Routing Protocols in Internet of Things

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with a few slides originated by Pascal
Overview of Presentation

• My standardization activities
• Design considerations
• Mobile Ad Hoc Networks
• RPL-based protocols
• L2R
• 802.15.llc
• Not covered: 6LowPAN, 6lo, Bluetooth Piconets, 802.15.3
• Not covered: privacy – but it is super-important
• Not covered: DTN (Delay Tolerant Network)
• Not covered: NB-IoT – New effort in 3GPP
Standardization activities

- For a long time: Ad hoc networks
- 802.15.10 in IEEE
- 802.15.LLC in IEEE
- Catching up to 6TiSCH in IETF, also detnet, 6lo
- In previous times: Mobile IP [mip4, mip6, mobopt, seamoby, netlmm, netext, ...], service discovery, autoconf, WiMAX, LTE
Design considerations

• Energy conservation; Must allow low duty cycle
• Protocols should be secure
• Manageability / configurability
• Packet size is a major issue
  – Even as IPv6 mandates support for 1280 bytes
• Minimal signaling
  – Every byte over the air is expensive
• Connectivity to Internet / gateway
• Scalability
• Dynamic connectivity / link repair
• Disparity between unicast and multicast power levels
Ad Hoc Network characteristics

- peer-to-peer
- multihop
- dynamic
- zero-administration
- low power
- autonomous
- autoconfigured

... but most conditions have exceptions...
For example, sensor networks are not dynamic
BoFs: link-state signaling using over 100% of media
Mobile Ad Hoc Routing: Reactive

- Reactive: routes discovered on demand
  - AODV, DSR, AODVv2 [DYMO] \{distance-vector\}
  - Typically better scalability compared to proactive
  - Discovery increases application launch latency
  - \(O(n)\) storage
  - \(O(n)\)*[cache-miss rate] signaling

- AODV is well-known, well-studied, and often adapted \{about 437,000 search results\}

- DSR uses source routes ➔ larger packet sizes

- Should use Dominating Set or MPU for broadcast
Mobile Ad Hoc Routing: Proactive

- Proactive: routes stored to all destinations
  - OLSR, TBRF, OLSRv2... {link-state routing}
  - $O(n^2)$ storage
  - $O(n) \times [\text{update-frequency} + \text{link-breakage}]$ signaling
- OLSR has had numerous interoperability tests and, since it is link-state, has well-understood properties
- Uses MPRs for broadcast, with some knobs
- Simulations have shown major congestion as number of nodes grows past 500
- Trickle helps in more static networks
RPL: Routing Protocol for Low-Power and Lossy Networks

- Work in [roll] WG (I wish it were done in [manet])
- Building Automation, Home Automation, Industrial
- Backbone-oriented
- Upward and downward routes
- **DODAG**: “Destination-oriented, directed acyclic graph”
  - DODAGID, Instance ID, DODAG versions(!)
- **DIO**: “DODAG Information Object”
- **DIS**: “DODAG Information Solicitation”
- Storing versus non-storing modes
ROLL RPL ("Ripple") conceptual basis
6tisch

• Uses the TSCH scheduling mode of 802.15.4
• Defines a minimal set of functions for bootstrapping
• Defines an interface, 6top, to the MAC layer
• Relies on scheduling functions $SF_n$
• Related to Deterministic Networking ("detnet")
• Second Plugtest scheduled for February
L2R: TG 802.15.10 “layer 2 routing”

D3_P802-15-10_Draft_Recommended_Practice
   – 3\textsuperscript{rd} letter ballot just commencing

Functionalities provided:
• Mesh construction
• Short address assignment (by PAN)
• L2R discovery, join, update, and recovery
• Security (use 802.15.9, for instance, or pre-shared keys)
• Unicast, multicast, and broadcast routing (also P2P)
• Hop-by-hop retransmission / sibling routing
• Data concatenation (DCat)
• Various metrics
IEEE 802.15.llc
(Proposed work on Logical Link Control)

• Study Group has met twice; target acceptance of PAR / CSD in March.
• NEW NAME: “uli” (Upper Layer Interface)
• Make 802.15.4 as easy to use as 802.11, 802.3
  – In particular to work with IETF 6TiSCH
  – Enable use of the higher layer protocols used by IEEE 802.11 and IEEE 802.3 without changes
  – New applications & backward compatibility
• Provide ULI for L2R, KMP, other protocols
New LLC work

IEEE 802.15.4 MAC
- CSMA
- TSCH

IEEE 802.15.4 PHY
- 2003
- 4g
- 4k
Conclusions / Final Thoughts

• RPL has a strong constituency but some flaws
• Reactive RPL or AODVv2 should be considered
• IEEE 802.15.4 is well positioned, but needs significant new features for scalable routing, security, and upper-layer interface to enable privacy and interoperability
• IETF is going forward rapidly but there is still room to contribute
  – Current approaches are minimalistic
  – More sophisticated solutions will come before long
Backup Slides

• Backup Slides
L2R mesh example

WHERE:
- $D(X)$ is the depth of $X$,
- $LQM(X,Y)$ is the metric for the link $X \rightarrow Y$, and
- $PQM(X \rightarrow Y, R)$ is the metric for the path from $X$ to $R$ over link $X \rightarrow Y$