A Software-Defined Approach for End-to-end IoT Networking

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Problem and Challenges

• Problems with end-to-end IP networking to resource-constrained IoT devices
  - Need adaptation and/or mapping functions for end-to-end global IP networking
  - Manage a large number of devices with variety of IoT protocols

• Capability mismatch between devices
  - MTU differences, simplified vs. full protocol stack (e.g., CoAP/UDP vs. HTTP/UDP), single stack vs. dual stack, processing and communications bandwidth, sleep schedule, security protocols, etc.

• Rapid interaction between services and infrastructure
  - E.g., More agile communication (e.g., scale-in/out)
### Variety of IoT Protocols

#### Various Physical Layers
- WiFi, WiMAX, BLE, NFC, LTE, ...

#### Various 6LO Functions
- IPv6-over-foo adaptation layer using 6LoWPAN technologies (RFC4944, RFC6282, RFC6775 ..)

#### Constrained Application Protocol
- RFC 7252 CoAP and related mapping protocols

#### Constrained Security Protocols
- DTLS In Constrained Environments (DICE, draft-ietf-dice-profile-05)
- Authentication and Authorization for Constrained Environments (ACE, Work-in-Progress)

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**Diagram:**

- **Application Layer:** CoAP, DICE, ACE, ....
- **System Layer:** CoAP, DICE, ACE, ....
- **Transport Layer:** UDP, IPv4/IPv6
- **Network Layer:** 6LO Adaptation Layer, MAC
- **Link Layer:** Radio Transmission
- **Physical Layer:** Wi-Fi, WiMAX, Bluetooth, NFC, LTE

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Note that we will mainly focus on end-to-end networking to resource-constrained nodes using 6LO, CoAP, DICE, RIOT protocols, etc.
6Lo Functions

• IPv6 over Networks of Resource-constrained Nodes (6Lo WG)
• IPv6-over-foo adaptation layer specifications using 6LoWPAN technologies (RFC4944, RFC6282, RFC6775 ….)
  → Transmission of IPv6 Packets over BLUETOOTH(R) Low Energy
  → Transmission of IPv6 Packets over DECT Ultra Low Energy
  → Transmission of IPv6 over MS/TP Networks
  → Transmission of IPv6 packets over ITU-T G.9959 Networks
  → Transmission of IPv6 Packets over IEEE 1901.2 Narrowband Powerline Communication Networks
  → Transmission of IPv6 Packets over Near Field Communication (NFC)
Our Approach

• SDN and NFV can solve those problems and challenges.
  ➢ SDIoT: A Software-defined end-to-end IoT infrastructure (including aka, IoT service chaining support)

• IoT Infrastructure could be built by means of NFV with integration of SDN which makes it more agile.

• SDN and NFV will be enablers for new IoT Infrastructure.
Two Basic Questions

1) How to relocate various IoT functions from HW appliances to VMs and make them connected or chained together?

2) How to abstract IoT’s behaviors by SDN concept?
1) How to relocate IoT GW functions?

Virtualization & Relocation
1) How to relocate IoT GW functions?

Virtualization & Relocation

- CoAP-to-HTTP, DICE-to-TLS
- UDP
- IPv4/IPv6
- 6LO Adaptation Layer
- MAC
- Radio Transmission

Wi-Fi  WiMAX  Bluetooth  NFC  LTE

System Layer

CoAP-to-HTTP, DICE-to-TLS

UDP
IPv4/IPv6
6LO Adaptation Layer
MAC
Radio Transmission

Wi-Fi  WiBro  Bluetooth  NFC  LTE

Application Layer

Controls (SDN)

System Layer

CoAP-to-HTTP, DICE-to-TLS

UDP
IPv4
6LO adaptation layer
MAC
Radio Transmission

Wi-Fi  WiBro  Bluetooth  NFC  LTE

Virtualization Layer

IoT GW (HW)

IoT VNF (SW)

IoT SDN (SW)
NFV IoT GW Functions Candidates

- IoT DPI functions
- L2~L3
  - IP mapping function for non-IP nodes
  - 6LO functions (IPv6 Packets over WPAN, BT, Low Power Wi-Fi, NFC, etc.)
    - RFC4944, RFC6282, RFC6775, and
    - Many other WG I-Ds (work-in-progresses)
- L4~L7
  - CoAP-HTTP protocols mapping <draft-ietf-core-http-mapping>
  - DICE-TLS protocols mapping …
Service Chaining Operation Example for E2E IoT Networking

SFC1: DPI → 6Lo(WPAN) → DICE/TLS
SFC2: DPI → 6Lo(NFC) → CoAP/HTTP
2) How to abstract IoT’s behaviors by SDN Concept?

Yang Data Modeling
- Properties and behaviors
- Connectivity (Mesh, radio/wireless …)
- QoS
- Real-time
- Delay/Jitter
- Reliability (Verification)
- Sensing/Actuation
- Robustness
- Security …

IoT’s Control Plane
- Control Abstraction Layer
- IoT Controls
- IoT-aware Services/Applications/Stuff

Device Abstraction Layer
- IoT Devices

Abstraction & Separation
Adding SDN Automation and Verification in NFV and IoT Infrastructure

Network service Descriptions
(High-level Programming /w Yang Modeling)

SDN/NFV Controller
Orchestrator

End Point

Virtualization

IoT Infrastructure

NBAPIs

VNF

VNF

VNF

VNF

VNF

End Point

VeriSDNFV GUI

Verification Process for IoT Properties /Behaviors

Formal Verifier
(Symbolic Verification)

Flow table, DBs, etc.
(Network/OpenStack Status/infos)

pACSR (Formal Language) description
Our Development and Prototype

SDN/NFV-enabled end-to-end IoT network services

OpenStack Controller/Orchestrator
SDN Controller
Yang Complier, Verification Tools …
OpenStack Agent
SDN Switch
Virtualization Layer
compute memory storage network

IPv6 over NFC functions
<draft-hong-6lo-ipv6-over-nfc>

Intel Galileo board with Debian Linux OS
NFC Shield
Wrap-up

• SDN and NFV offer a new way to design, deploy and manage IoT end-to-end network services.
  • SDN provides rapid interaction between services and infrastructure.
  • NFV makes IoT service functions chaining more agile.

• Our challenge is that how to relocate various IoT functions to VMs on top of generic servers and abstract their behaviors by SDN.

• We are now developing a prototype, which is mainly focused on various 6LO functions chaining.

• We are also planning to propose a new (bar) BoF for I2NCN (Interface to Network of Constrained Nodes) at next IETF92 meeting.