

Optimized vs. ad-hoc routing

- 1980: Exxon used supercomputers of the era for continuous time-critical control loop optimization
- For critical control, optimized routing can double network performance vs. ad-hoc
- Critical control impacts directly how much profit is extracted from raw materials (e.g. barrel of oil)
- Centralized optimization can use existing plant databases and actual pairwise attenuation/fading as measured in-situ by operating devices

RPL applicability

- RPL coexists with optimized routes, for construction of initial suboptimal routes and for repair of optimized routes
- RPL is adequate for non-production phases (unit startup and shutdown), for emergency rerouting, for non-critical applications, for small plants
- Mobile devices (e.g., cranes) may need RPL
- When using a reference (optimized) DODAG version from a centralized computer, RPL would provide local repair

Bootstrapping / Link mgt

- ISA100.11a, WirelessHART, WIA-PA provide secure bootstrap, so a device can find a parent
- control channel? Default, provisioned before or at device installation, initial low capacity; at link level this is ‘out of the box’
- Comm moves rapidly to secure, alternate, scheduled control channel via OTA provisioning
- Then RPL can play over the control channel
- TDMA channel/slot allocation is ‘chicken & egg’

Why go wireless?

- Better process optimization and more accurate predictive maintenance increase profit; 1% improvement in a refinery with a $1.5B annual profit leads to $40k/day ($15M/yr) more profit
- Thus more and different sensors can be justified economically, if they can be connected
- But wire buried in conduit has a high installation and maintenance cost, with long lead times to change, and is difficult to repair
- The solution: wireless sensors in non-critical applications, designed for the industrial environment: temperature, corrosion, intrinsic safety, lack of power sources (particularly when there is no wire)
- For critical control loops, use wireless control room links with controllers located in the field, possibly connected over local wiring

Wireless BRs

- 4Hz and 1Hz are common rates for primary process control loops
- When most high-rate wireless devices are 1 hop from a BR, the BRs are transmitting or receiving during most communications
- Duocast, which requires two receiving BRs, increases that load
- Antenna placement for collocated BRs is problematic, due to the need to separate the antennae to avoid the near/far problem, where receiver front-ends overload from any nearby transmission
  - Real process environments have few places to mount a BR antenna
- Thus a low-cost high-capacity multi-channel shared-antenna BR (which also shares LNA and PA) makes enormous sense
  - However, such a multi-channel BR can't transmit on any channel while receiving on others (due to the near/far problem)
  - Requires co-scheduling of channels and alignment of time slots in which the BR is active, including alignment of potential Acks in those time slots

Evolution

- Multiple link types, optimized for minimal energy and interference at varying degrees of per-trial communication success
- Would use FEC selectively when links support it
- Might adjust xmit power (e.g. emergency safety message within 1s; required by law)
- Different operating tradeoffs use different OF
- RPL separates links by OF/constraints/colors