Named Data Networking and Service Migration in the IoT

ADISORN LERTSINSRUBTAVEE, UNIVERSITY OF CAMBRIDGE
ARJUNA SATHIASEELAN, UNIVERSITY OF CAMBRIDGE
UPEKA DA SILVA, ASIAN INSTITUTE OF TECHNOLOGY (AIT)
KANCHANA KANCHANASUT, ASIAN INSTITUTE OF TECHNOLOGY (AIT)

Computer Laboratory: University of Cambridge

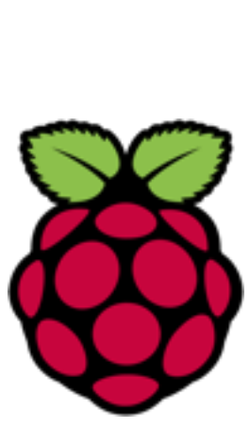
41 Academic Staff

29 Support Staff

5 Research Fellow

81 Post-doc

commercial spin-off from our lab



MIRAGE OS

119 Phd students

300 Undergraduates

36 MPhil

Mathematics

Computer Science

Technology Engineering

Outline

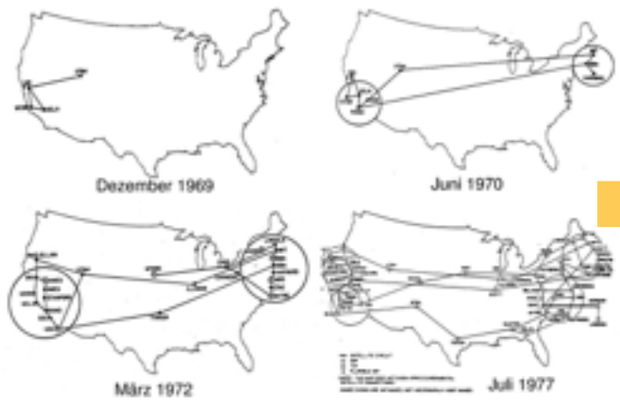
- Challenges in IoT
- Introduction to ICN
- Named Data Networking (NDN)
- Lab: Content Delivery with NDN
- NDN-IoT with smart lighting use case
- Service Migration
- Demo: Service Migration with Docker

IoT Concept

The Internet of Things is made up of hardware and software technologies. The hardware consists of the connected devices – which range from simple sensors to smartphones and wearable devices – and the networks that link them, such as 4G Long-Term Evolution, Wi-Fi and Bluetooth[1].

[1] The Internet of Things: making the most of the Second Digital Revolution, A report by the UK Government Chief Scientific Adviser

Evolution



1969

CONNECTING PLACES

2007

CONNECTING PEOPLE

2020

CONNECTING THINGS

6 Faces of Challenges in IoT

How are devices named and organised?

How do devices communicate with each other?

Device to Cloud

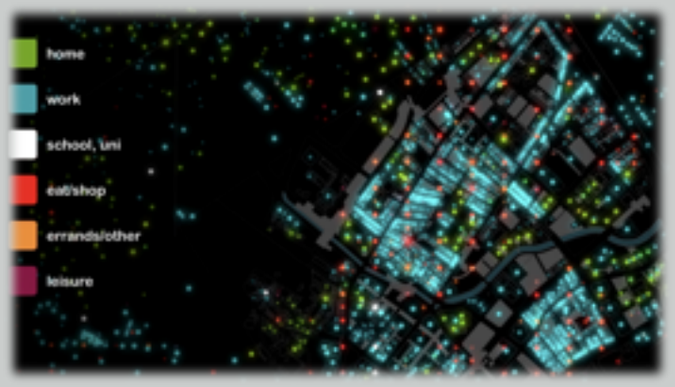
Device to Device

How are devices tracked and monitored?

How is traffic managed and optimized?

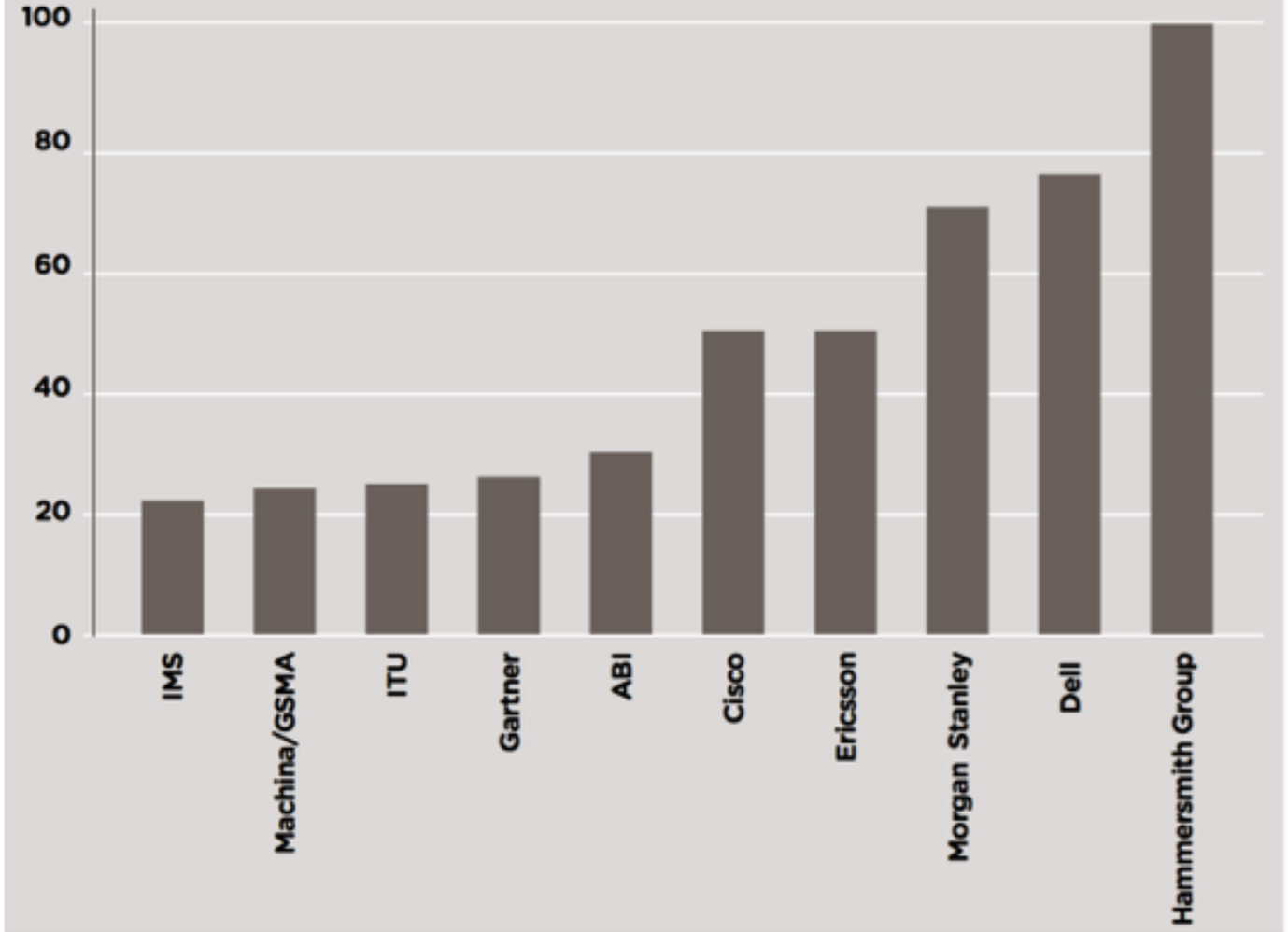
How is security and privacy protected across billions of connected things?

How are these devices configured and managed?



Can current Internet support those challenges ?

Industry estimates for connected devices (billion) in 2020[2]



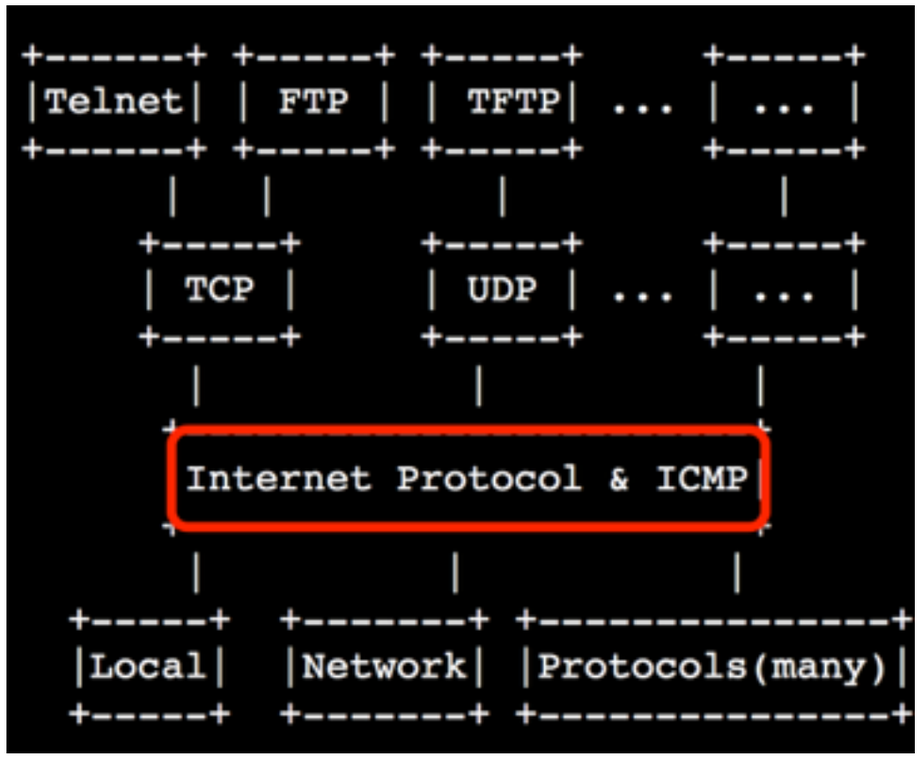
SCALABILITY ISSUE ?

INTERNET ONLY JUST WORKS[1]

The core Internet protocols have not changed significantly in more than a decade.

[1]M Handley, “Why the Internet only just works”
[2] The Internet of Things: making the most of the Second Digital Revolution, A report by the UK Government Chief Scientific Adviser

From Architecture Perspective

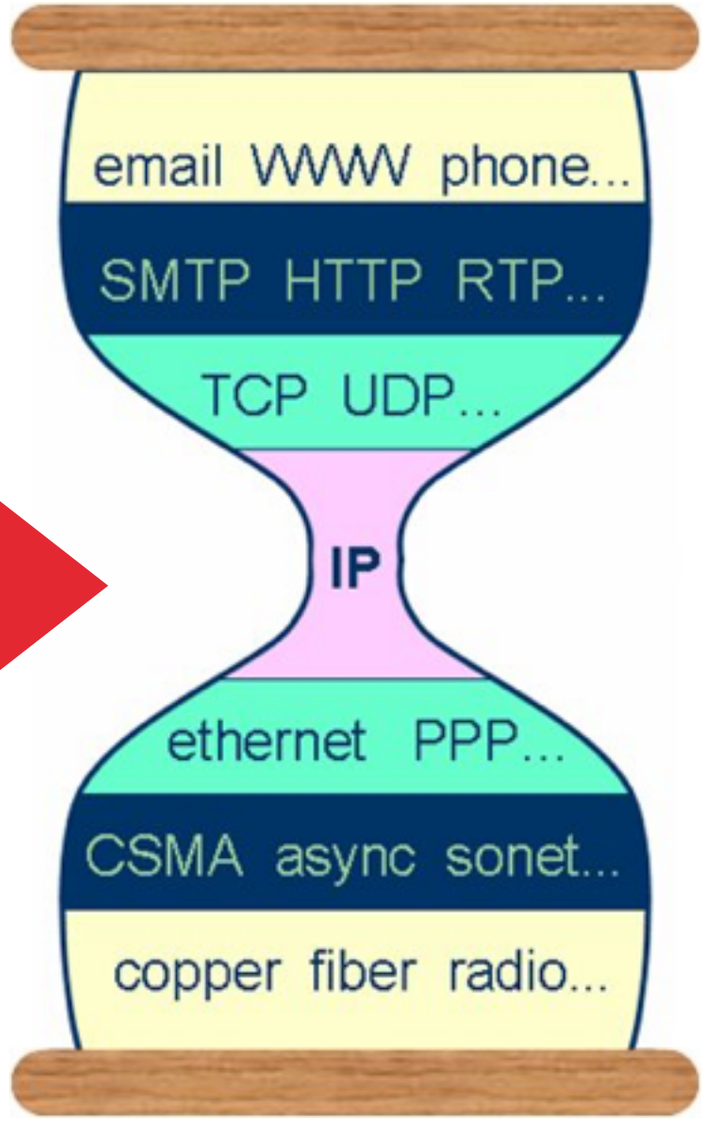


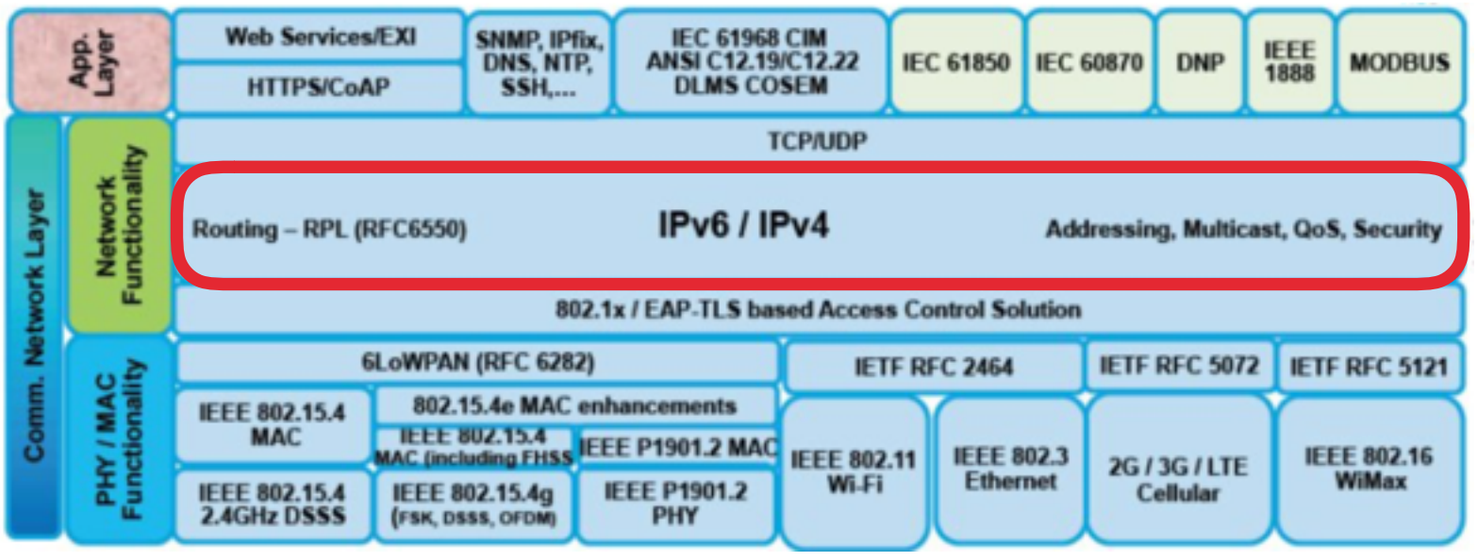
RFC791: Internet Protocol Specification

Solutions ?

DNS, NAT, …

INTERNET AS A HOURGLASS





IoT Protocol stacks: open standards reference model[1]

[1] David E. Culler - The Internet of Every Thing - steps toward sustainability CWSN Keynote, Sept. 26, 2011

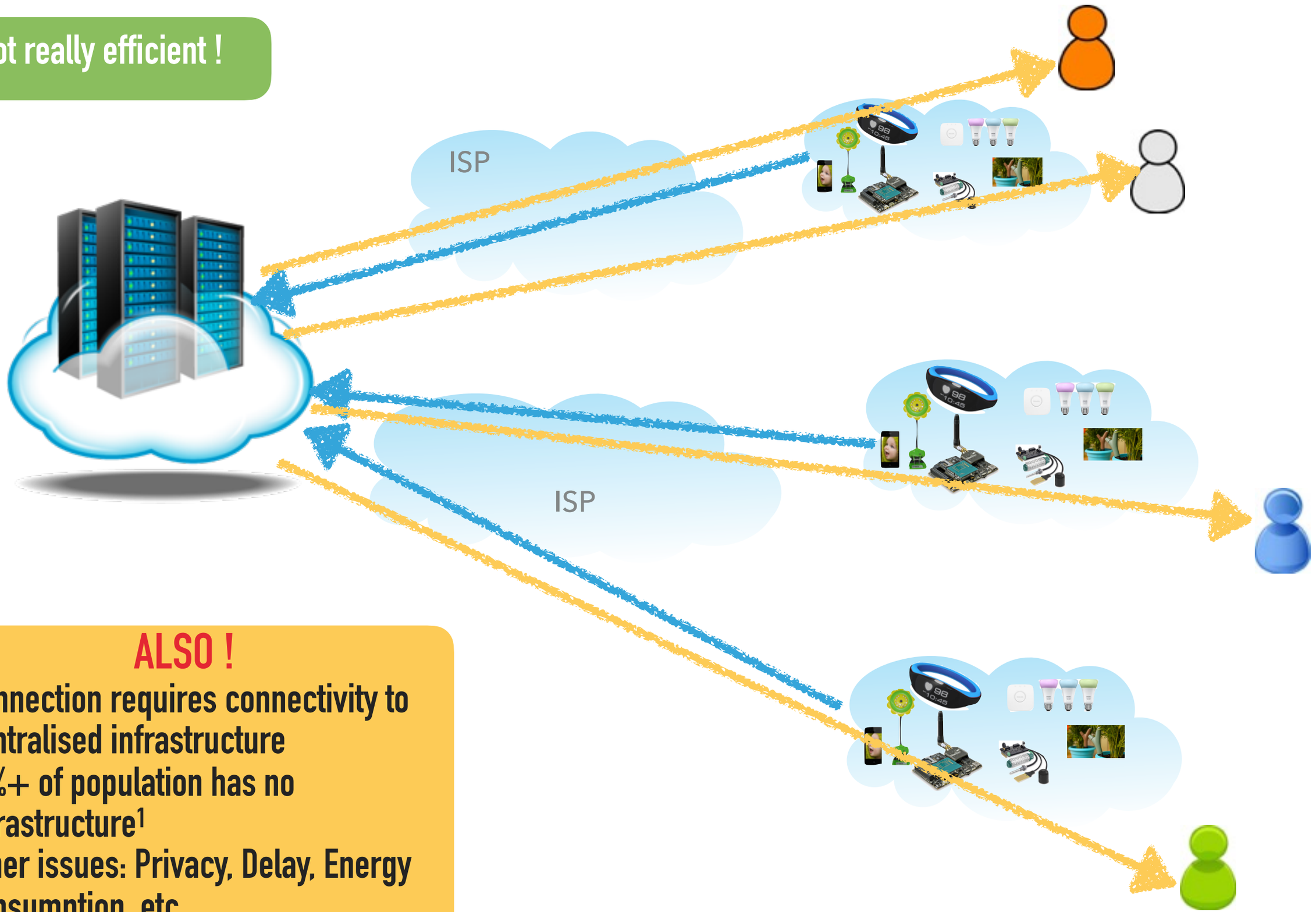
Devices to Cloud Communication Model

Get Data from Cloud

Push Data to the some specific servers (Cloud)

Devices to Cloud Communication Model

Not really efficient !



ALSO !

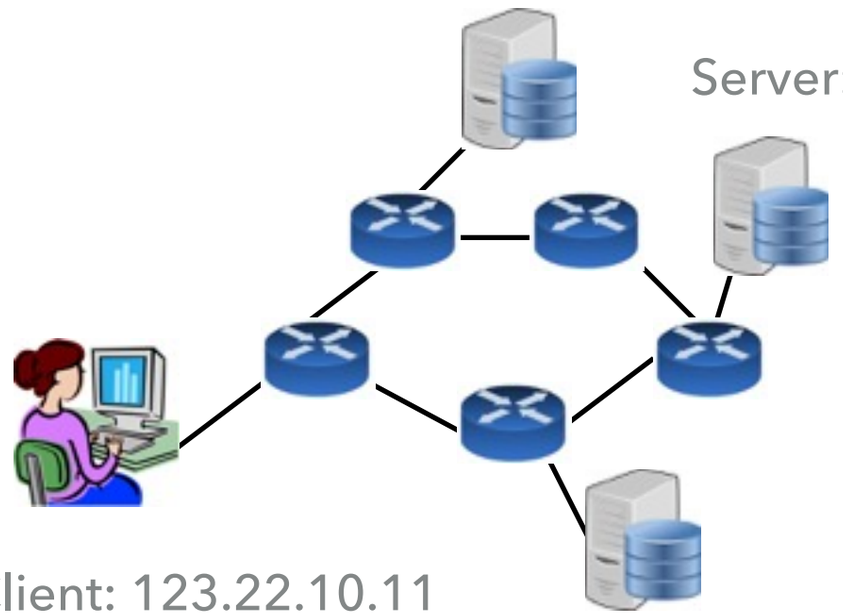
- Connection requires connectivity to centralised infrastructure
- 50%+ of population has no infrastructure[1]
- Other issues: Privacy, Delay, Energy consumption, etc.

[1] kc claffy, *"A Brief History of Future Internet: Named Data Networking Architecture", USENIX LISA conference*

Information Centric Network

Original's Internet

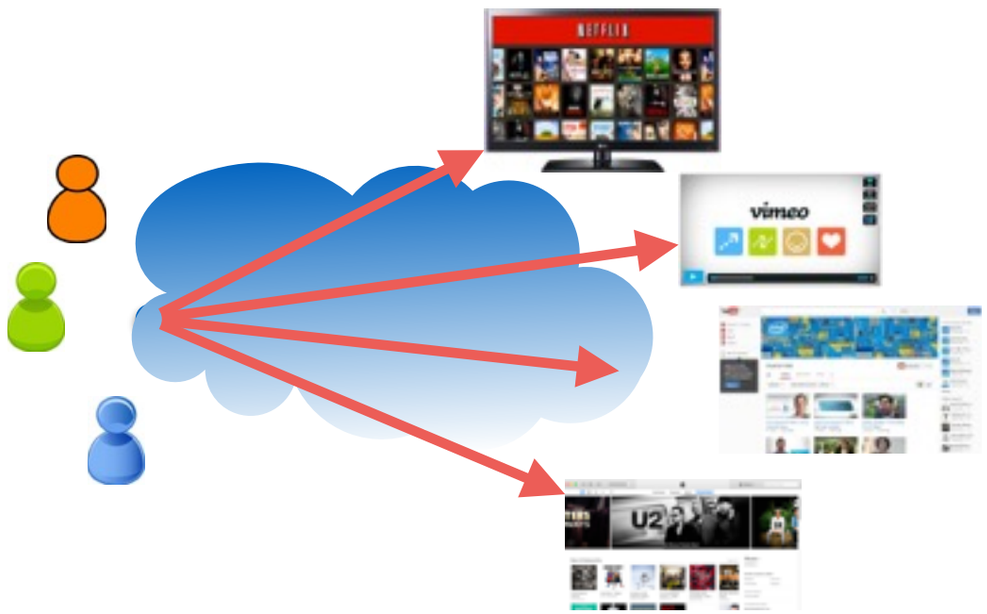
Focus on host-centric



- Connection is established based on IP
- Fix point between source and destination
- Client – Server
- Less mobility

Information Centric Network

Focus on content-centric



- Consumer driven – subscribe/get content of interest.
- Communication is initiated by named content not IP address of content' host (support location transparency)
- Provide in-network caching so that content is distributed in a scalable.
- Support security trust model, each data chunk get signed

ICN Projects

NAMED DATA NETWORKING

http://www.named-data.net/

PURSUIT

http://www.fp7-pursuit.eu/

http://www.anr-connect.org/

COMET

http://www.comet-project.org/

nvergence

http://www.ict-convergence.eu/

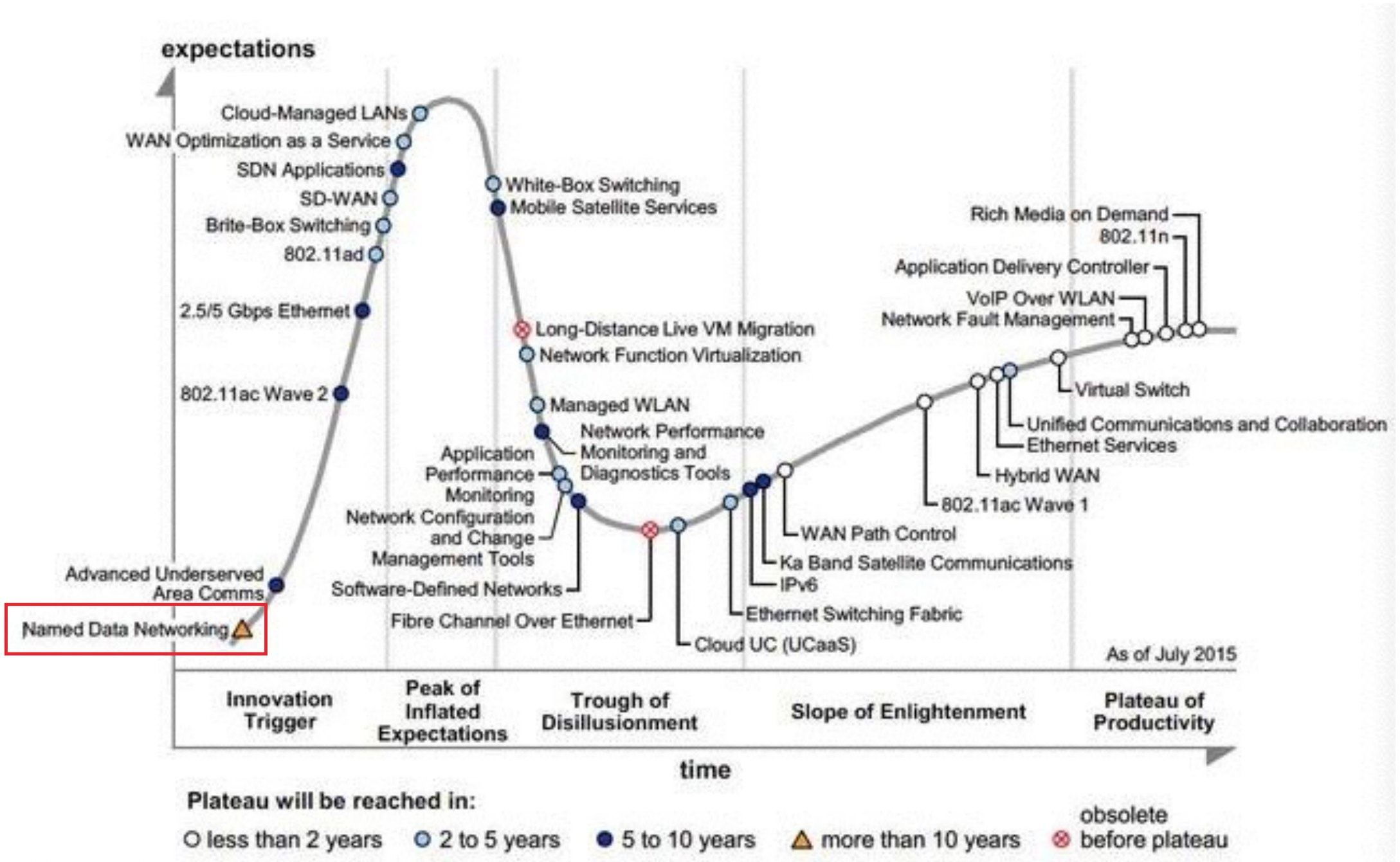
SAIL

http://www.sail-project.eu/

IRTF ICNRG

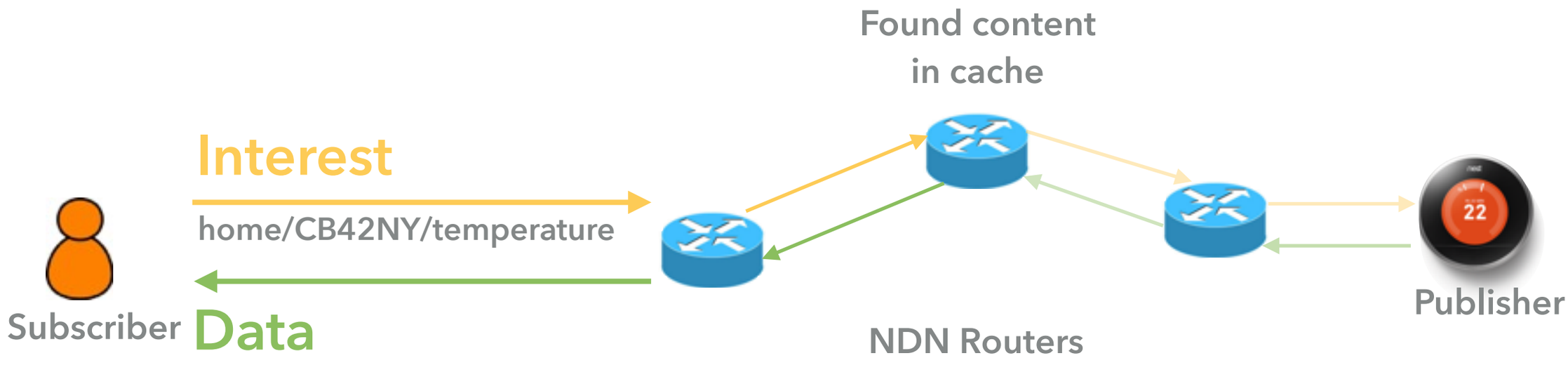
https://irtf.org/icnrg

Gartner: Technology Trends for 2016



Source: Gartner (July 2015)

Named Data Networking (NDN)

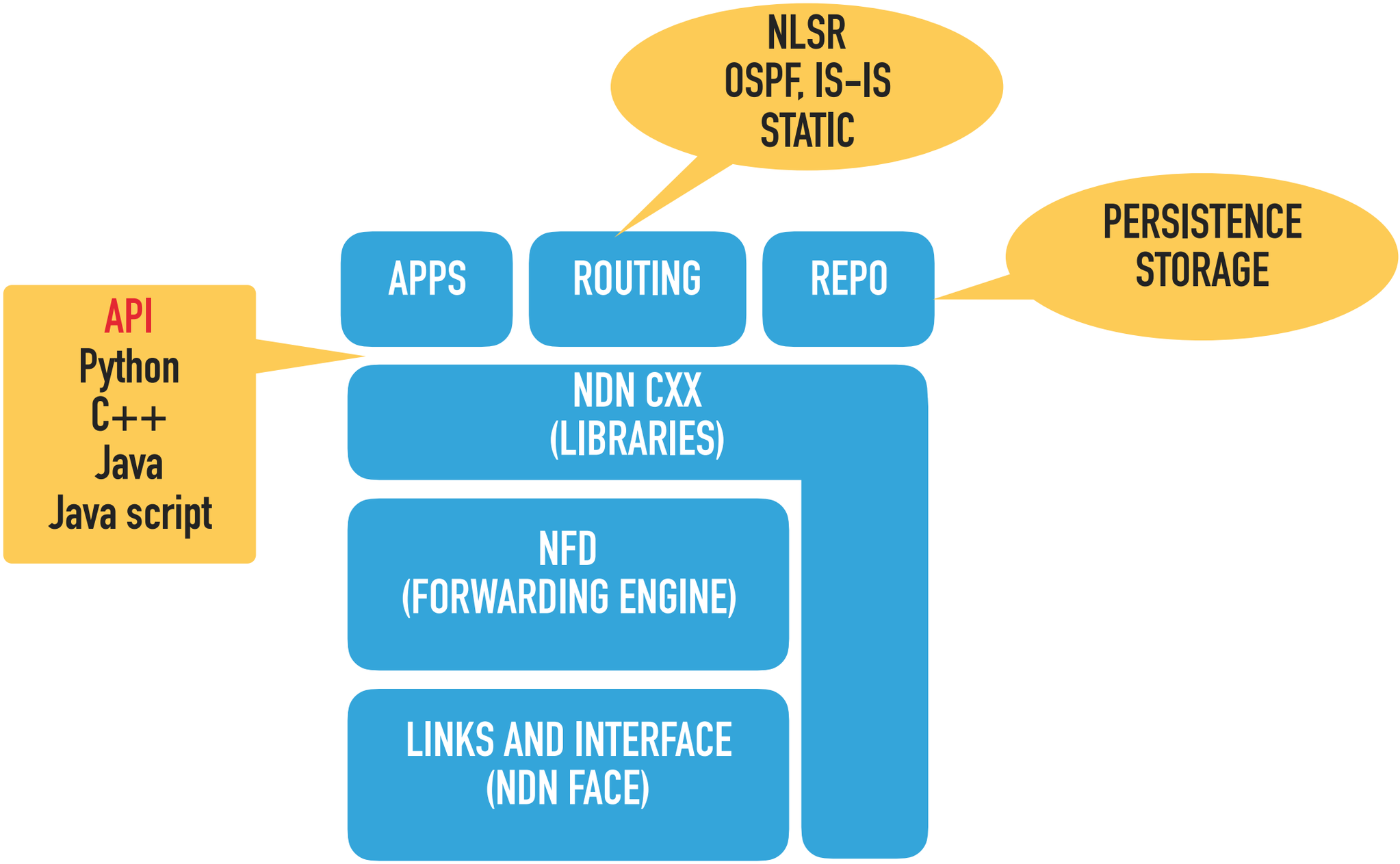


NDN has only two packet types (very simple):

- Request desired content by name (subscribe)

- Publishers bind names to data and publish to the network
- Delivery from the cached node or origin publisher

NDN Nuts and Bolts



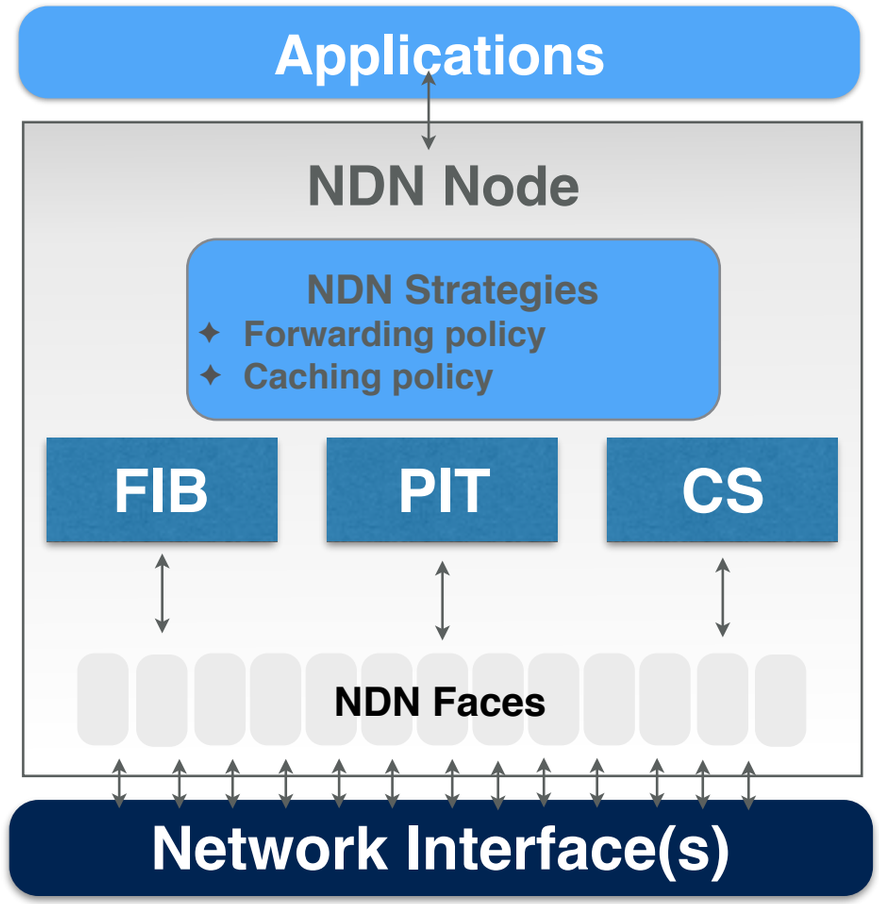
Named Data Networking (NDN)

FIB (Forwarding Information Base)

maps information names to the output interfaces (NDN faces) to forward Interest messages towards appropriate data source.

PIT (Pending Interest Table)

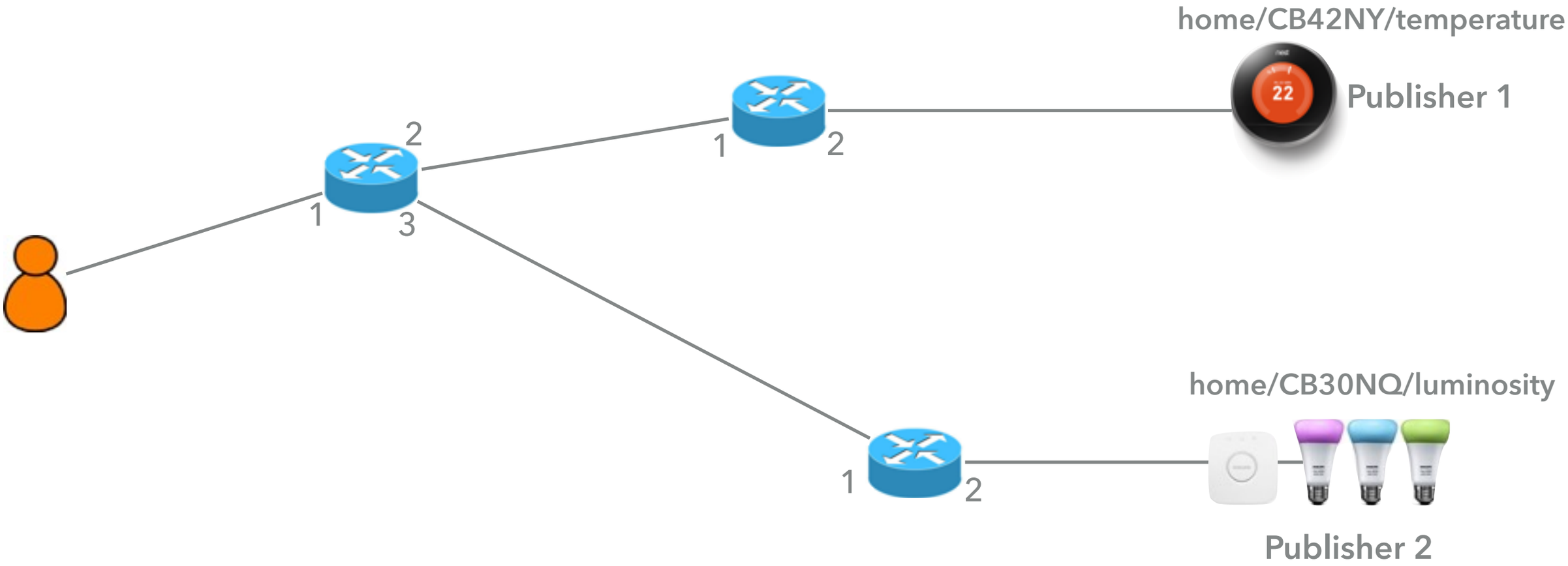
keeps track the incoming Interest messages, enabling the aggregation of request, so that returned Data message can be sent downstream to multiple request users.



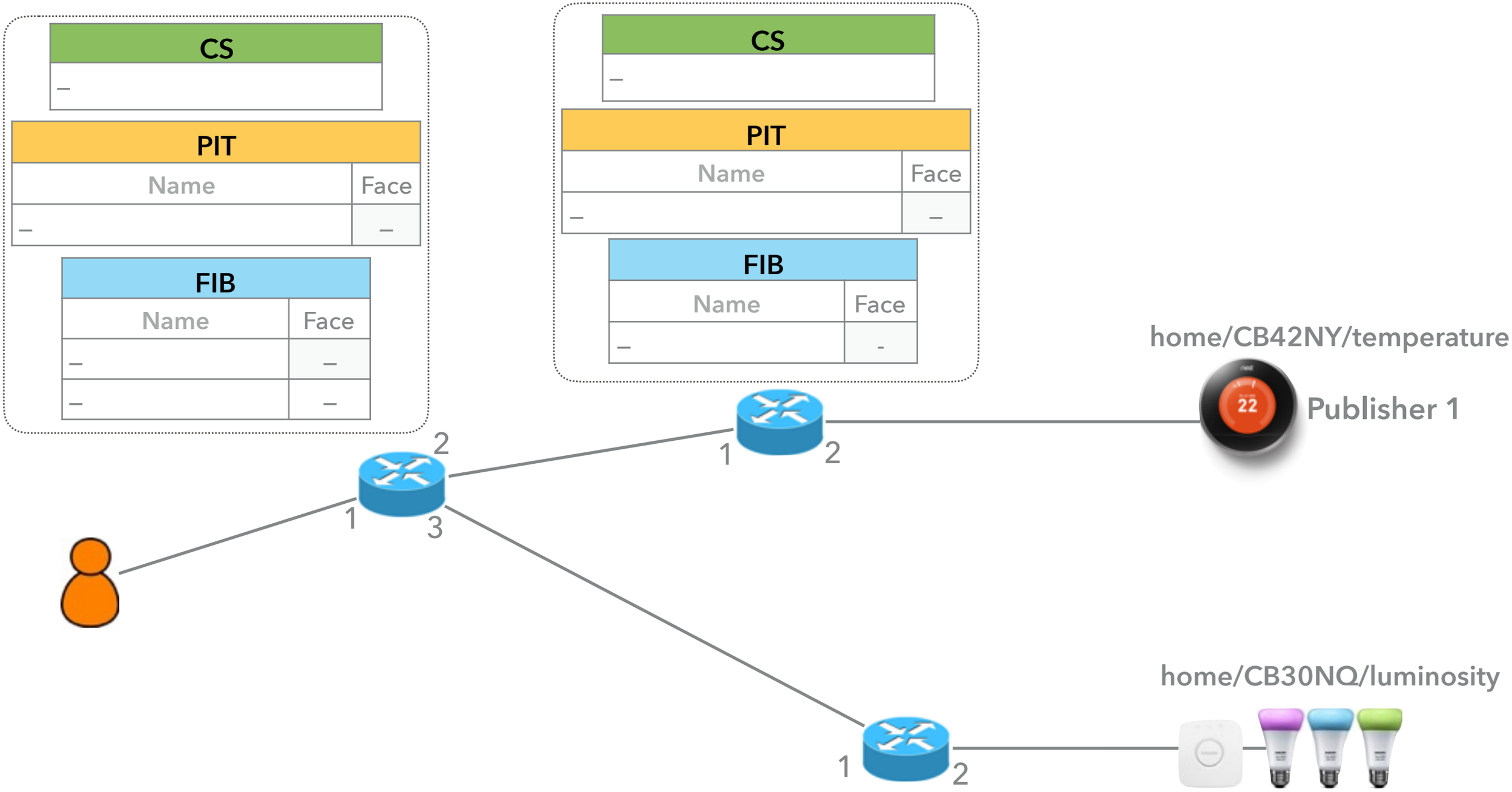
CS (Content Store)

serves as a local storage to cache NDN packet that has passed through the NDN node along the *"reverse path forwarding"*
Caching policy: LRU, LFU, FIFO, etc.

NDN – Publish and Subscribe model



NDN – Publish and Subscribe model



NDN – Publish and Subscribe model

Publish name prefix

CS
–

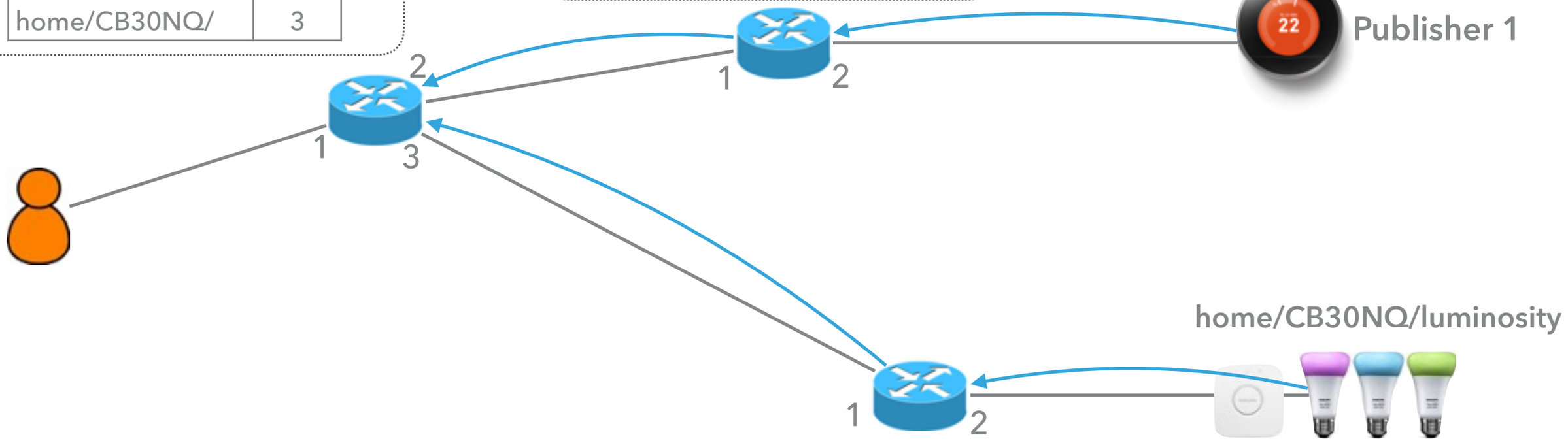
PIT	
Name	Face
–	–

FIB	
Name	Face
home/CB42NY/	2
home/CB30NQ/	3

CS
–

PIT	
Name	Face
–	–

FIB	
Name	Face
home/CB42NY/	2



FIB	
Name	Face
home/CB30NQ/	2

PIT	
Name	Face
–	-

CS
Name
–

NDN – Publish and Subscribe model

Request Content

CS
–

PIT	
Name	Face
home/CB42NY/temperature	1

FIB	
Name	Face
home/CB42NY/	2
home/CB30NQ/	3

CS
–

PIT	
Name	Face
home/CB42NY/temperature	1

FIB	
Name	Face
home/CB42NY/	2

home/CB42NY/temperature

Publisher 1

Interest:
/home/CB42NY/temperature

home/CB30NQ/luminosity

Publisher 2

FIB	
Name	Face
home/CB30NQ/	2

PIT	
Name	Face
–	-

CS
Name
–

NDN – Publish and Subscribe model

Data Delivery "reverse path forwarding"

CS
home/CB42NY/temperature

PIT	
Name	Face
–	–

FIB	
Name	Face
home/CB42NY/	2
home/CB30NQ/	3

CS
home/CB42NY/temperature

PIT	
Name	Face
–	–

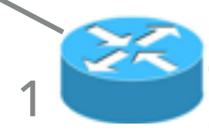
FIB	
Name	Face
home/CB42NY/	2

home/CB42NY/temperature

Data:
Home temperature = 10 c

Publisher 1

Interest:
/home/CB42NY/temperature



home/CB30NQ/luminosity

Publisher 2

FIB	
Name	Face
home/CB42NY/	2

PIT	
Name	Face
-	-

CS
Name
-

NDN – Publish and Subscribe model

Data Delivery "From cache"

CS
home/CB42NY/temperature

PIT	
Name	Face
–	–

FIB	
Name	Face
home/CB42NY/	2
home/CB30NQ/	3

CS
home/CB42NY/temperature

PIT	
Name	Face
–	–

FIB	
Name	Face
home/CB42NY/	2

home/CB42NY/temperature

Data:
Home temperature = 10 c

Publisher 1

Interest:
/home/CB42NY/temperature

home/CB30NQ/luminosity

Publisher 2

FIB	
Name	Face
home/CB42NY/	2

PIT	
Name	Face
-	-

CS
Name
-

NDN

LAB

Installation (Linux)

- ndn-cxx + NFD

Download Source Code

```
git clone https://github.com/named-data/ndn-cxx
git clone --recursive https://github.com/named-data/NFD
```

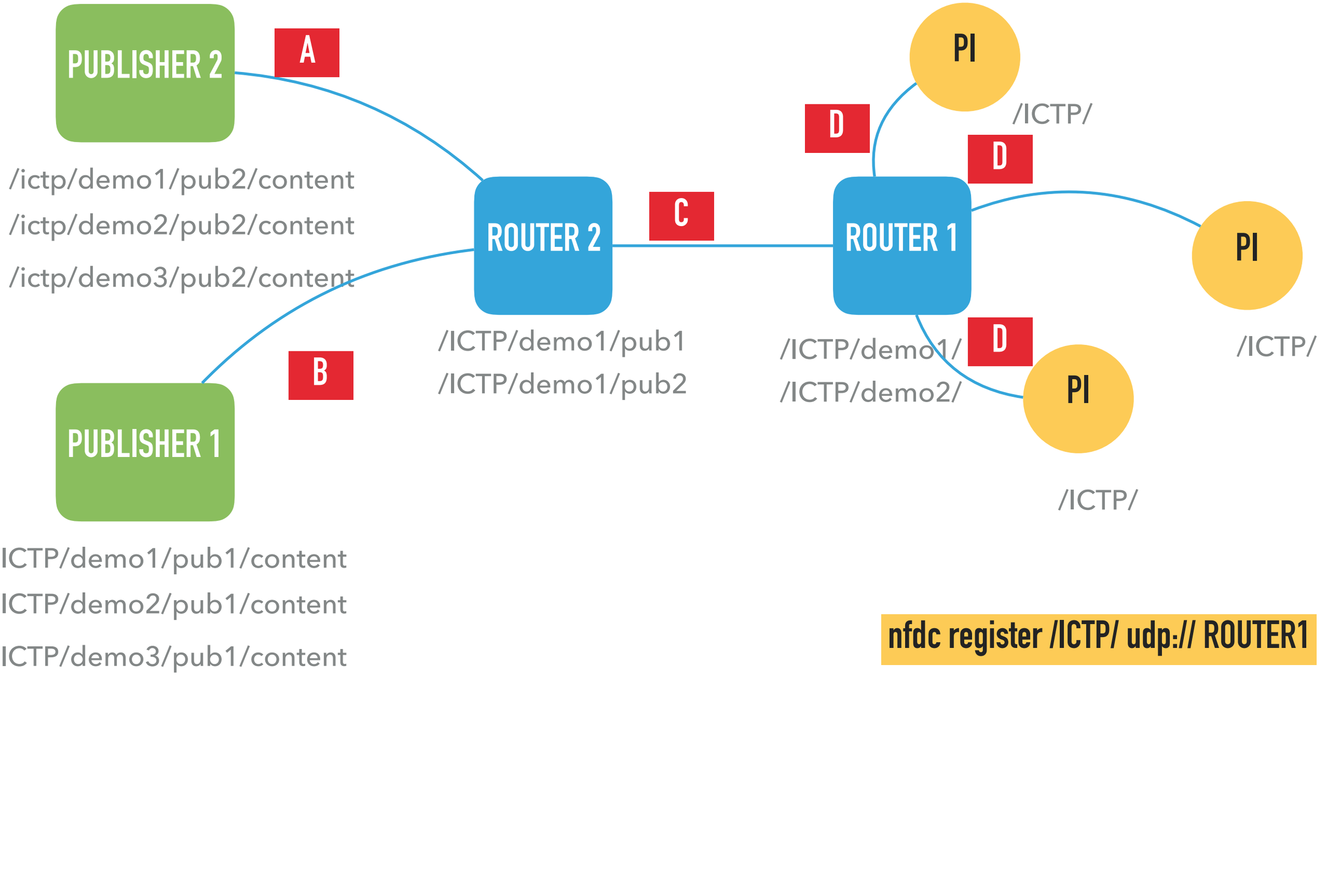
Prerequisites

```
sudo apt-get install build-essential
sudo apt-get install libsqlite3-dev libcrypto++-
dev

# For Ubuntu 12.04
sudo apt-get install libboost1.48-all-dev

# For all other Ubuntu versions
sudo apt-get install libboost-all-dev
```

Build

```
cd ndn-cxx
./waf configure
./waf
sudo ./waf install

cd..
cd NFD
./waf configure
./waf
sudo ./waf install
```

Configuration



Check the FIB

nfd-status

????

DISCUSSION

Test

- Interest

1: /ICTP/demo1/pub1/content

2: /ICTP/demo1/pub2/content

3: /ICTP/demo2/pub1/content

4: /ICTP/demo2/pub2/content

5: /ICTP/demo3/pub1/content

6: /ICTP/demo3/pub2/content

Question?

Can you receive the content?

Where the Interest message is stopped?

UPEKA DA SILVA, KANCHANA KANCHANASUT,
ASIAN INSTITUTE OF TECHNOLOGY (AIT)

Ndn Based Smart Home Lighting Solution

Smart Lighting System

Automated Light Control
Lights are programable

Improve users' Comfort
- User's preference
- User' activities (e.g., working, rest, party)

Energy Saving
- Daylight harvesting
- Occupancy Control

Challenges

High cost products (i.e., Philips Hue 180 pounds for the starter pack, 50 pound per extra light bulb)

Easy implementation and configuration for developers

NAMED DATA NETWORKING

PURSUIT

COMET

IRTF

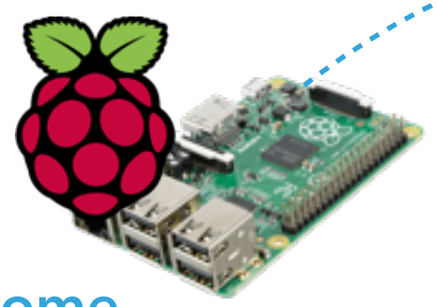
Is it possible to implement with ICN technologies?

System Architecture

Smart Home Controller

Home nodes (light, luminosity, occupancy)

Home Router

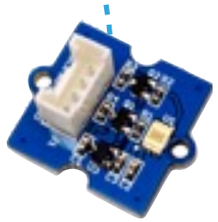


Smart Home Controller

Control the lights based on room occupancy and daylight

Light node

Consisted with a light, an actuator circuit to switch ON/OFF the light



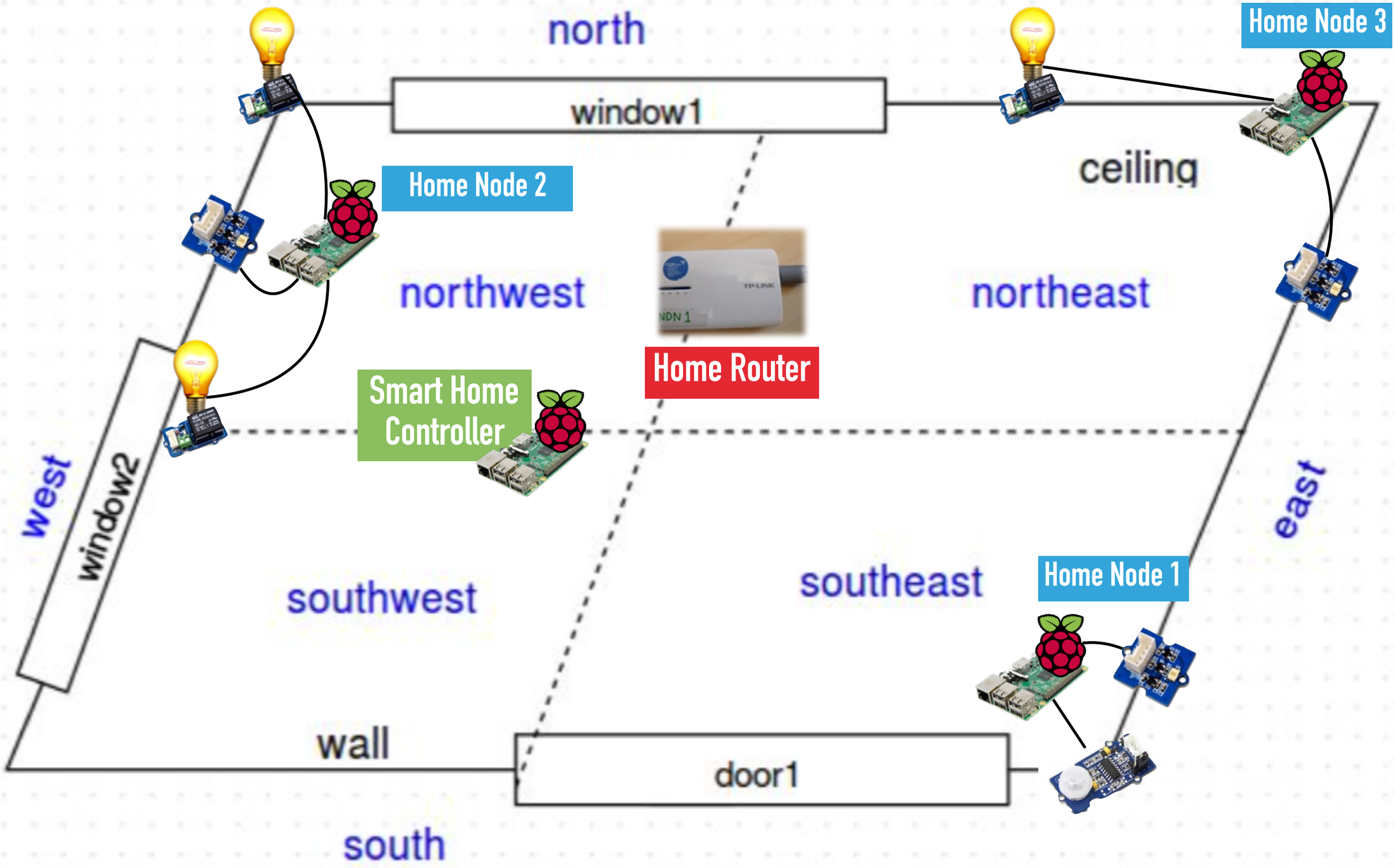
Luminosity Detector

Measure natural light intensity in the room in lux

Occupancy Detector

Tracks IN/OUT movements to/from the room

Smart Home Prototype



Named-based Routing

Smart Home Controller (SHC)

- Collects data from occupancy and luminosity detectors
- Controls lights (ON/OFF) based on occupancy and luminosity

Home Router (HR)

- Forward NDN packets

Home Node (HN)

- Publish luminosity and occupancy data

FIB	
Name	Face
home/light/	HR

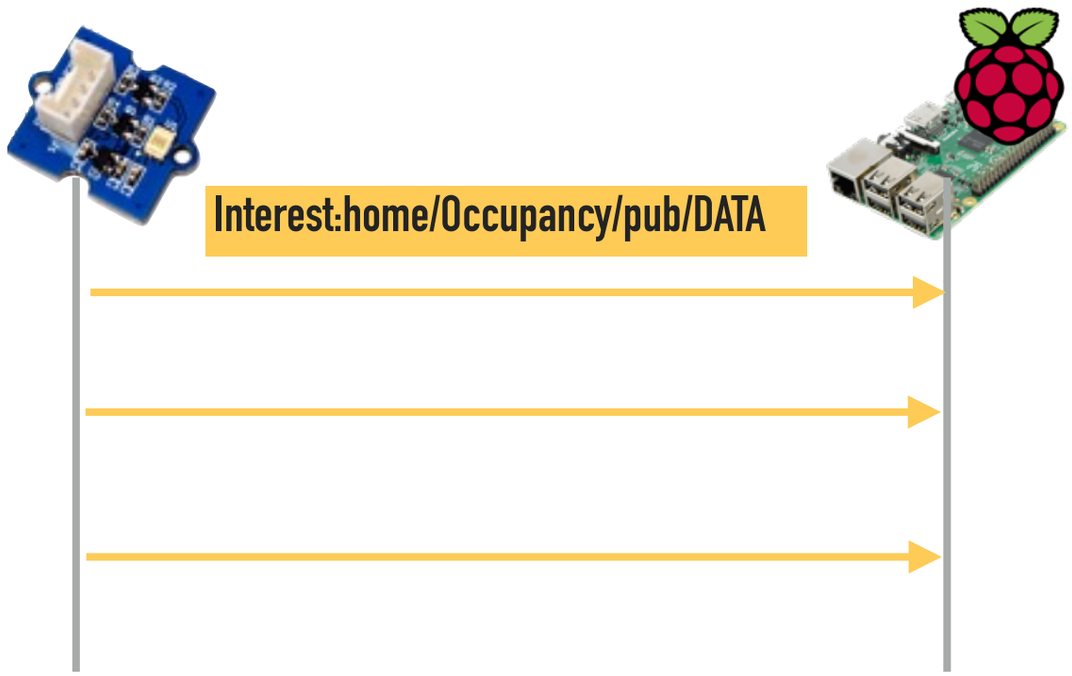
FIB	
Name	Face
home/light/1	HN1
home/light/2	HN2
home/light/3	HN3
home/luminosity/publish	SHC
home/occupancy/publish	SHC

FIB	
Name	Face
home/light/ID	LI
home/luminosity/ID	LM
home/occupancy/ID	OC

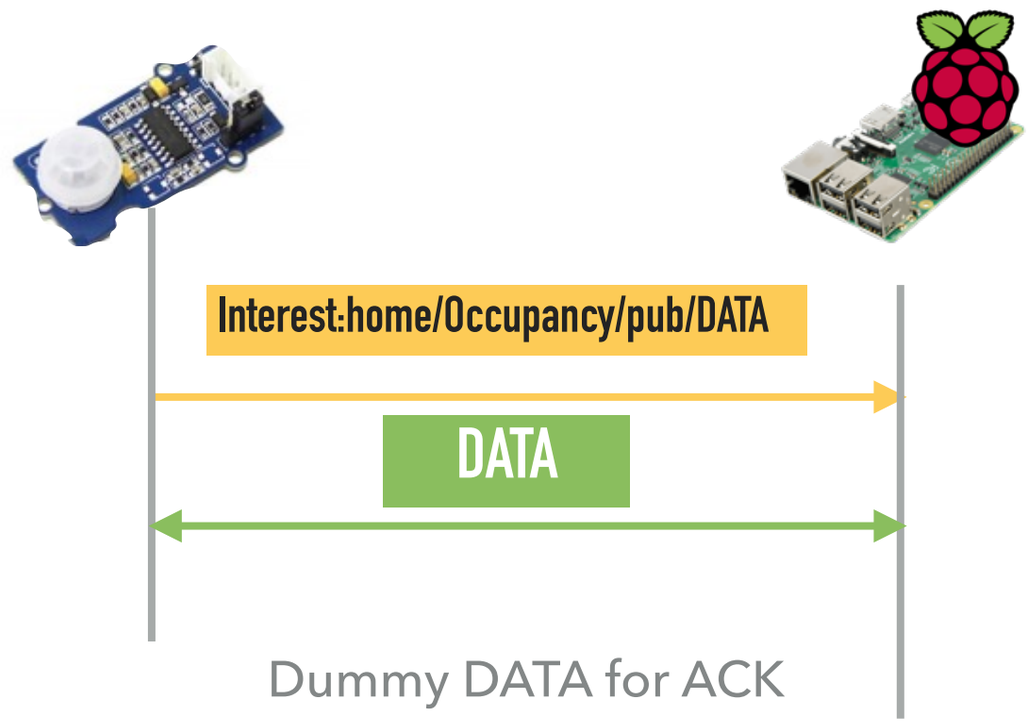
COMMUNICATION IS "PUSH BASE", BUT NDN IS DESIGNED AS A "PULL BASE"

How can we do Push in NDN ?

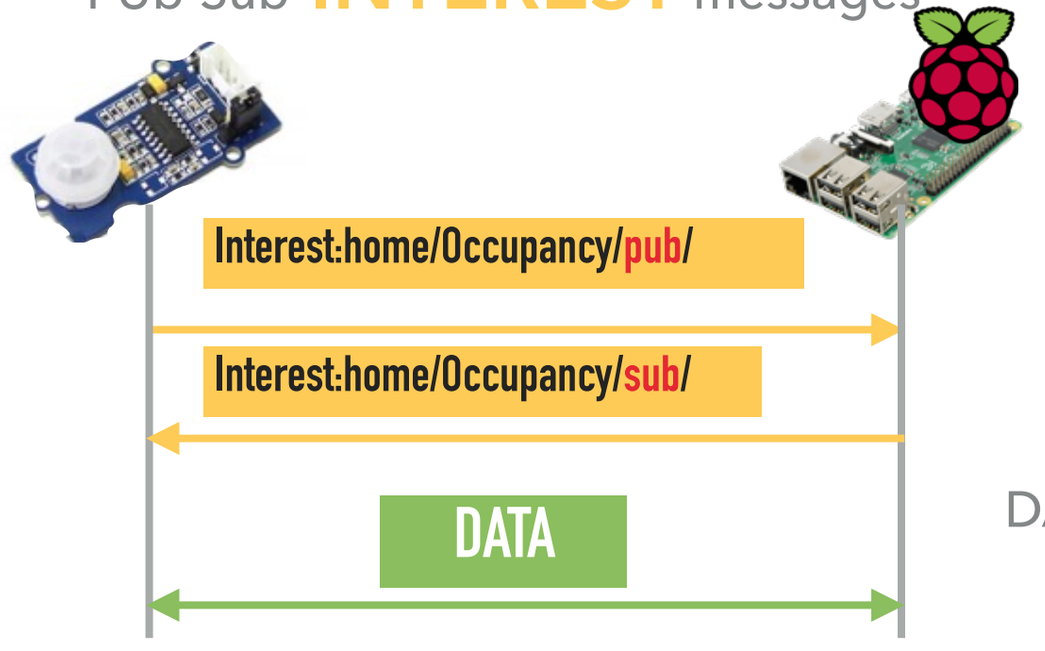
Integrate DATA into INTEREST message



with DUMMY DATA ACK



PUb-Sub INTEREST messages



DATA size is large

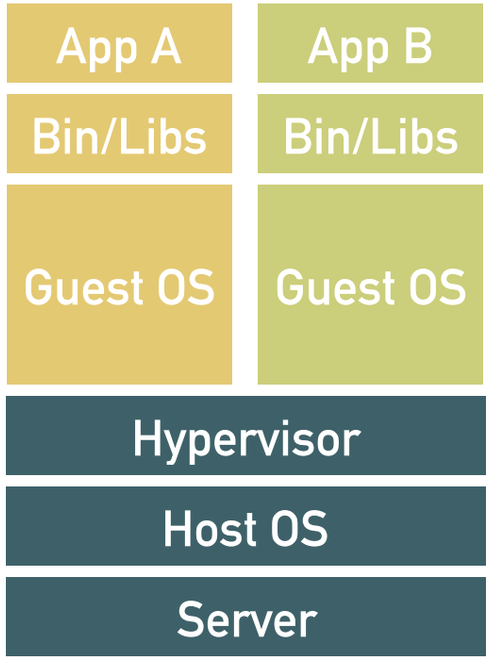
Discussion

- Real Implementation with NDN
- New paradigm of application development (Pub-Sub model
- Progress
  - Calibration, Performance Evaluation
- Large scale deployment
- Exhibition hall
- Smart village
- Efficient Content Delivery

Service Migration

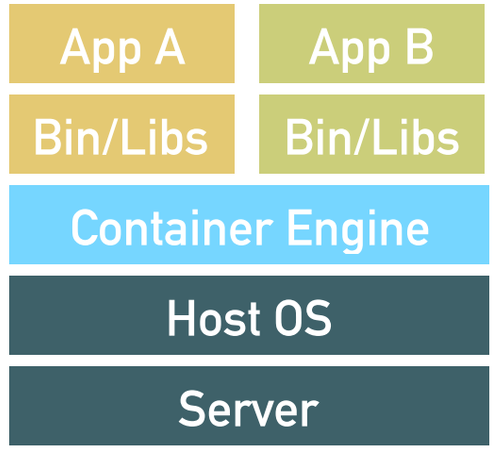
What's Service Migration ?

Virtualisation Technologies



VMs

- Guest OS for each VM
- Expensive middle box (multi cores server)
- VM's size can vary from 100 MB to 50GB[1]
- Migration needs high speed bandwidth link



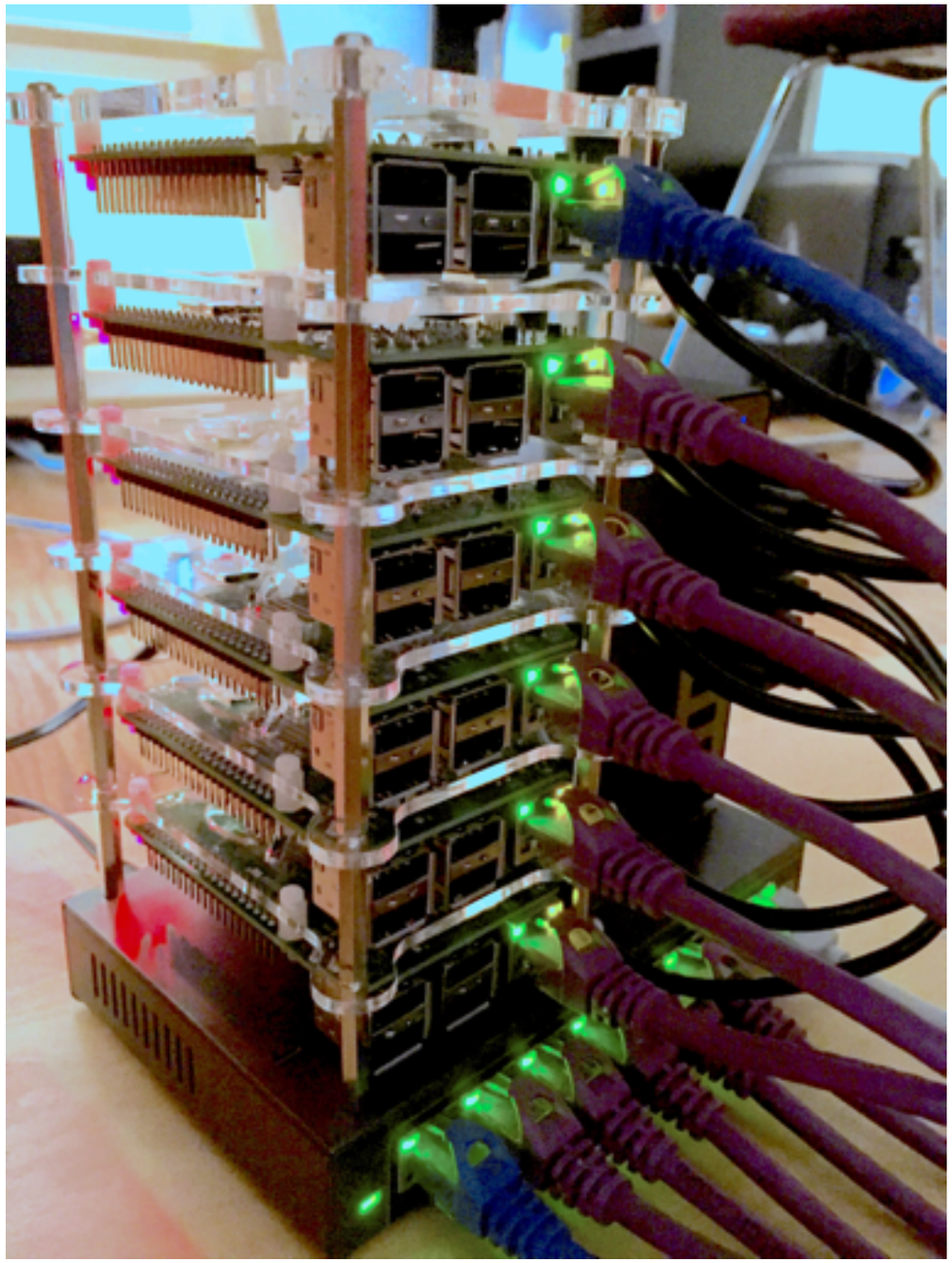
Containers

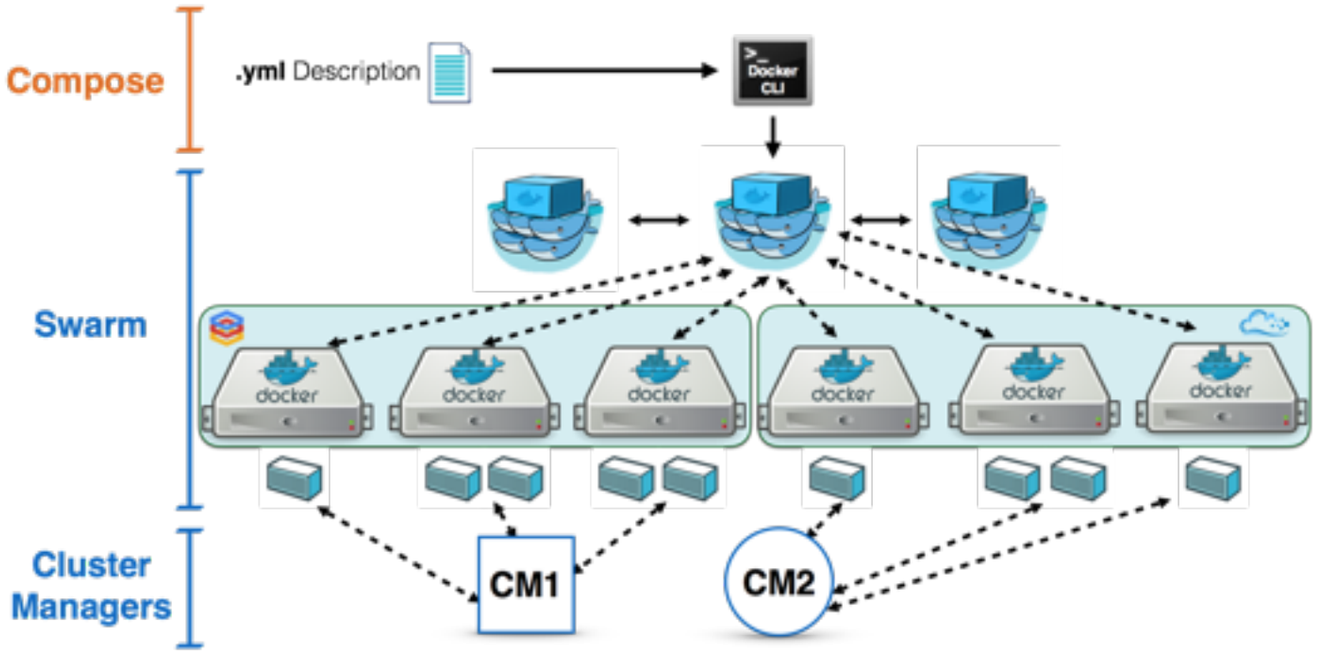
- Bins/Libs for each containers
- Low cost middle box (rasPi, ARM)
- Containers' size is very small (small web server ~2MB[2])
- Migration can be done through low speed link (image file is very small)

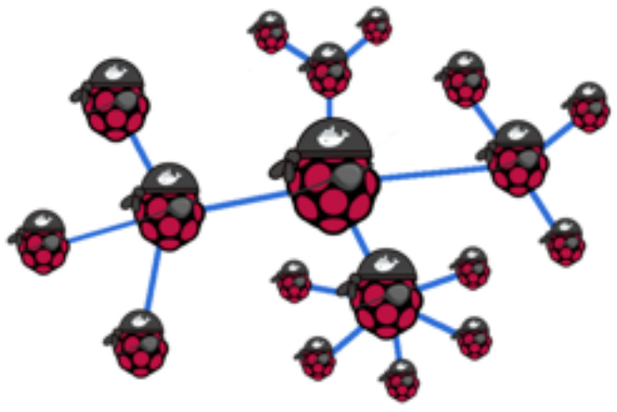
[1] Sijin He; Li Guo; Yike Guo; Chao Wu; Ghanem, M.; Rui Han, "Elastic Application Container: A Lightweight Approach for Cloud Resource Provisioning," in Advanced Information Networking and Applications (AINA), 2012 IEEE 26th International Conference on , vol., no., pp. 15-22, 26-29 March 2012

[2] https://github.com/shijuvar/golang-docker

Micro Services > Micro Datacenter







ARM

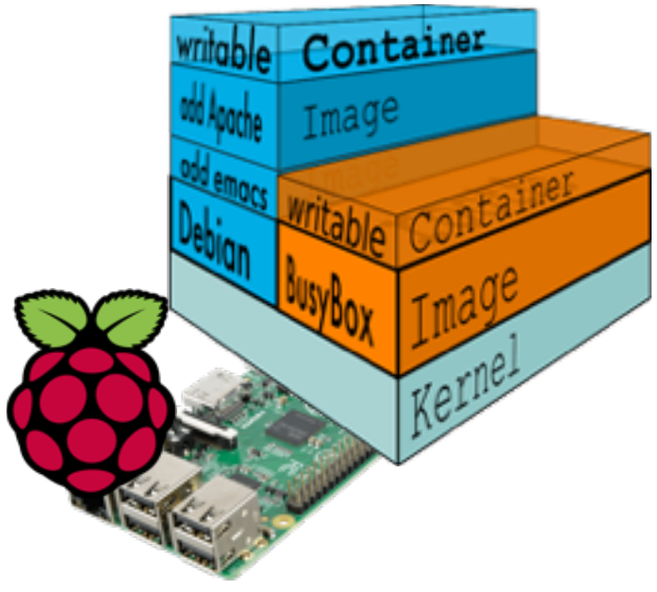
How service migration will benefit IoT ?

IoT requires a new kind of infrastructure

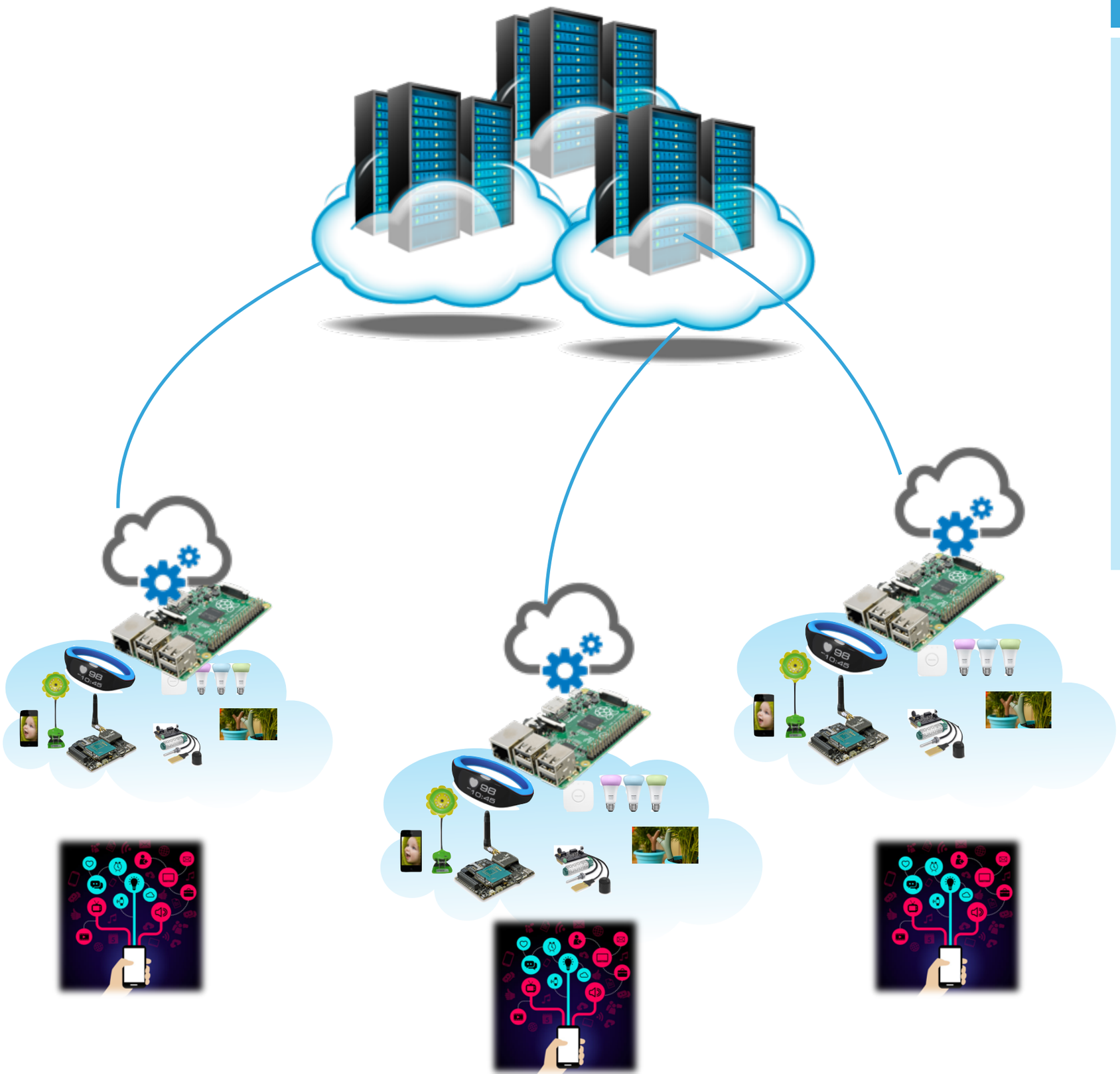
- The cloud by itself can't connect millions of things spread over the large areas.
- Hugh amount of traffic
- Connectivity between IoT devices and Cloud can be very poor (slow bandwidth, intermittent, delay, etc.).

Improve capabilities of IoT devices

- IoT devices can do more rather than sending data.
- With the lightweight visualisation, IoT devices can do some complex commutation.



How service migration will benefit IoT ?



Decentralised Cloud

- Reduce bandwidth consumption
- Services can be provided right at the edge
- Improve QoS (e.g., latency, reponse time)
- Secure IoT devices and protect personal data

How service migration will benefit IoT ?

Central Cloud

Home nodes/Fog nodes (Cisco), Relay nodes, Service nodes

Update new services, policies, algorithms

Data Reduction (e.g., transcoding, compression)

Upload to the Cloud when there is good connectivity (e.g., DTN)

Large volume of Data

High Velocity of Data Generation

Wide Variety of Things

Access Data from the edge

Data visualisation

Service Locality

Services over the air

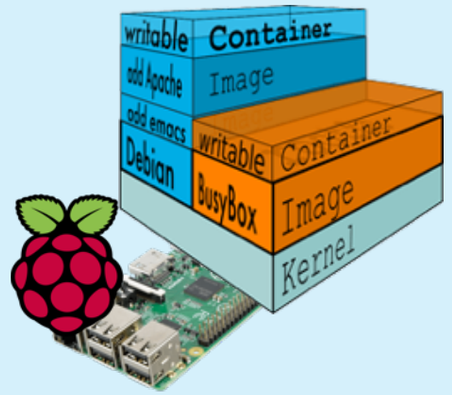
DRONES CAN PROVIDE SERVICES OVER THE AIR, NOT JUST TAKING PHOTOS

EMERGENCY SITUATIONS

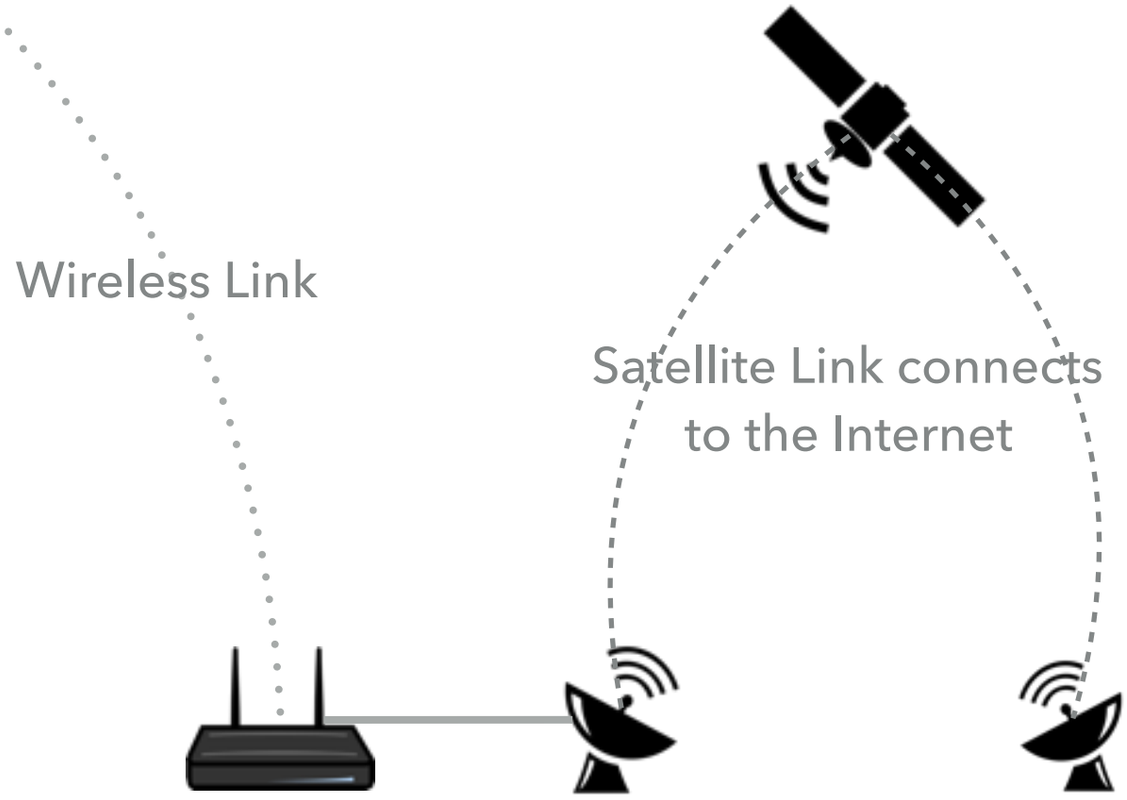
MIGRANT CRISIS

Not only connectivity, but people also need services.

Lightweight and self contain service:
Unikernel, Docker, IncludeOS



Build: Ship :
Run on small devices

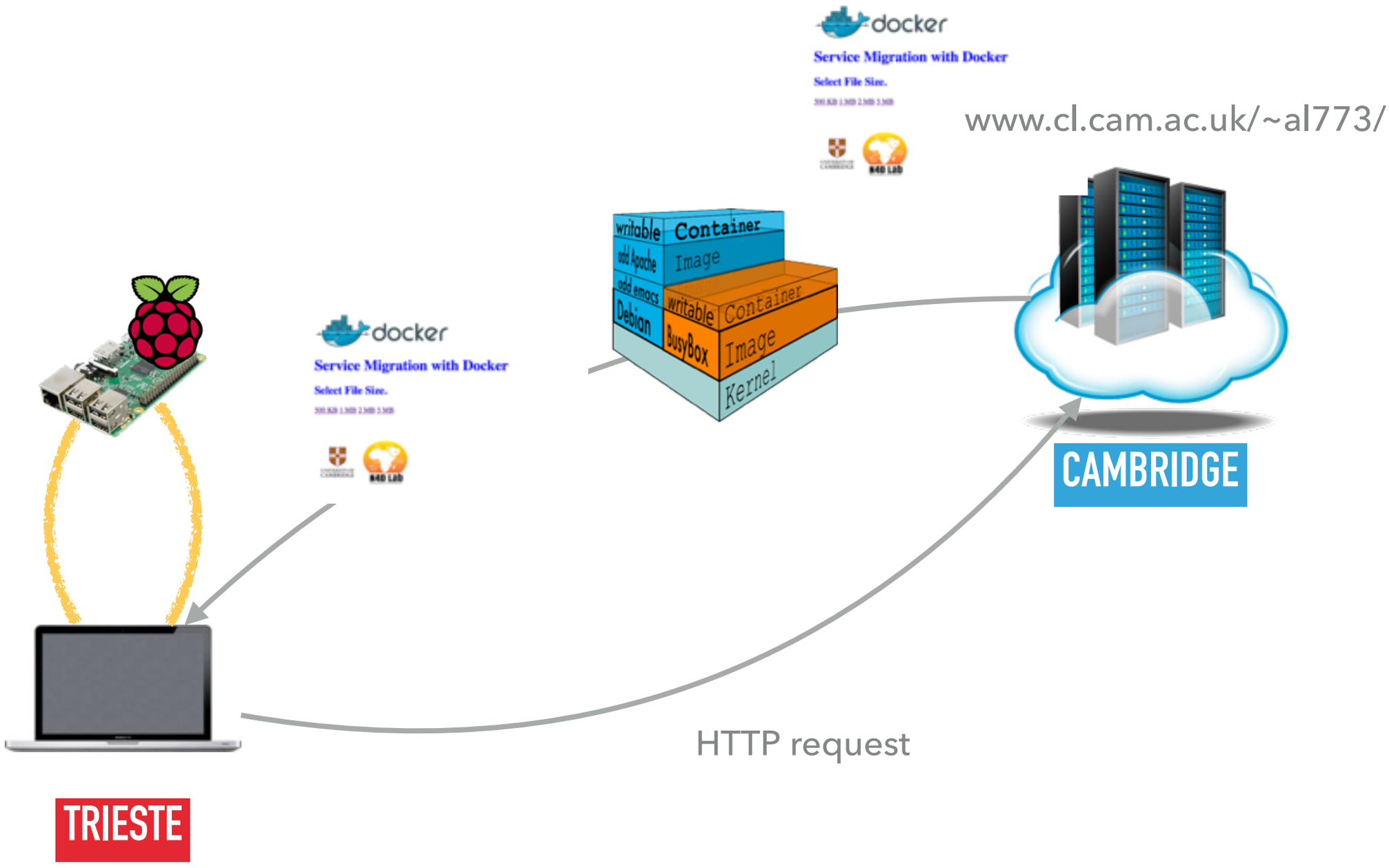


BASE CAMP COMMAND CENTER

TUTORIAL

Service Migration with Docker

DEMO



COMPARE RESPONSE TIME