Automatic Construction of Name-Bound Virtual Networks for IoT

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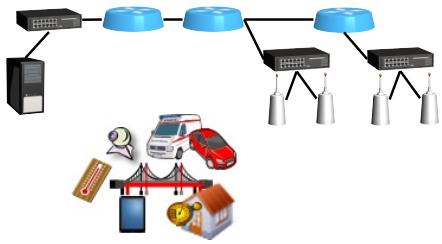
Contents

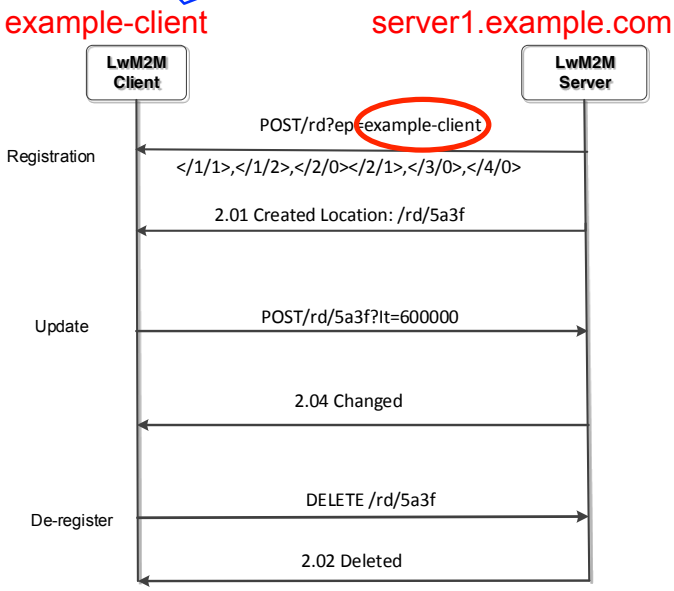
Backgrounds (1)

Who specifies the names of IoT devices?

- Networks are constructed for various IoT services
  - e.g. connected vehicles and smart city, etc.



- IoT communication APIs are defined by some organizations
  - IoT devices are recognized by names
  - Who specifies the names of IoT devices when constructing IoT network using a virtual network?

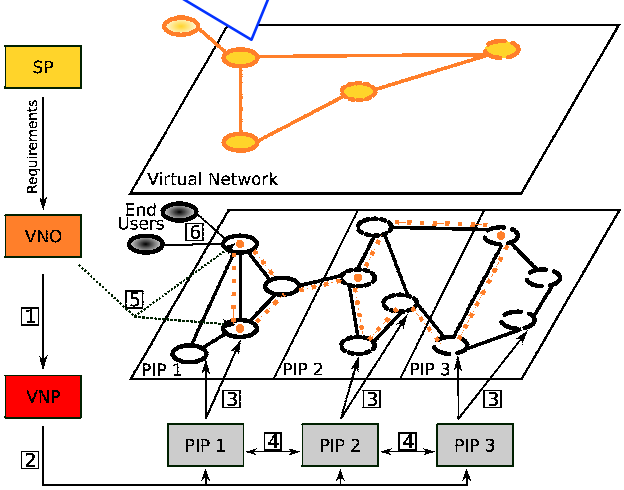


[1] OMA Alliance, Lightweight Machine to Machine Technical Specification, Approved Version 1.0 – 08 Feb 2017

Backgrounds (2)

Who operates naming and addressing for VNs?

- Business players for constructing Virtual Networks (VNs) are defined [2]
  - Service Provider (SP)
  - Virtual Network Operator (VNO)
  - Virtual Network Provider (VNP)
  - Physical Infrastructure Provider (PIP)



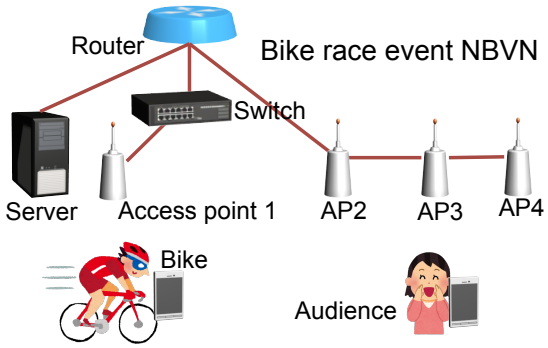
- It is not clear who operates naming, addressing, and configuration of name resolution system for the constructed VN?
  - Is the human network manager of VNO responsible for these operations?

[2] G. Schaffrath, at el., ``Network Virtualization Architecture: proposal and initial prototype,'' Proc. of the 1st ACM workshop on Virtualized infrastructure systems and architectures, 2009.

→ Propose a method for automatic construction of VNs with named components and name resolution system, called Name-Bound Virtual Network (NBVN)

Objectives of NBVN (Name-Bound Virtual Network)

- Construct NBVNs for IoT services such as outdoor concerts and sporting events
  - Those services are area-bound and time-bound (may last for hours or days)
  - Quick construction is required
  - Automation is important

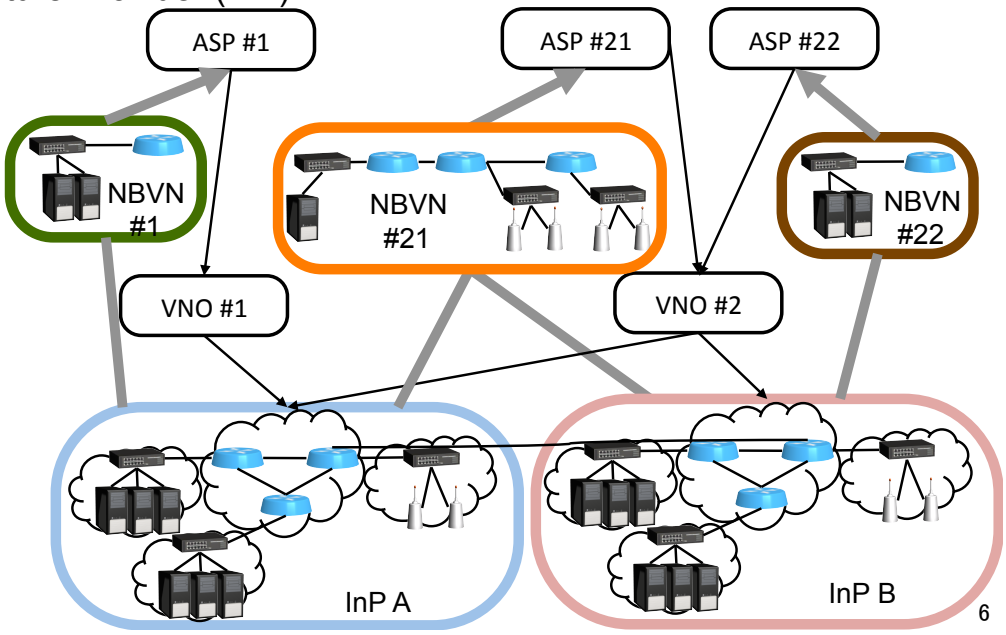


In this presentation:

- For the automatic construction of NBVNs, re-define business players, and propose their roles and interactions between them
  - Especially, clarify which player operates naming, addressing and construction of a name resolution mechanism for NBVNs
  - Manual operations are avoided as far as possible
- Design and Implement a simple proof-of-concept system

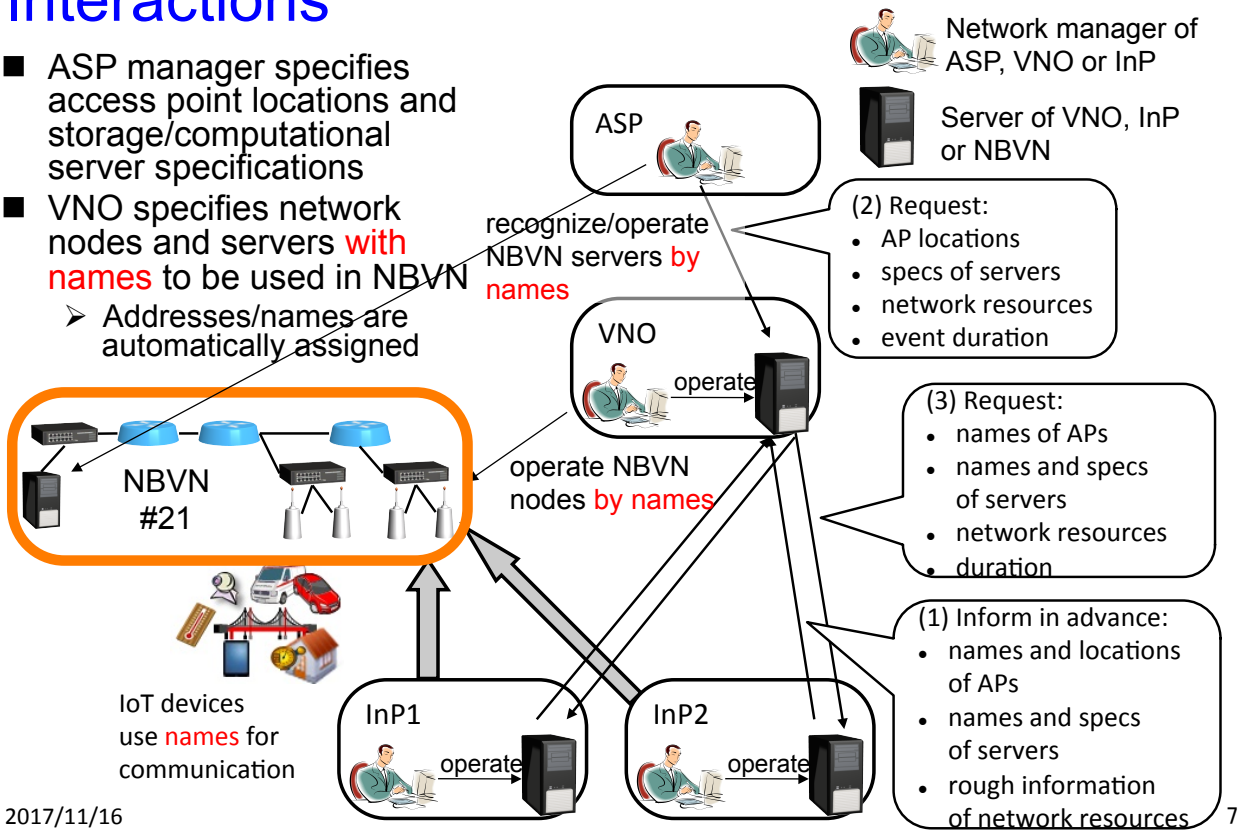
Business Players and Information Flows

- Re-define business players
  - Application Service Provider (ASP)
  - Virtual Network Operator (VNO)
  - Infrastructure Provider (InP)



Proposal of ASP/VNO/InP Roles and Interactions

- ASP manager specifies access point locations and storage/computational server specifications
- VNO specifies network nodes and servers with names to be used in NBVN
  - Addresses/names are automatically assigned



Proposal of ASP/VNO/InP Roles and Interactions

- ASP manager specifies access point locations and storage/computational server specifications
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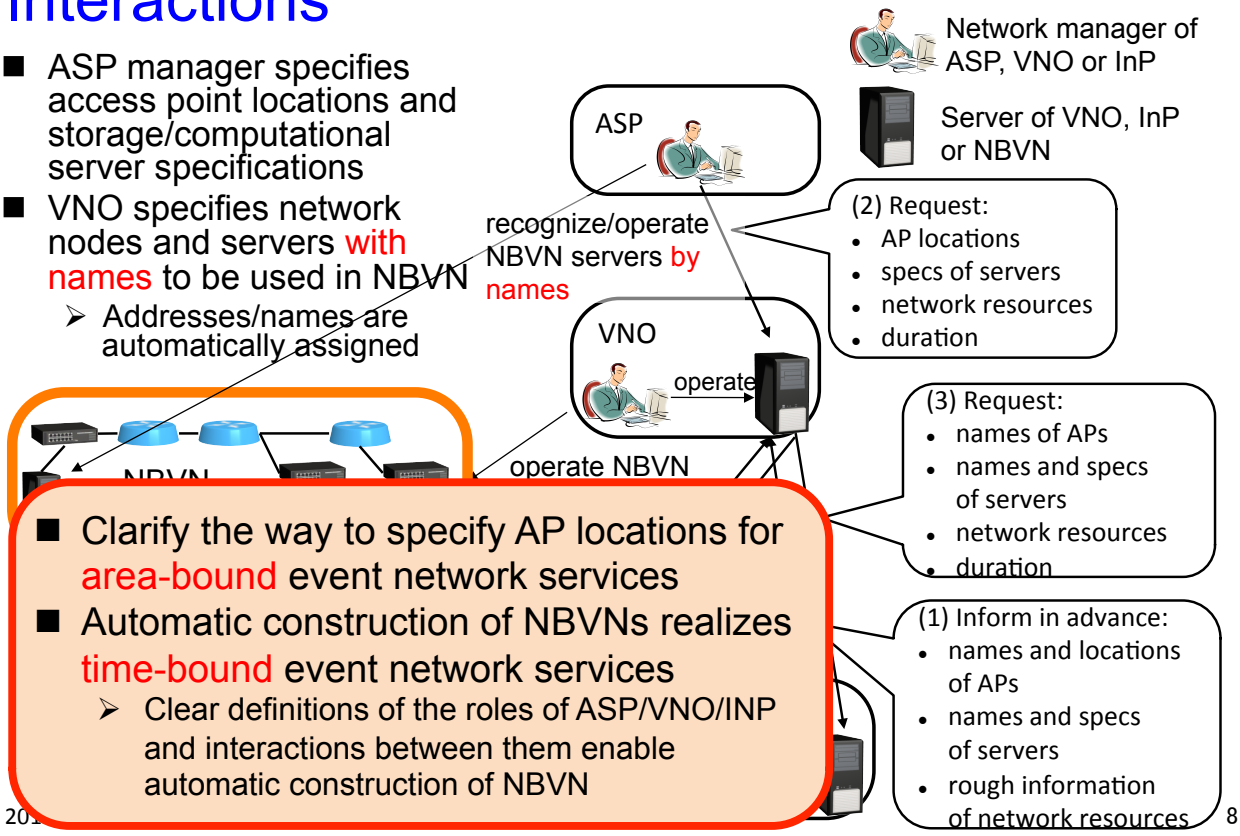
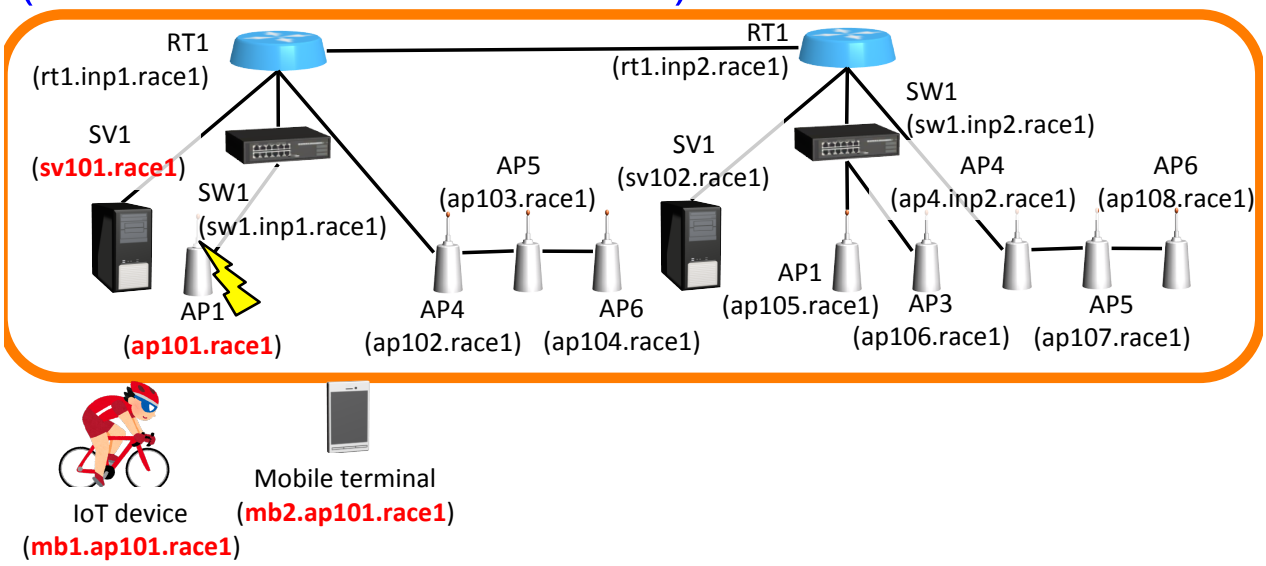


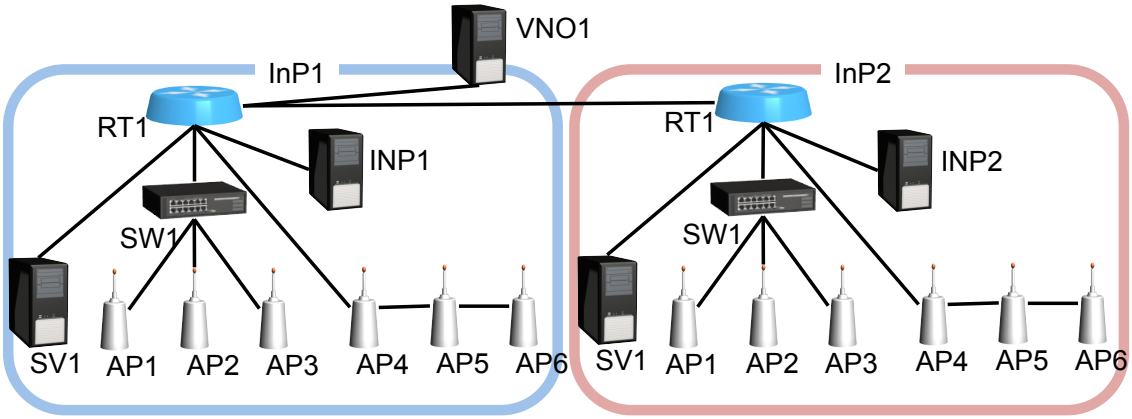
- Clarify the way to specify AP locations for area-bound event network services
- Automatic construction of NBVNs realizes time-bound event network services
  - Clear definitions of the roles of ASP/VNO/INP and interactions between them enable automatic construction of NBVN

Example Construction of NBVN
(a Bike Race Event Network)



- Network node names are assigned by VNO
  - e.g. ap101.race1 sv101.race1
- IoT device names are assigned according to the AP names
  - e.g. mb1.ap101.race1 mb2.ap101.race1

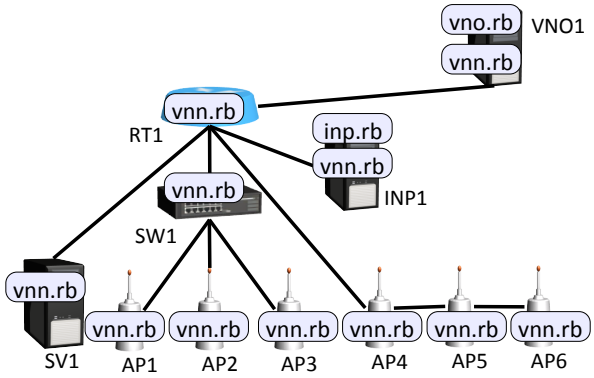
Infrastructure Networks



SV1: Server (for service in NBVN)
RT1: L3 router
SW1: L3 switch
AP1-AP6: Access points
INP1,INP2: InP server (for management)
VNO1: VNO server (for management)

- Each InP assigns names to network nodes within the InP
  - Note that ASP can assign different names in NBVN

Developed Programs (Ruby Scripts)



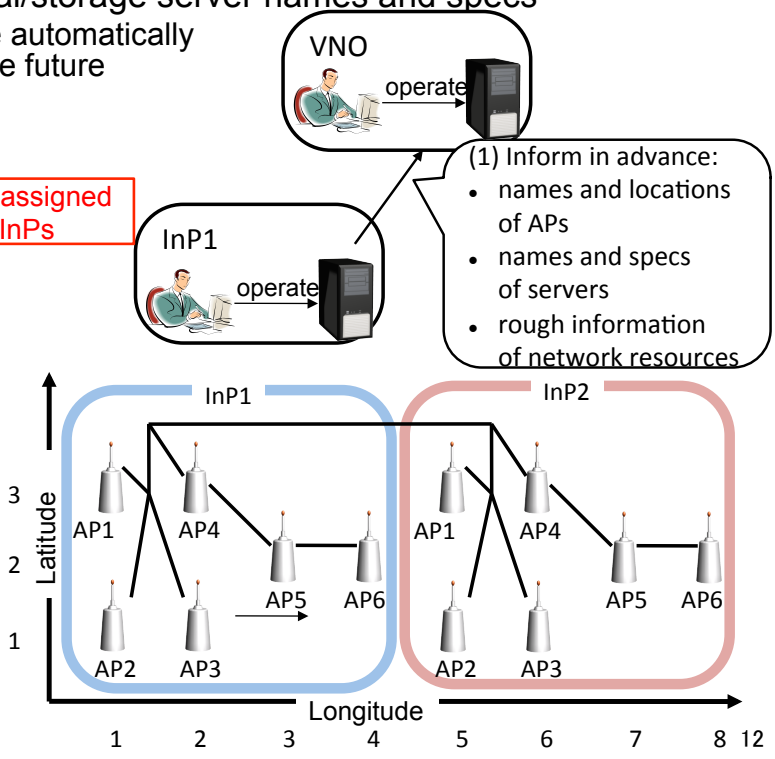
- vnn.rb: Virtual Network Node Script
- inp.rb: Infrastructure Provider Server Script
- vno.rb: Virtual Network Operator Server Script
  - ➢ Read JSON- or YAML-formated data

VNO Configuration (vno.rb)

- Vno.rb is configured with information about InP servers (inp.rb), AP names and locations, computational/storage server names and specs
  - ➢ This information should be automatically sent from InP to VNO in the future

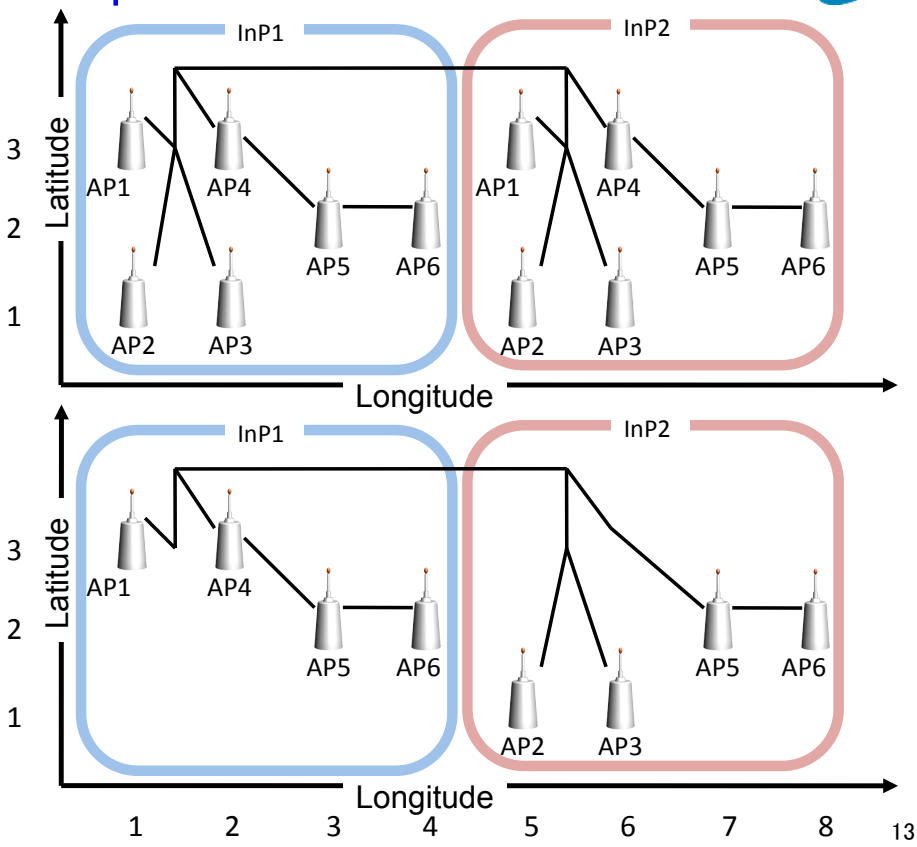
```
vno1# cat vno1.conf
 inp:
  - { name: inp1.inp1, port: 4001 }
  - { name: inp2.inp1, port: 4001 }
 accesspoint:
  - { name: ap1.inp1, latitude: 3, longitude: 1 }
  - { name: ap2.inp1, latitude: 1, longitude: 1 }
  - { name: ap3.inp1, latitude: 1, longitude: 2 }
  - { name: ap4.inp1, latitude: 3, longitude: 2 }
  - { name: ap5.inp1, latitude: 2, longitude: 3 }
  - { name: ap6.inp1, latitude: 2, longitude: 4 }
  - { name: ap1.inp2, latitude: 3, longitude: 5 }
  - { name: ap2.inp2, latitude: 1, longitude: 5 }
  - { name: ap3.inp2, latitude: 1, longitude: 6 }
  - { name: ap4.inp2, latitude: 3, longitude: 6 }
  - { name: ap5.inp2, latitude: 2, longitude: 7 }
  - { name: ap6.inp2, latitude: 2, longitude: 8 }
 server:
  - { name: sv1.inp1, memory: 4G, hdd: 10G }
  - { name: sv1.inp2, memory: 4G, hdd: 10G }
vno1# ./vno.rb --port 4000 --conf vno1.conf
```

Names assigned by InPs



Access Points Required for a Bike Race Event

- AP locations from the satellite view
- APs required for covering a bike race event

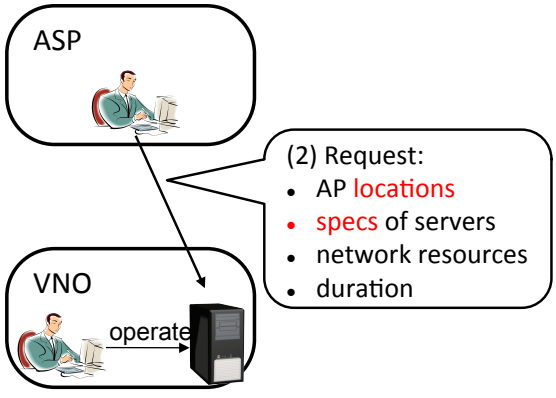


ASP's request to VNO (vnn.rb)

- ASP sends a request to VNO
  - The network manager of ASP grasps the required locations for the access points, however does not know the names of the access points in those locations

```
asp# cat race1.conf
event: race1
accesspoint:
  - { latitude: 3, longitude: 1 }
  - { latitude: 3, longitude: 2 }
  - { latitude: 2, longitude: 3 }
  - { latitude: 2, longitude: 4 }
  - { latitude: 1, longitude: 5 }
  - { latitude: 1, longitude: 6 }
  - { latitude: 2, longitude: 7 }
  - { latitude: 2, longitude: 8 }
server:
  - { memory: 4G, hdd: 10G }
  - { memory: 4G, hdd: 10G }
duration:
  from: 2016-05-31 06:00:00 +09:00
  to:   2016-05-31 12:00:00 +09:00
asp# curl -X POST --data-binary @race1.conf \
        -H "Content-type: text/x-yaml" \
        http://vno1.somewhere:4000/
asp#
```

- Include location info
- Does not include names of APs or servers



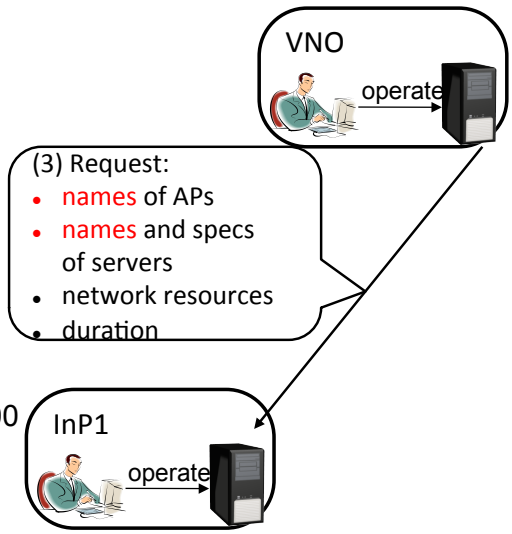
Request from VNO (vno.rb) to InP1 (inb.rb)

- Request includes actual names of access point and server names in InP1

```
domain: race1
vnno: 3
accesspoint:
 - { nodename: ap101, name: ap1.inp1 }
 - { nodename: ap102, name: ap4.inp1 }
 - { nodename: ap103, name: ap5.inp1 }
 - { nodename: ap104, name: ap6.inp1 }
server:
 nodename: sv101
 name: sv1.inp1
 memory: 4G
 hdd: 10G
 offer: yes
duration:
 from: 2016-05-31 06:00:00.000000000 +09:00
 to: 2016-05-31 12:00:00.000000000 +09:00
```

VNO specifies new names

Names assigned by InPs in advance



Executed Vnn.rb Command on Each Node and Assigned Names/Addresses to be Used within the NBVN

- InP1 executes vnn.rb on each node

Names assigned by InPs in advance

Names specified by VNO

```
sv1.inp1# vnn.rb –nodename   sv101 --vnno 3 --domain race1 --offer eth1
ap1.inp1# vnn.rb --nodename  ap101 --vnno 3 --req eth1 --dhcps eth3
ap4.inp1# vnn.rb --nodename  ap102 --vnno 3 --req eth1,eth2 --dhcps eth3
ap5.inp1# vnn.rb --nodename  ap103 --vnno 3 --req eth1,eth2 --dhcps eth3
ap6.inp1# vnn.rb --nodename  ap104 --vnno 3 --req eth1 --dhcps eth3
```

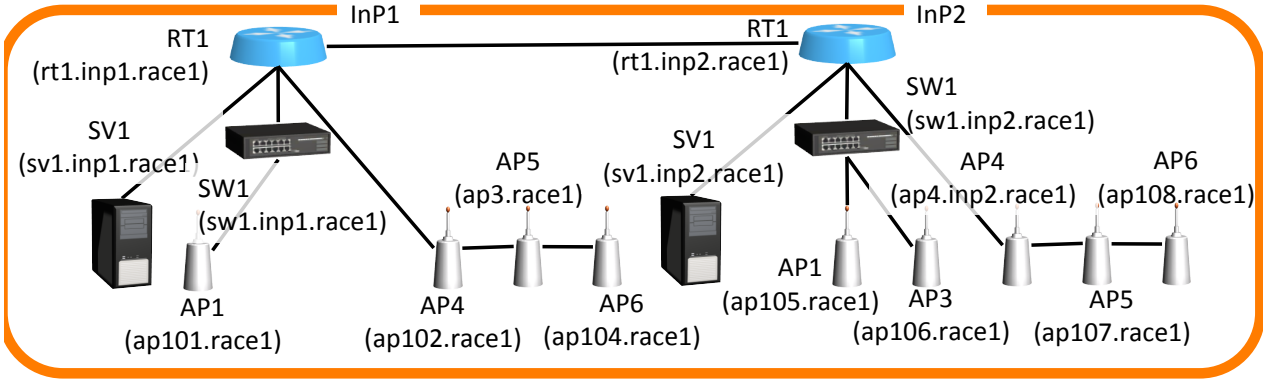
- IPv6 addresses are automatically assigned to all the network nodes
- IPv6 forwarding tables are also configured
- Name resolution system (DNS) is simultaneously/automatically configured

Names specified by VNO
These names are used within NBVN

```
sv101.race1.        300 IN AAAA 2002:db8:3:2::3
ap101.race1.        300 IN AAAA 2002:db8:3:5::4
ap102.race1.        300 IN AAAA 2002:db8:3:3::5
ap103.race1.        300 IN AAAA 2002:db8:3:7::6
ap104.race1.        300 IN AAAA 2002:db8:3:8::7
mb1.ap101.race1.    300 IN AAAA 2002:db8:3:6::2
mb2.ap101.race1.    300 IN AAAA 2002:db8:3:6::2
```

Names for IoT devices, of which base name is specified by VNO

Constructed Bike Race Network



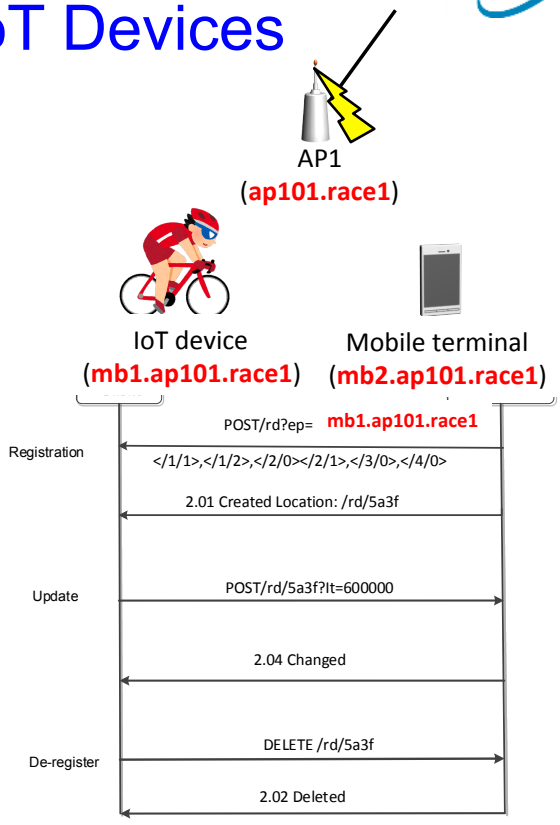
NBVN #3 for bike race event (2002:db8:3::/48)

DNS entries	IP addresses	Construction time of NBVN (sec)
15 (+1600)	36 (+1600)	52.18 (avg. 3.48)

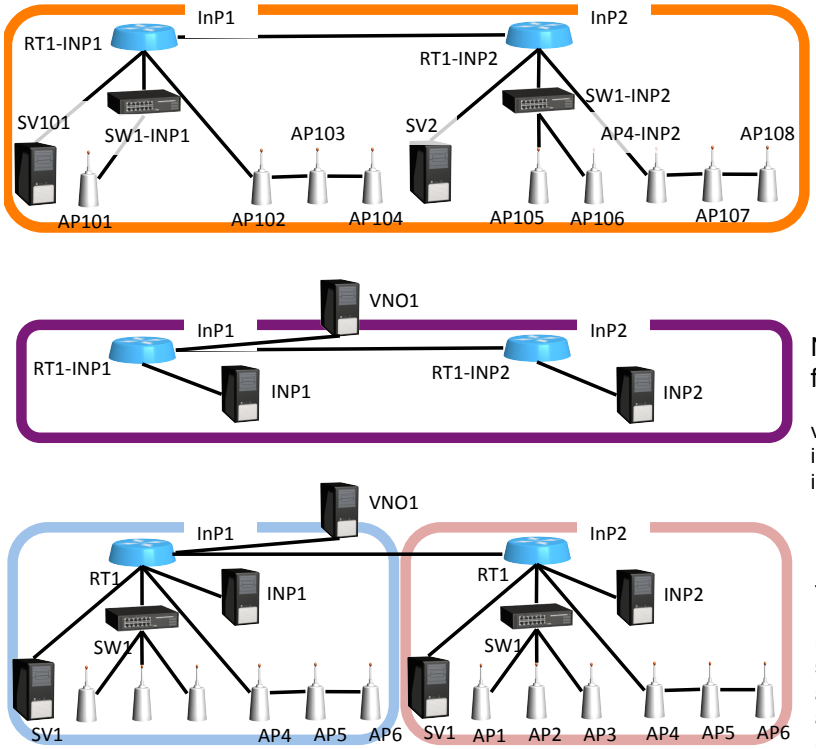
- We validated that our proposed system practically constructs NBVNs that are used for area/time-bound events
- It is expected to take tens of minutes to construct the NBVN for the event of tens of thousands attendees from our PoC net experiments

Names and Addresses assigned to Mobile Terminals and IoT Devices

- ***ap101.race1*** starts a DHCP server with an address space of 2002:db8:3:6::/64, and provides wireless access with SSID containing domain name ***race1***
- Mobile terminals and IoT devices searches SSID containing ***race1***, and connect to NBVN race1.
- According to DHCP, access point ***ap101.race1*** assigns IP addresses and DNS names such as ***mb1.ap101.race1*** and ***mb2.ap101.race1*** to mobile terminals and IoT devices



Example Construction of Multiple NBVNs on the Shared Infrastructure



NBVN #3 (RACE1, 2002:db8:3::/48) for a bike race event

```
sv101.race1.        300 IN AAAA 2002:db8:3:2::3
ap101.race1.        300 IN AAAA 2002:db8:3:5::4
ap102.race1.        300 IN AAAA 2002:db8:3:3::5
ap103.race1.        300 IN AAAA 2002:db8:3:7::6
(snip)
mb1.ap101.race1. 300 IN AAAA 2002:db8:3:6::2
mb2.ap101.race1. 300 IN AAAA 2002:db8:3:6::2
(snip)
```

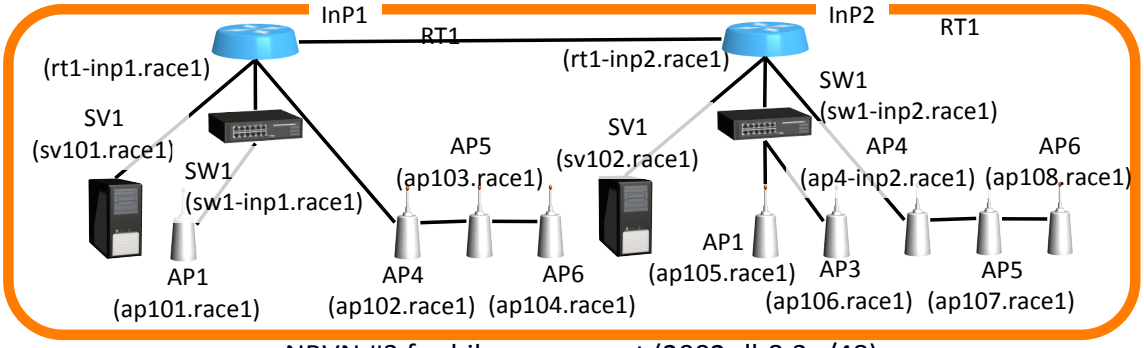
NBVN #2 (VNO1, 2002:db8:2::/48) for VNO1 to communicate with InP1/2

```
vno1.vno1.          300 IN AAAA 2002:db8:2:1::1
inp1.vno1.          300 IN AAAA 2002:db8:2:2::2
inp2.vno1.          300 IN AAAA 2002:db8:2:3::3
```

NBVN #1 (INP2, 2002:db8:1::/48) for internal management of InP2

```
rt1.inp2.           300 IN AAAA 2002:db8:1:1::1
sw1.inp2.           300 IN AAAA 2002:db8:1:2::2
ap1.inp2.           300 IN AAAA 2002:db8:1:3::3
ap2.inp2.           300 IN AAAA 2002:db8:1:4::4
(snip)
```


Constructed Bike Race Network



NBVN #3 for bike race event (2002:db8:3::/48)

	DNS entries	IP addresses	Construction time of NBVN (sec)	Average time of starting one node (sec)
Race event NBVN	15 (+1600)	36 (+1600)	34.15	2.28

- We validated that our proposed system practically constructs NBVNs
- It is expected to take tens of minutes to construct the NBVN for the event of tens of thousands attendees from our PoC network experiments

Conclusions

- Proposed an automatic construction mechanism of NBVNs for IOT
- Re-defined ASP, VNO, and InP, and proposed the roles of ASP/VNO/InP and the required interactions among them
- Developed a poof-of-concept system that implements the operations of ASP/VNO/InP, and automatically constructs NBVNs.
  - IPv6 addresses are automatically assigned to the network nodes and IoT devices
  - The data forwarding and name resolution mechanisms are also automatically configured
- The automatic construction system of NBVNs enables area-/time-bound event-oriented NBVNs for IoT applications such as outdoor concerts and sporting events

Future work

- Network resource (e.g. bandwidth/delay) management
- Function of polling network resources

Packet Formats and Protocol Formats