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

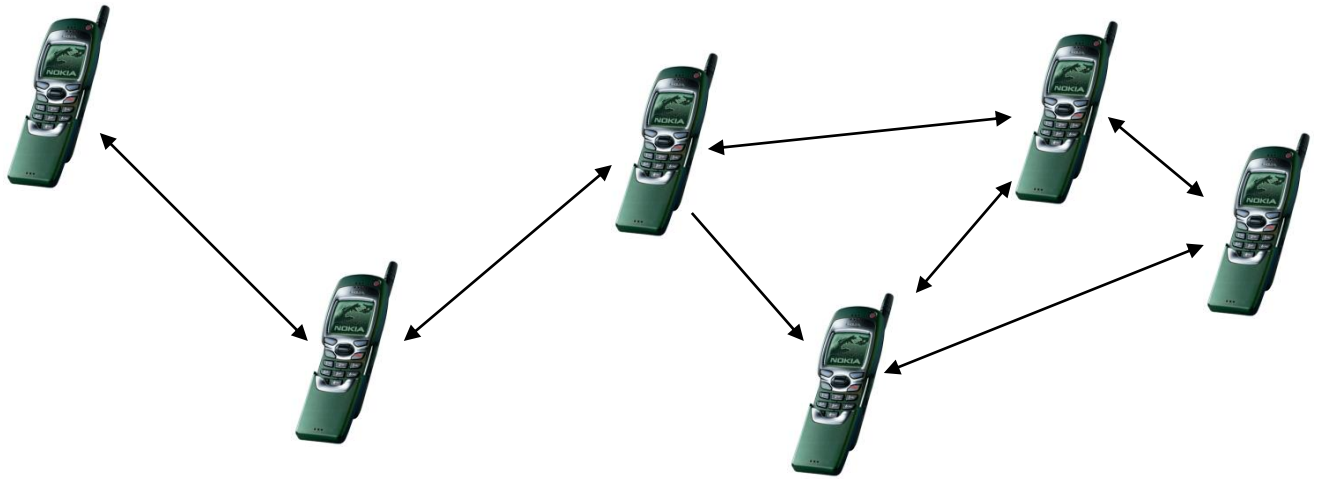
Standardization activities

- 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

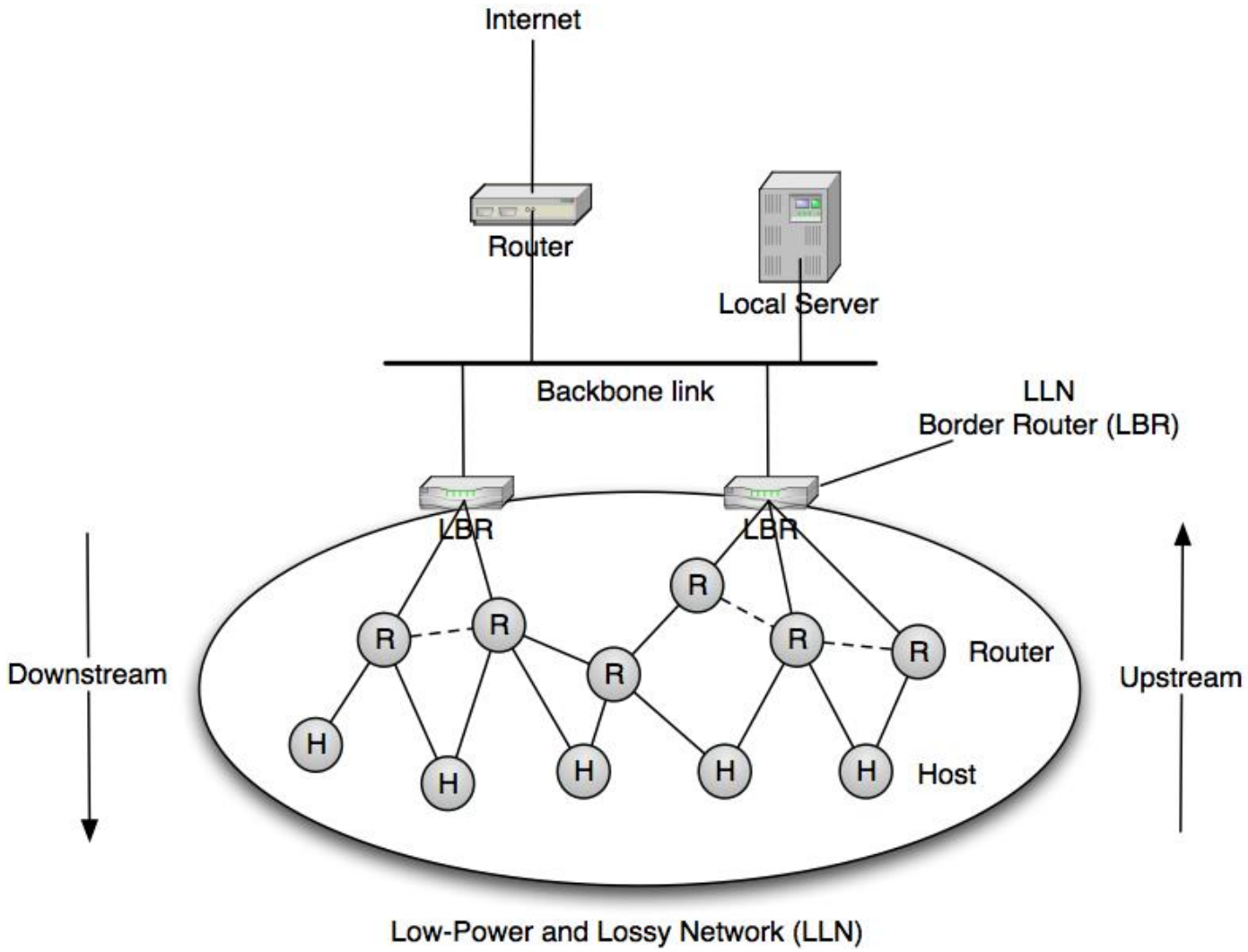
Mobile Ad Hoc Routing: Proactive

- Proactive: routes stored to all destinations
  - OLSR, TBRF, OLSRv2… {link-state routing}
  - $O(n^2)$ storage
  - O(n)*[*update-frequency* + *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

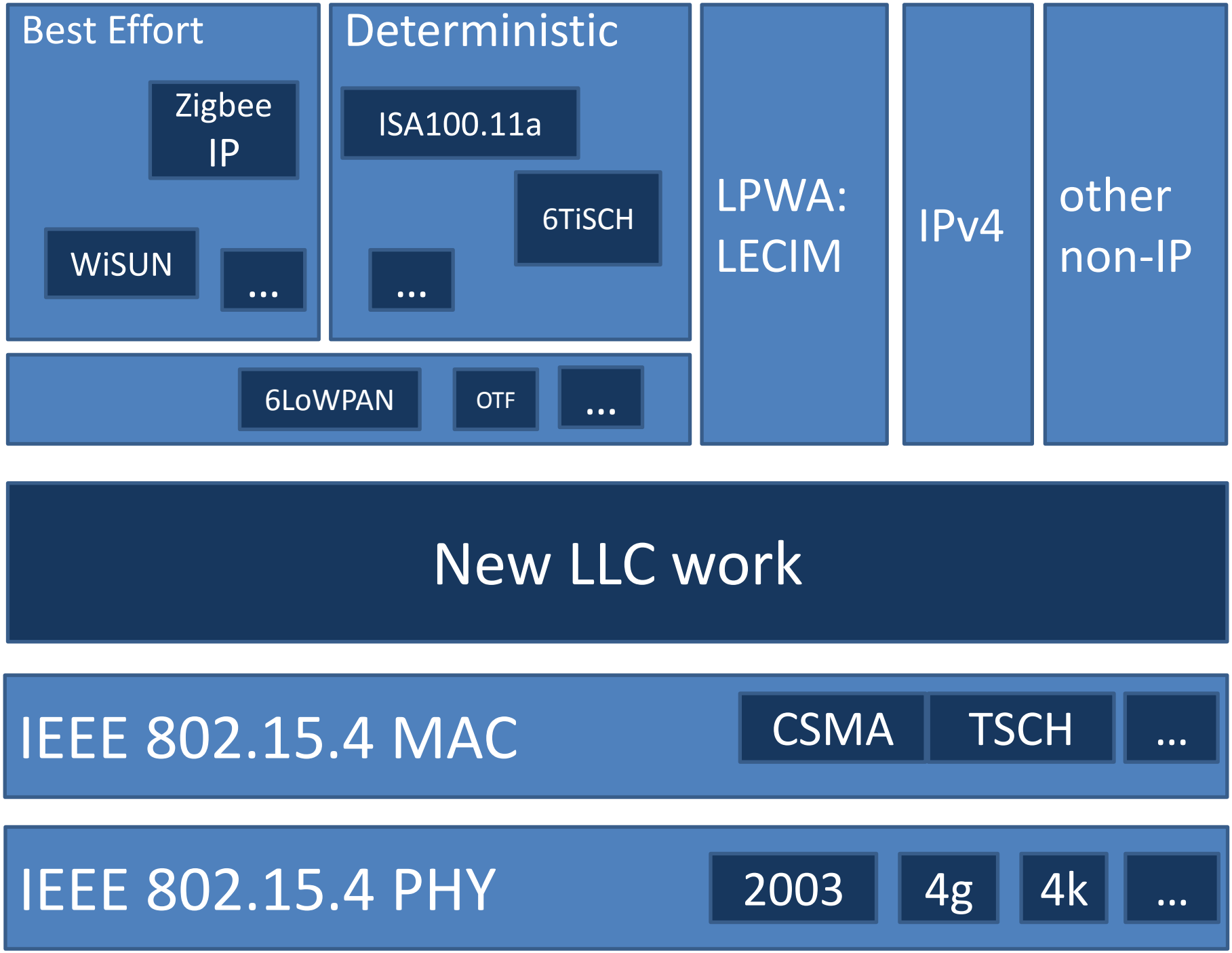
- 3rd letter ballot just commencing

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


Best Effort
Zigbee IP
WiSUN
...
Deterministic
ISA100.11a
6TiSCH
...
LPWA: LECIM
IPv4
other non-IP
6LoWPAN
OTF
...
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