Breaking out of the cloud:
Local trust management and rendezvous in Named Data Networking of Things

Wentao Shang, Zhehao Wang, Alexander Afanasyev,Jeff Burke, Lixia Zhang

UCLA

The Rise of IoT at Home

Cloud-centric (Silo) Approach to IoT
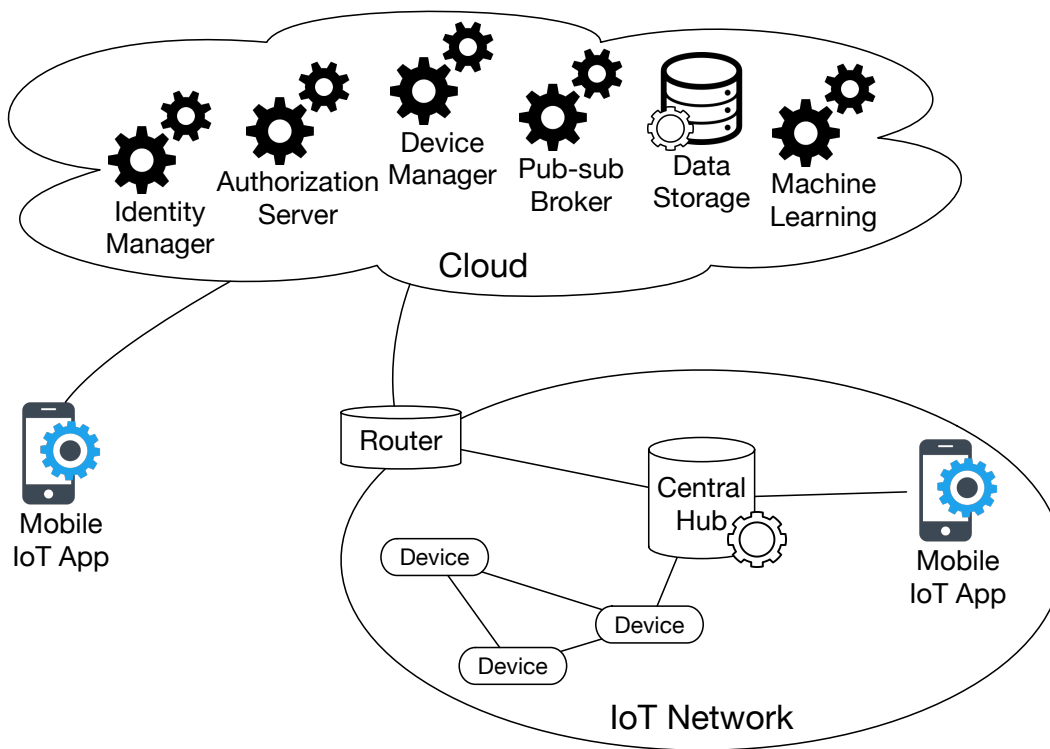
Problems with Cloud-centric IoT

Rethink the IoT Service Architecture

Example: AWS IoT platform

Resource Name (ARN) of my living room lamp:
:iot:us-west-1:wentao:things/LivingRoomLamp

AUTHENTICATION & AUTHORIZATION

REGISTRY

DEVICE GATEWAY

Amazon SNS

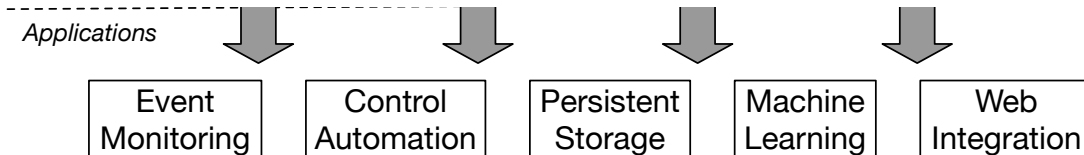amazon webservices™

S3

DynamoDB

Kinesis

Lambda

5

Rethink the IoT Service Architecture

Example: AWS IoT platform

Resource Name (ARN) of my living room lamp:
:iot:us-west-1:wentao:things/LivingRoomLamp

Applications

Event Monitoring	Control Automation	Persistent Storage	Machine Learning	Web Integration

AUTHENTICATION & AUTHORIZATION

REGISTRY

amazon web services™

Amazon SNS

S3

DEVICE GATEWAY

DynamoDB

Kinesis

Lambda

Rethink the IoT Service Architecture
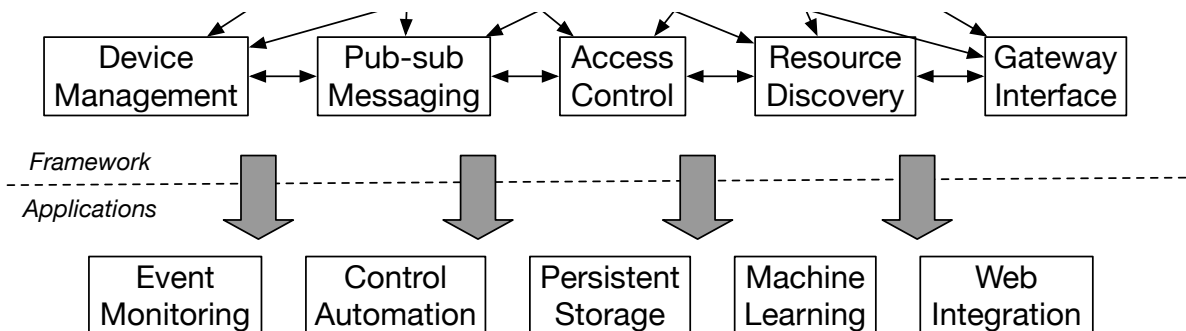
Example: AWS IoT platform

Resource Name (ARN) of my living room lamp:
:iot:us-west-1:wentao:things/LivingRoomLamp

Device Management ↔ Pub-sub Messaging ↔ Access Control ↔ Resource Discovery ↔ Gateway Interface

Framework

Applications

Event Monitoring

Control Automation

Persistent Storage

Machine Learning

Web Integration

AUTHENTICATION & AUTHORIZATION

REGISTRY

DEVICE GATEWAY

Amazon SNS

amazon web services™
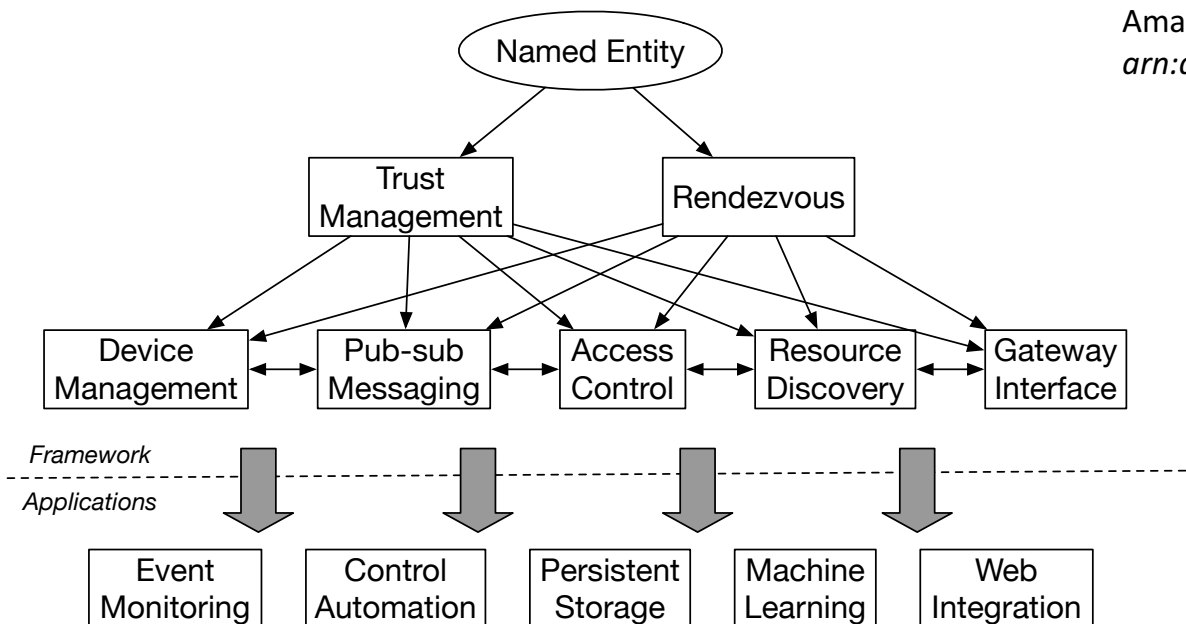
S3

DynamoDB
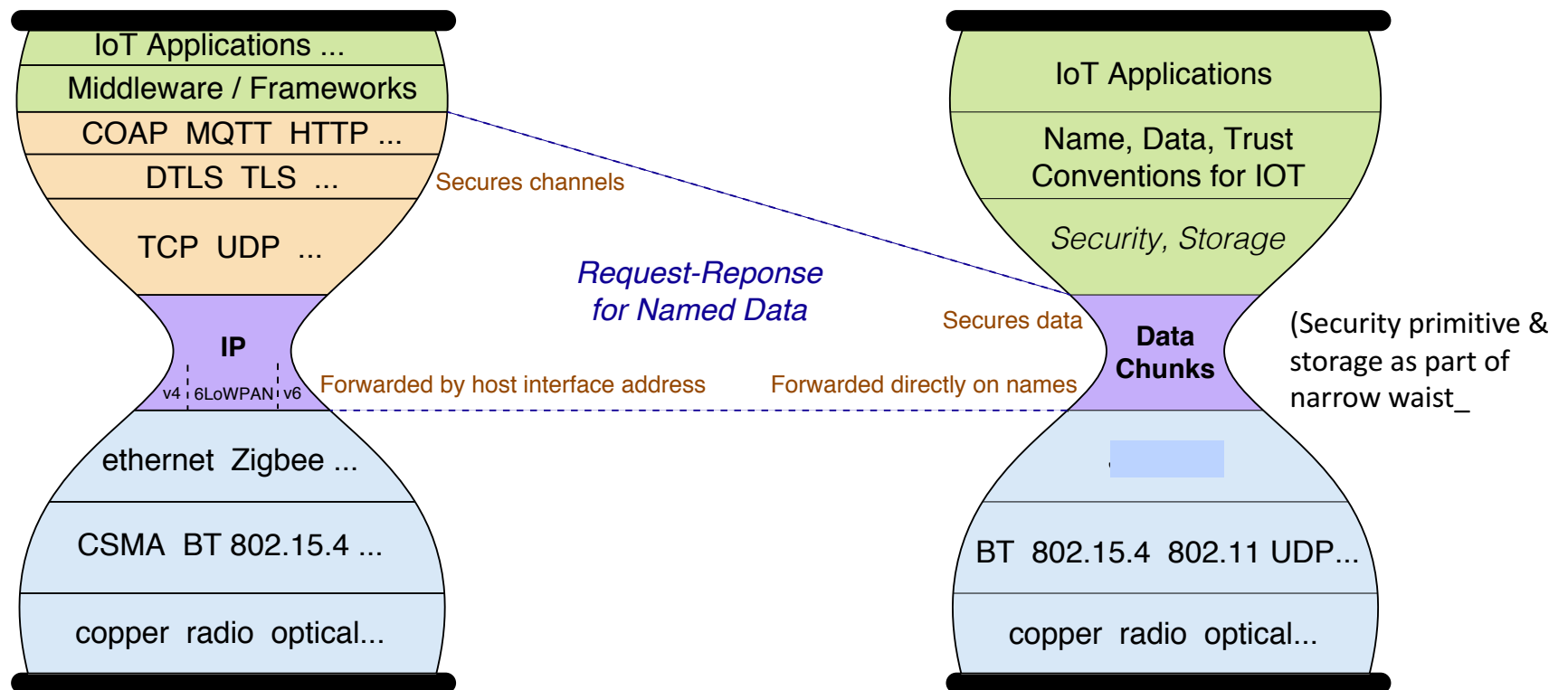
Kinesis

Lambda

Rethink the IoT Service Architecture

Example: AWS IoT platform

Amazon Resource Name (ARN) of my living room lamp:
arn:aws:iot:us-west-1:wentao:things/LivingRoomLamp

Named Entity

Trust Management

Rendezvous

Device Management

Pub-sub Messaging

Access Control

Resource Discovery

Gateway Interface

Framework

Applications

Event Monitoring

Control Automation

Persistent Storage

Machine Learning

Web Integration

AUTHENTICATION & AUTHORIZATION

REGISTRY

Amazon SNS

DEVICE GATEWAY

amazon web services

S3

DynamoDB

Kinesis

Lambda

8

Named Data Networking of Things (IoTDI'16)

Left hourglass (top to bottom):
- IoT Applications ...
- Middleware / Frameworks
- COAP MQTT HTTP ...
- DTLS TLS ...
- TCP UDP ...
- **IP** — v4 6LoWPAN v6
- ethernet Zigbee ...
- CSMA BT 802.15.4 ...
- copper radio optical...

Right hourglass (top to bottom):
- IoT Applications
- Name, Data, Trust Conventions for IOT
- *Security, Storage*
- **Data Chunks**
- BT 802.15.4 802.11 UDP...
- copper radio optical...

Secures channels

Request-Reponse for Named Data

Secures data

Forwarded by host interface address   Forwarded directly on names

(Security primitive & storage as part of narrow waist_

Cloud-independent IoT with NDN

- **Named entities**: name the "things" *within local context*

- **Trust management**: express the relation between data names and signing key names, *within local context*

- **Rendezvous**: publish & synchronize application names under a local discovery namespace, *within local network/context*
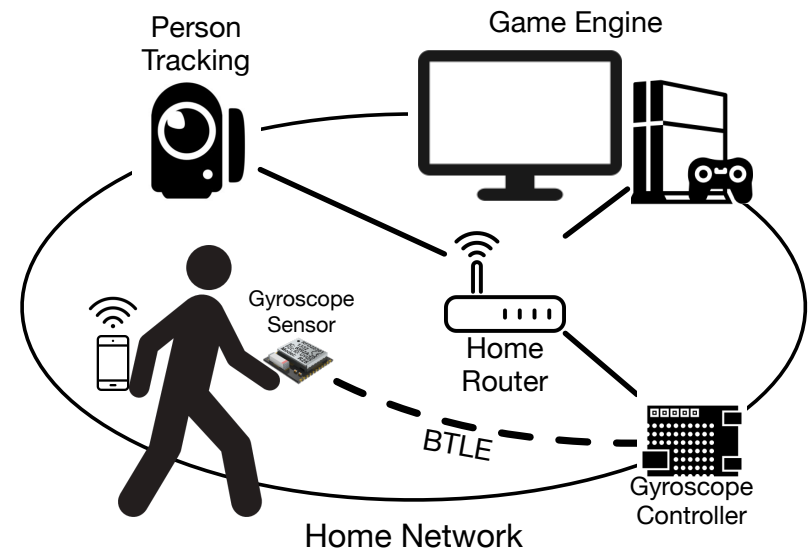
Cloud-independent IoT with NDN

- **Named entities**: name the "things" *within local context*

- **Trust management**: express the relation between data names and signing key names, *within local context*

- **Rendezvous**: publish & synchronize application names under a local discovery namespace, *within local network/context*

- Other services and applications can be bootstrapped from the above

- Optional cloud components can provide functions beyond the capability of local IoT systems (e.g., voice recognition and search)

Flow: a cloud-independent home entertainment system

A multi-user "exploration game" prototype using:

- *Indoor positioning*: player's physical position modifies virtual game world
- *Wearable sensing*: player wears or carries gyroscope to control orientation of virtual camera
- *Mobile phone interface*: player controls actions in virtual game world via smartphones.
- *Game engine*: visualization rendered in Unity.

Architecture: AWS-IoT vs. NDN-IoT
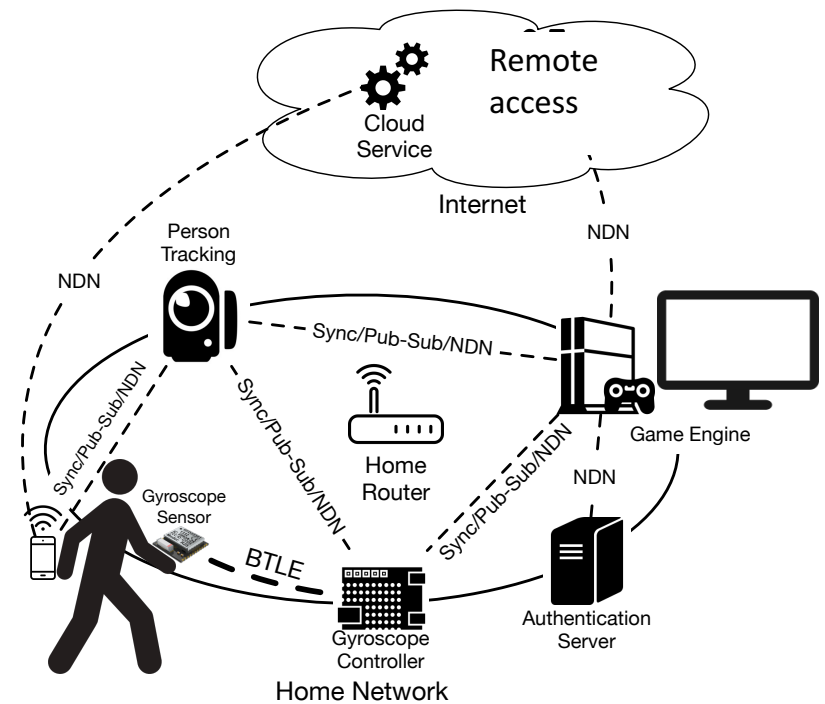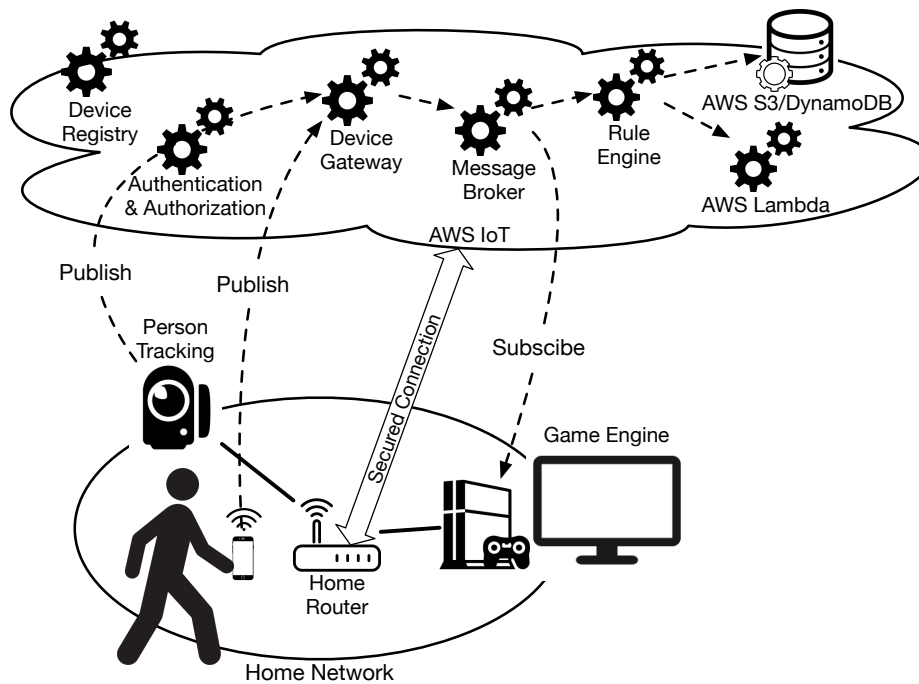
Conclusion

- Existing cloud-centric IoT systems represent a "path of least resistance" in the IoT revolution under TCP/IP architecture

- Great opportunity for cloud-independent IoT design
  - Application-defined data naming within local context
  - Securing and exchanging named data at network layer
  - Expressing trust relations by names with schematized trust
  - Discovering new entity names through local synchronization

Many challenges remain for the IoT and NDN research

- Easy-to-use, encryption-based access control

- Global access to the manufacturer namespaces

- Quantitative evaluation against similar applications based on TCP/IP

- Better generalization / interface design in NDN IoT framework

Implementation

- Indoor positioning with OpenPTrack over NDN
  - Publish position data at 30Hz and metadata at lower rate

- Wearable sensing with RFduino22301 and gyroscope MPU6050
  - RFduino generates NDN data at 2Hz and transfers to a Raspberry Pi 2 controller for signing and publishing

- Mobile interface on Android phone using NDN.JS library
  - Generates command Interests to control virtual environment and update player's position

- Visualization with Unity3D game engine
  - Consumes positioning and gyro data, and receives command Interests

Links to code

- Code repository (https://github.com/remap/ndn-flow)
  - NDN-IoT framework (https://github.com/remap/ndn-flow/tree/master/framework)
    - Functionality overview
    - Interface description
  - Flow application (https://github.com/remap/ndn-flow/tree/master/application)
- Technical guide (installation and troubleshooting)
- Demo poster
- Application screen recording