IPv6 Subnet auto-configuration for sensor network trees

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Section 1

Introduction
About me

- Embedded Engineer at ML!PA Consulting
- Projects for Industrial customers
  - Condition Monitoring, Failure Prediction & Detection, Wear Analysis
- Full Stack Solutions:
  - developing sensor nodes for data collection on installations or vehicles
  - data analysis in cloud or on edge device
  - business data analysis
  - frontend development (App or Web based)
Wired Sensor Networks

- works well for fixed installations
- homogeneous network allows custom protocols
- ‘software Ethernet’ via UART / CAN bus (DOSE)
  - works with any MCU, only needs CAN transceiver (PHY)
  - only a single pair of differential data wires
- no need for dynamic routing algorithm - topology is fixed
- branches in the network may still require routing
- everything should be configured automatically
IPv4

- typically deployed with private addresses & NAT
- multiple routers can create multiple levels of NAT
  - computational overhead on the routers
  - works for HTTP, but not much else

Figure 1: double NAT
IPv4 - bridged

- ‘Solution’: bridge everything on layer 2
  - single broadcast domain

**Layer 2 Switch Trick**

- works for switched networks, but wireless / bus networks require 4-Address mode (source - router - router - destination)

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**Figure 2: layer 2 routing**
IPv6

- IPv6 has large address space (128 bit) to ease subnet creation and auto-configuration
  - SLAAC (*Stateless Address Autoconfiguration*): Host receives prefix via Router Advertisement, picks last 64 bit of address on its own
  - Provider hands out /56
  - /64 needed for SLAAC
    - $2^8$ subnets possible on a typical connection
- *Is there something like Stateless Subnet Autoconfiguration?*
ICMPv6

- more than just ping
- replaces ARP

**Router Solicitation**
- Is there any router?

**Router Advertisement**
- I'm a router!
- My default route is valid for $n$ seconds
- Prefix Information: You can choose an address from 2001:db8/64
- Route Information: You can reach 2001:db8:c::/62 through me

**Neighbor Solicitation**
- Who has 2001:db8::8cca:efff:fe8b:d64e?

**Neighbor Advertisement**
- I am 2001:db8::8cca:efff:fe8b:d64e
  - receiver stores l2 source address in Neighbor Information Base
Section 2

Subnet Auto-Configuration
Recapitulation

- SLAAC only uses lower 64 bit of address
- If we have a large prefix (> /64) we can sub-divide it
- Hierarchical subnets make for efficient routing
- Subnet-Prefix must not be used by another Subnet

Where to get a large prefix?
- request large prefix via DHCPv6 IA_PD
- configure `radvd` to advertise large prefix
‘Skinny Tree’ / Linear Topology

- Only a single router on each level (link)
- Routers can have multiple downstream interfaces
- Any amount of leaf nodes
- No coordination between routers needed outside standard ICMPv6 messages
- When prefix is received create subnets for each downstream interface
  - Consume as many bits as required to map number of subnets
  - Count up starting with 1, shift to end of prefix
- `gnrc_ipv6_auto_subnets_simple`
Multiple Downstream Interfaces

1st level router
- 2001:db8::/60
- 2001:db8:::c8f4:13ff:fece:3f43

2nd level router
- 2001:db8:0:8::/61
- 2001:db8:0:8::3c27:6dff:fe25:e95d
- 2001:db8:0:8::5075:35ff:fe0a:30bc

3rd level node
- 2001:db8:0:a::/63
- 2001:db8:0:a:::2ca3:9eff:9e9f:68f7
- 2001:db8:0:c::/63
- 2001:db8:0:c:::2ca3:9eff:9e9f:68f7
- 2001:db8:0:c:::a8d9:e1ff:feab:d544

3rd level node
- 2001:db8:0:a::/63
- 2001:db8:0:a:::fc33:13ff:fe93:5ae4

3rd level node
- 2001:db8:0:c::/63
- 2001:db8:0:c:::a8d9:e1ff:feab:d544
IPv6 Subnet auto-configuration

Figure 6: Linear Network

- 1st level router
- 2nd level router
- 3rd level router
- 1st level host
- 3rd level host
IPv6 Subnet auto-configuration

Figure 7: Linear Network

- 1st level router (A)
- 1st level host (B)
- 2nd level router (C)
- 3rd level router
- 3rd level host
Figure 8: missing downstream route
Figure 9: Route Information Option advertises downstream route
General Tree Topology

- Multiple routers on each level (link)
- Routers can have multiple downstream interfaces
- any amount of leaf nodes
- Routers have to coordinate so the same subnet does not get used twice
  - no standard solution :(  
  - custom UDP protocol, but very simple  
  - routers announce the number of subnets they want to create, l2 address order used to determine prefix ID  
  - remove invalid prefixes if new router joins (send ICMPv6 RA:PIO with lifetime 0)
- gnrc_ipv6_auto_subnets
Synchronisation Algorithm

I want to create 2 local subnets

I want to create 1 local subnet

I want to create 1 local subnet

I want to create 1 local subnet

index: 0 local subnets: 2

index: 0 local subnets: 1

index: 0 local subnets: 1

index: 0 local: 2
total subnets: 4

index: 3 local: 1
total subnets: 4

index: 2 local: 1
total subnets: 4

index: 2
total subnets: 3

index: 2
total subnets: 3

index: 2
total subnets: 3

2e:a3:9e:a9:68:42

Figure 11: IPv6 Subnet auto-configuration
Questions?
Section 3

Demo