N4D Lab
Networking for Development

Workshop on New Frontiers in Internet of Things
ICTP, Trieste - Italy

ICN and IoT

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RIFE

ICTP The Abdus Salam International Centre for Theoretical Physics

Agenda

- A general Information Centric Networking architecture considering IoT
- Information Centric Networking over IoT: a use-case with There equipment
- Increasing the Scale
- Standardisation effort (IETF)

A general Information Centric Networking architecture considering IoT

[Song et al., 2013]

Design Tenets

- Weak networked devices with restricted capacity
- Super Routers designed with core network capacity not appropriate for edge networks
- Proposing an architecture for **task mapping**: mapping the overcapacity tasks (store/pub/sub,pull,retrieve)
- Propose different strategies for task mapping
- Camera use-case

Context

- Four layers for IoT: object sensing/controlling, data communication, information integration, app and service layer.
- CCN as an architectural base for data communication.
  - SR with large content stores.
- Millions of ND connected with restricted storage, computing and communication.
  - **ND as consumer**: difficult to retrieve content or services on the edges
  - **ND as a producer**: not having large enough storage to publish the produced content.

Some preliminary of Work

- Named data support in V2V communication (not considering storage and computing capabilities)
- Efficient ad-hoc networking. Content within the ad-hoc network, thus content retrieval from the edge (non-existent)
- Multicast for mobility (Motioncast)

CCN for resource constrained ND

- ND are restrained enough to interact directly with CCN basic model.
- Proposed memory-in-core-networks, having the following messages
  - IM from ND
  - IM from SR (the nearest optimal) after decoding what the IM/ND transport
  - Data to SR
  - Data (ACK) to the ND

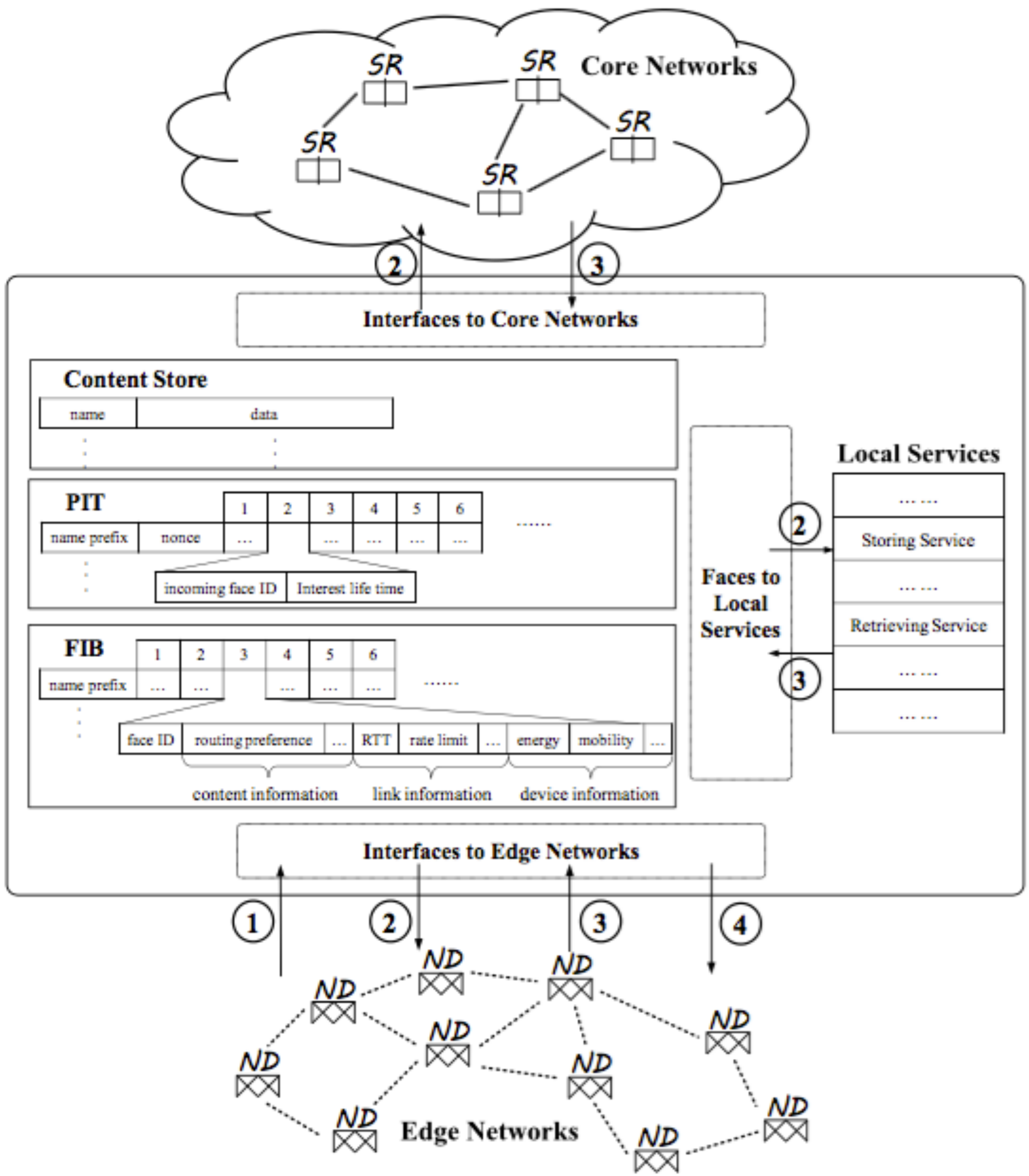


Fig. 1. Content-Centric Internetworking scheme for resource-constrained

Features

- SR-dependent (there is no separation in original CCN)
- ND-driven: CCN is a consumer driven architecture, IM being sent from consumers. In this architecture IM are sent for both consuming and producing.
- 2 Nested IM/data
- Memory in core network.

Case 1: ND as producer

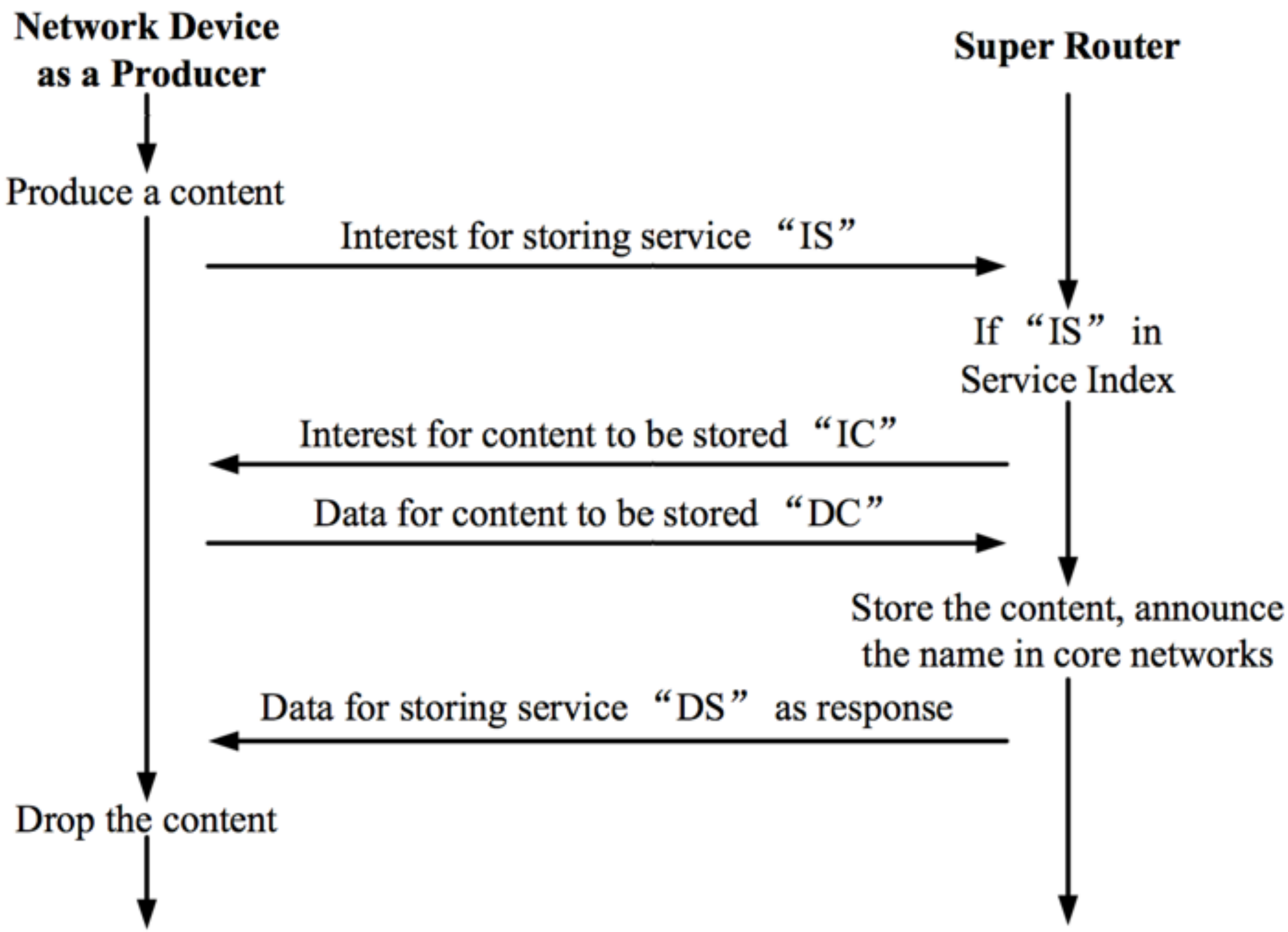


Fig. 2. Strategy for resource-constrained ND as a producer

Case 2: ND as consumer

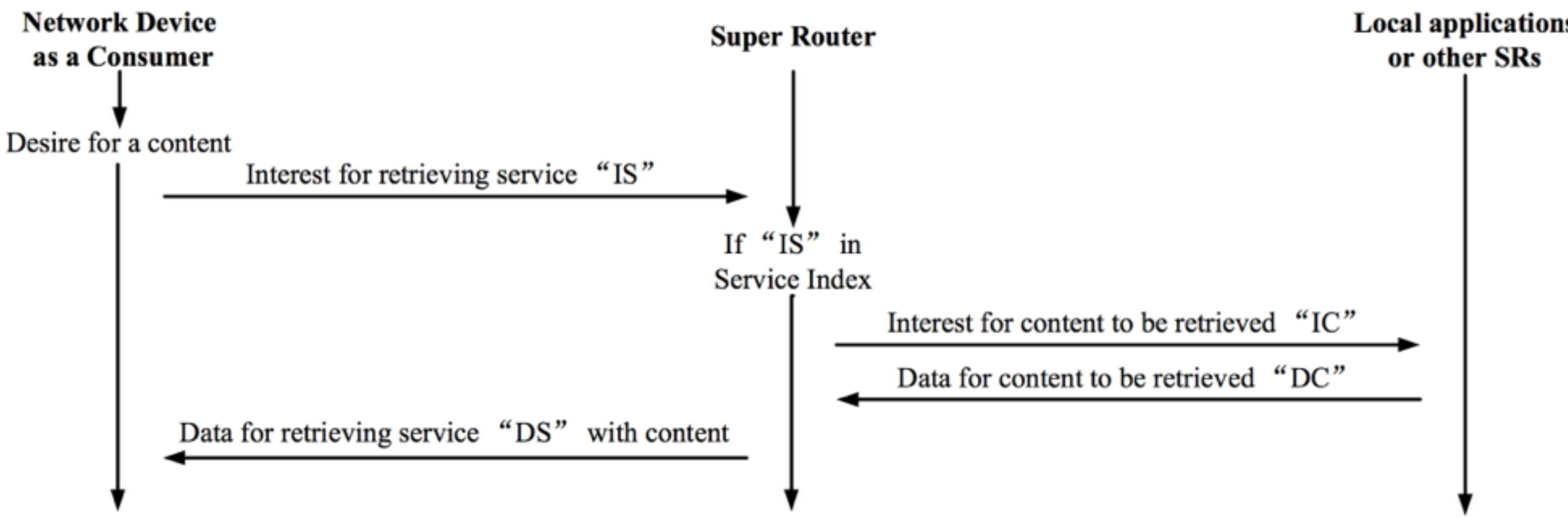


Fig. 3. Strategy for resource-constrained ND as a consumer

Use Case

service/storing-publishing/video/traffic/{Tucheng Road, Xueyuan Road}/{1334601700,1334604800}

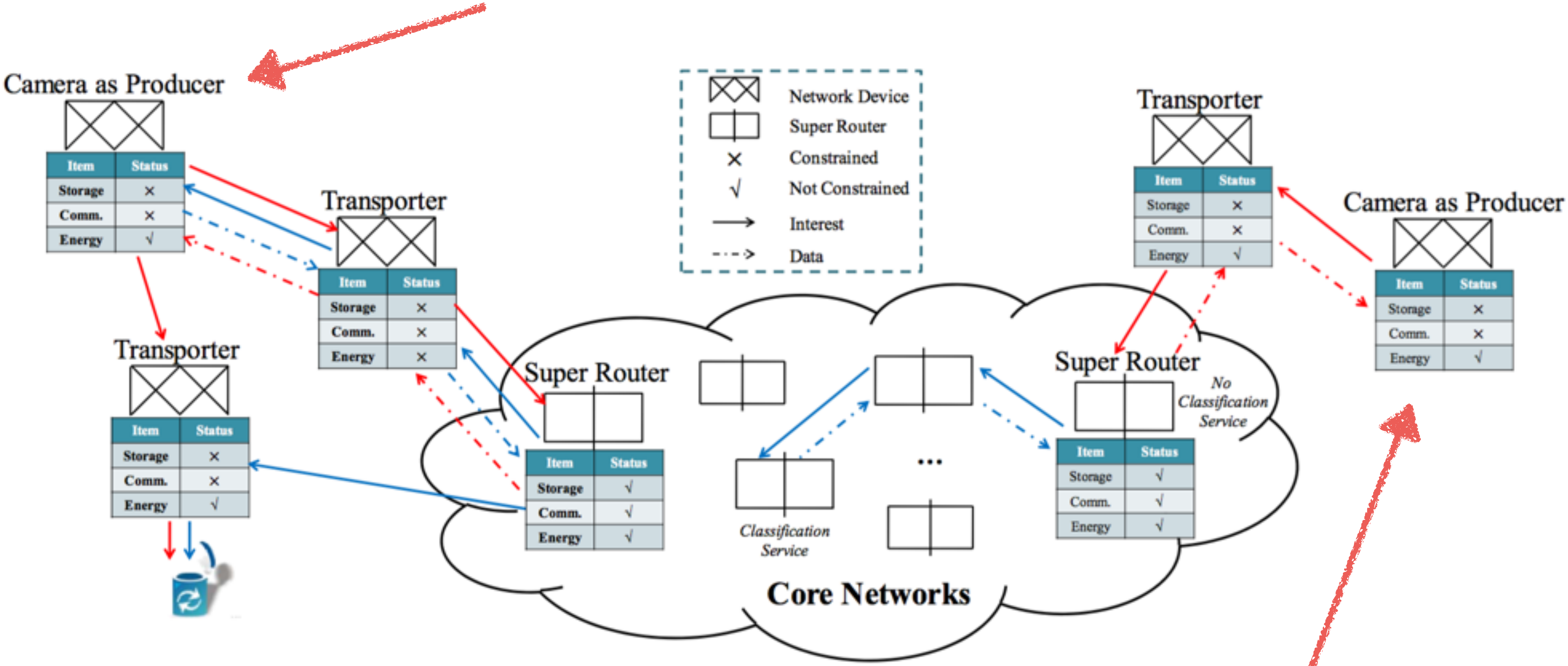


Fig. 4. Cases for content-centric internetworking scheme based on task mapping

/service/service-retrieving/target- classification/surveillance-HOG/FHOG(HOG features)

Information Centric Networking over IoT: a use-case with There equipment

[Waltari, 2013]

Content Centric Networking in IoT

- IoT seen as a large scale sensing eco-system (all possible devices contribute)
  - Information not being produced by humans
- The internet was not designed for data sharing use-case
- Network services for IoT through CCN
- Two main challenges: connectivity & communication

Why CCN / IoT

- Most current communication protocols rely on point to point connections (vulnerable to link breakdowns)
- Relying on data storages (single point of failures)
- High diversity of IoT protocols

What problems to address

- Connectivity
  - Naming of every point of communication (universally addressed)
- Communication
  - Competing protocols
  - Gateways and protocols to interconnect competing protocols
  - Central data storages
  - Opaque network caching

Goals

- No point to point connections
  - ICN network definition
- Transparent in-network caching
  - ICN network infrastructure
- In-network storage of sensor data
  - ICN in-network support for alternative storage
- Reduced workload for sensor devices
  - Caching alleviates sensor’s load
- High level abstraction layer to access sensor devices
  - Naming in ICN

Architecture

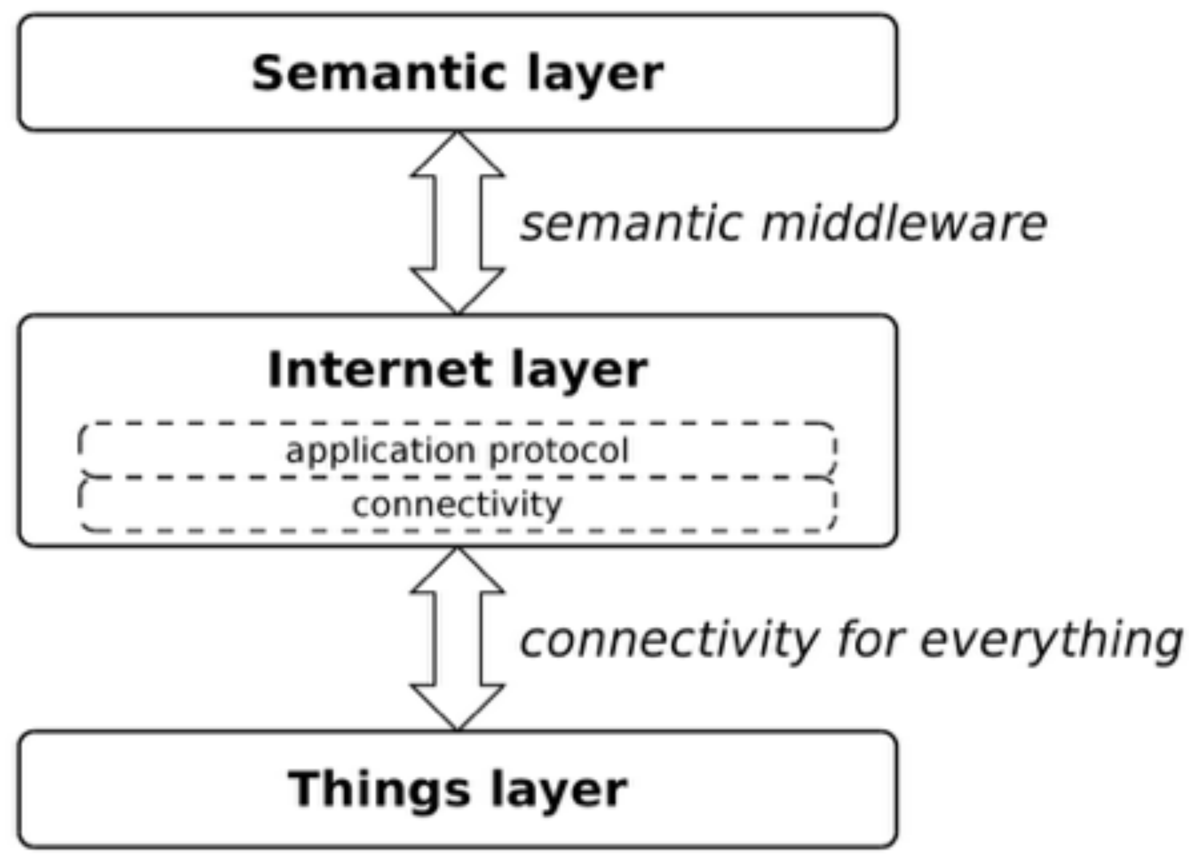


Figure 2: Internet of Things paradigm illustrated as a stack.

accessing content

- client accessing ccnx://foobar, will obtain ccnx://foobar/index.html

ccnx://foobar/login.html

ccnx://foobar/video

CCN architecture

- IM: interest messages, CO: content objects, CR: content routers
- Forwarding Information Base (FIB)
  - forwarding info for routing IM
- Pending Interest Table (PIT)
  - traces left on each CR to find way back when IM has been satisfied
- Content Store (CS)
  - cache within CR that stores CO
- Caching is done in all CCN enabled routers

Data Retrieval

- CCN is pull-data driven (hierarchical name plus some description)
- IM is sent by a client and either obtains a response or Interest lifetime expires.
- Data returns in the way back of the IM marked path and leave copies of the CO

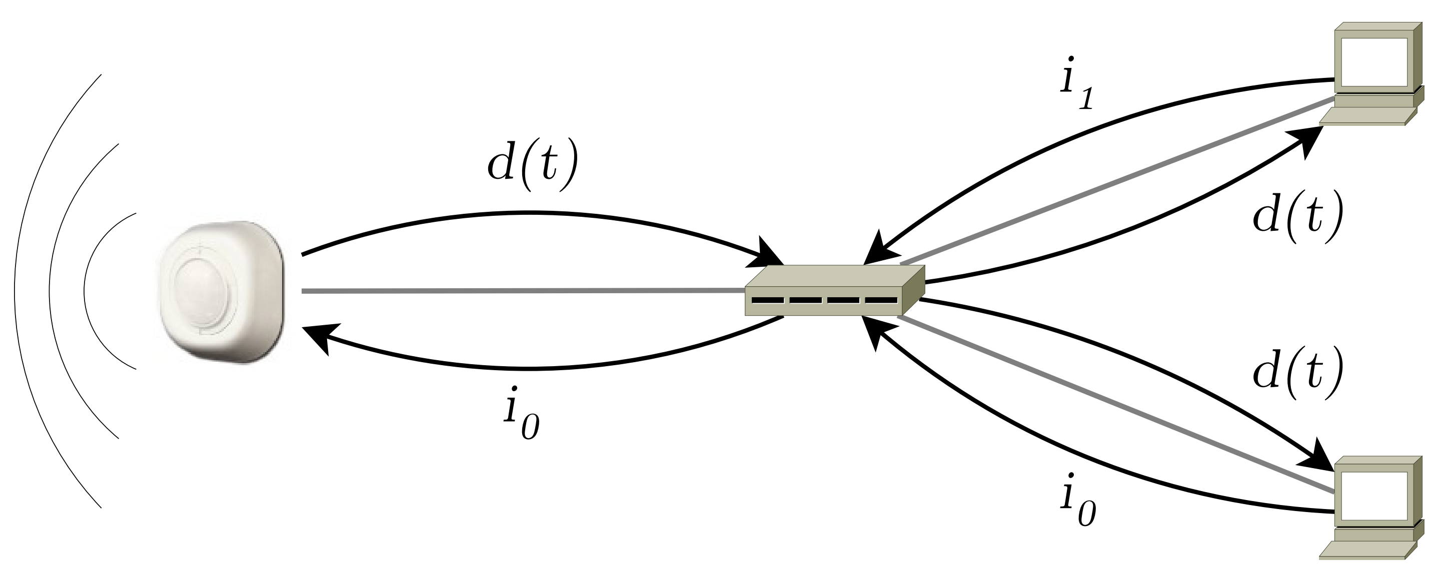


Figure 5: Two clients are interested in data object $d(t)$. Intermediate CCN router provides a cached copy of $d(t)$ in exchange to the second interest i_1.

One sensor multiple consumers

- n clients scattered around the network, data d generated at time t (d(t)) from the sensor
- each of the n clients generated IM matching d(t)
- one of n messages arrive first to the sensor, then:
  - the CR caches a copy of the Object which is sent back to other clients also waiting for it.

Stored Data Retrieval

- Since caches are volatile there has to be a permanent repository in a CCN (on a CR)
- Criteria has to be defined to store in permanent rep
- the Start Write command has to be issued from sensor to the Rep (asynchronously)
  - IM goes directly to the Rep therefore the sensor has control of the data pushing (and energy consumption)

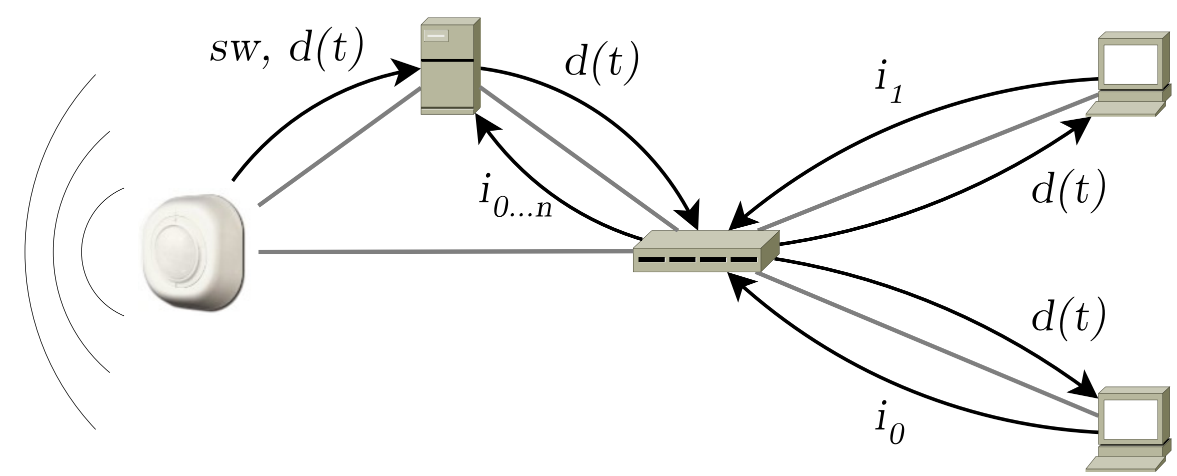


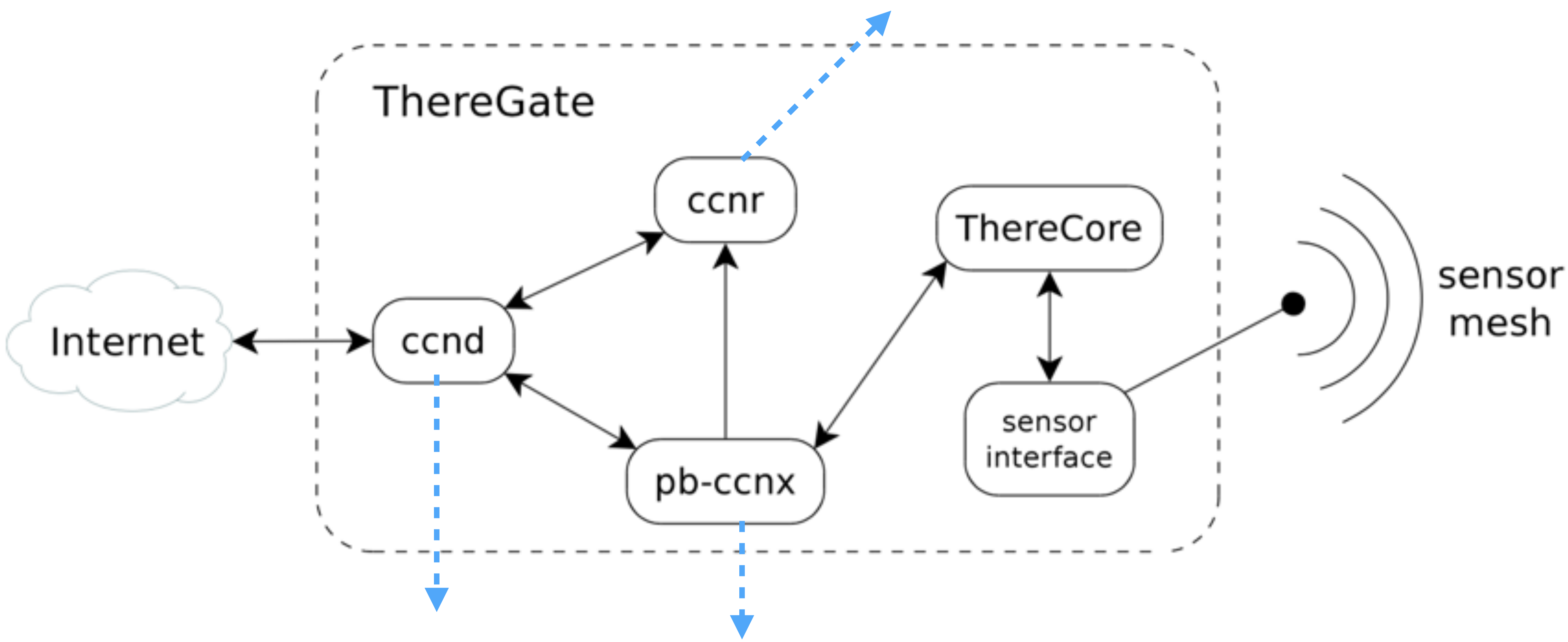
Figure 6: Sensor node pushes its data to a CCN repository. Data is available at the repository even if cached copies at the CCN router had expired.

Actuators

- a prefix per action should be appended to the name, ex. ccnx://alice/light/on
- IM on "light on" is routed to the actuator, which sends in turn an ACK saying "light is on".
- Some contradictions with ICN
  - Location matters
  - No benefits from in-network cache, actually caching tends to be harmful

Implementation PoC

repository



PIT, FIB

Interface with sensors (handlers):
* registers serving sensors
*

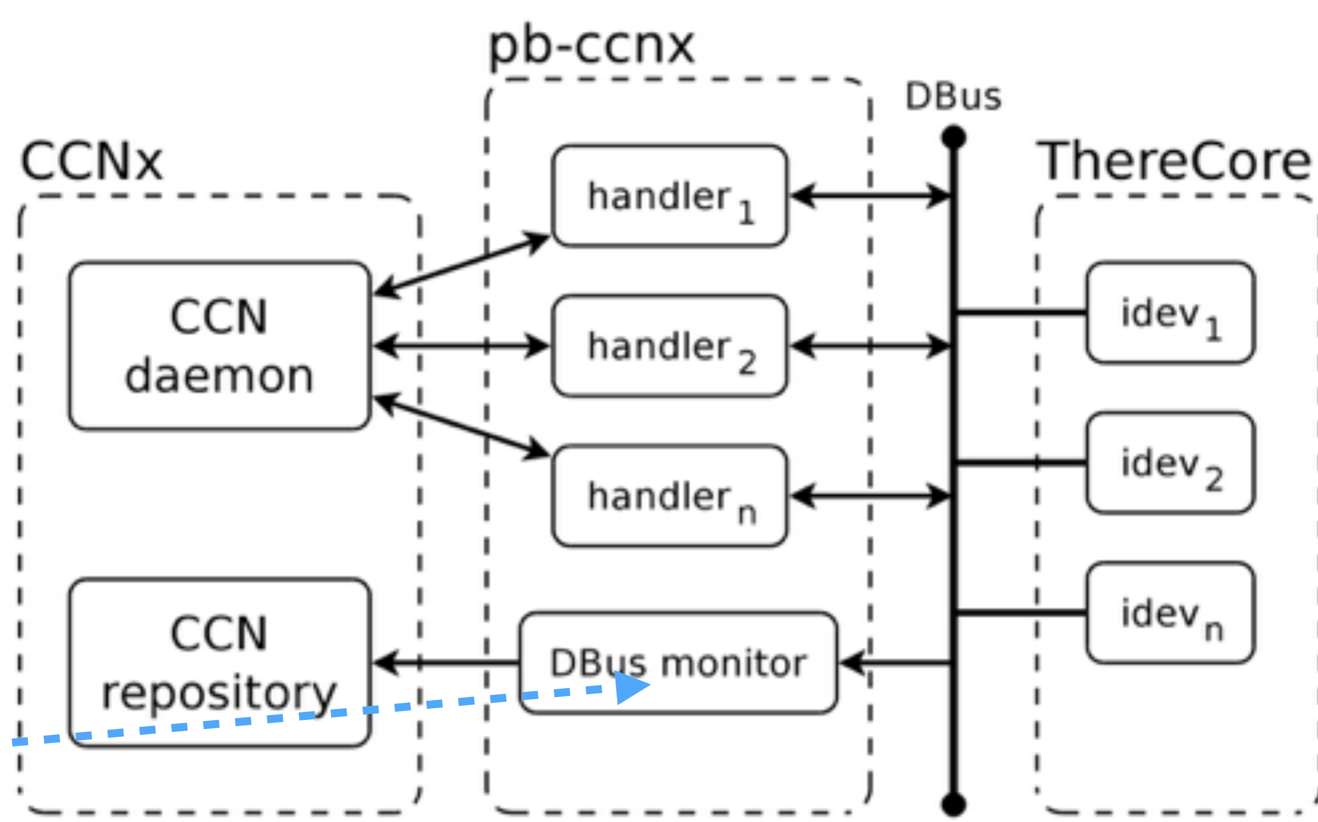
Specifics of pb-ccnx


```
{
  "ts":"1379431971",
  "prev":"1379431671",
  "data": [
    {
      "attr":"Temperature",
      "val":"22.50"
    }
  ]
}
```


linked list (n = curr = prev+1)

access: **ccnx://my/temperature/n**
ccnx://my/temperature/n+1

JSON for CO of a temperature sensor



pulls special names and control data

Tests Performed (reviewed)

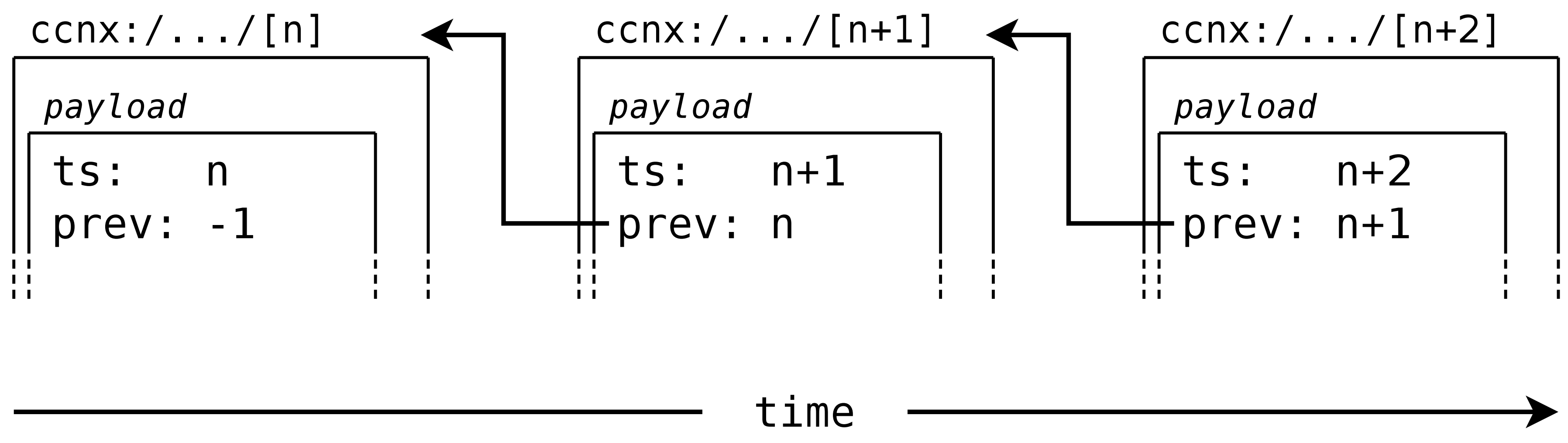


Figure 11: Linked list construction where previous link is carried within the payload.

- Transparent in network caching
- In network storage of sensor data
- High level abstraction of devices

Increasing the Scale

[Baccelli et al., 2014]

Implication of Routing Approaches

- Current ICN proposals rely on IP routing or use proactive link state algorithms.
  - large amount of control traffic (with or without data)
  - large amount of memory O(n), where n is the number of nodes in the network
- Routing protocols should aim for O(1) routing state and minimal control

An implementation ICN/IoT

- Porting of CCN-lite (NDN) to RIOT
  - CCN-lite less than 1000 LoC in C and low memory footprint
- restrictions
  - appropriate configuration of FIBs
  - for hierarchical namespaces space should be restricted. 30 to 100 bytes per packet, and link layer does not support fragmentation

Experiments

- Large scale deployment set-up
  - 60 nodes distributed in: rooms, floors, buildings, producing 200 bytes/min
  - Node: sub GHz wireless interface, humidity, temperature, etc. Max frame size 64 bytes.
  - Experiments: 400 ms interest timeout (stop-n-go, expiring after 5 tries) 900 ms nonce timeouts, content named in NDN fashion.
  - names: /riot/text/a (CCN: 16+12=28 bytes)
  - single producer, one or multiple consumers, topology can change due to link layer (wireless) nature.

3D visualisation of the topology

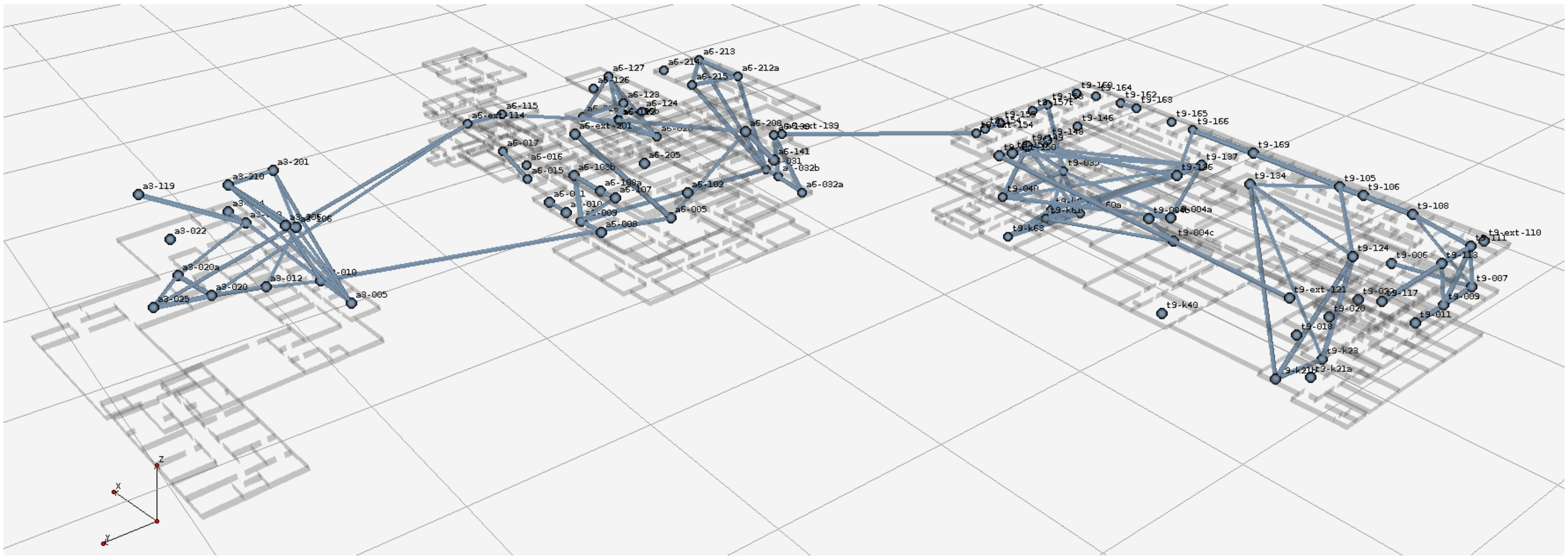
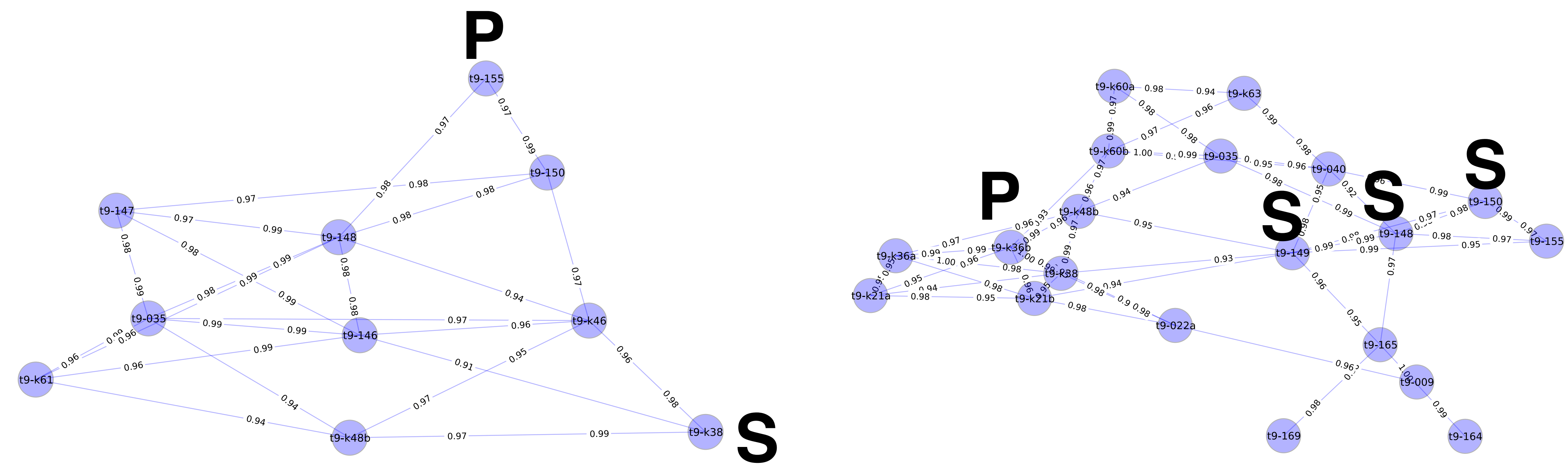


Figure 1: 3D visualization of the topology of the deployment, consisting in 60 nodes that interconnect via wireless communications (sub-GHz) and that are physically distributed in multiple rooms, multiple floors, and multiple buildings.

Test



(a) 10 nodes are involved when a single consumer (t9-k38) requests content published by t9-155.

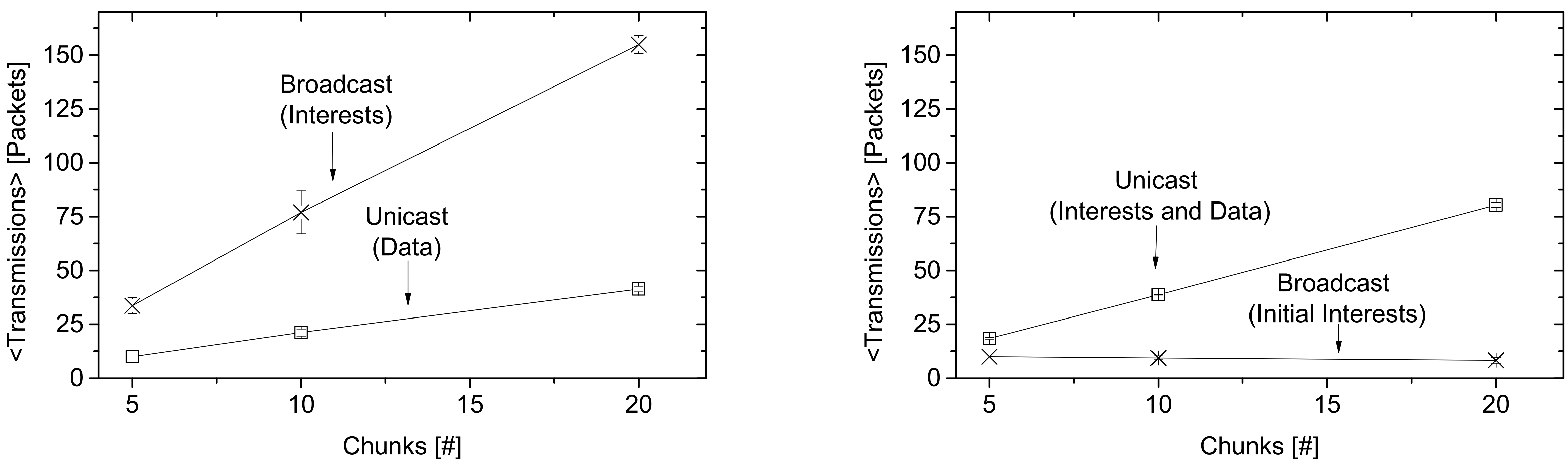
(b) 20 nodes are involved when multiple consumers (t9-149, t9-148, and t9-150) request content published by t9-k36a

Figure 2: Snapshot of the link-layer network topologies used in the experiments for single and multi consumer scenarios. Each topology spans over 3 floors in the right-most building shown in Figure 1. Link weights describe % of received packets, per link, per direction.

Flooding Mechanisms

- Vanilla Interests Flooding
  - To flood the entire network for every chunk.
  - FIB are empty, and the content sent in the reverse path
  - VIF suits IoT: no additional control to maintain FIB, minimal state on FIB for reverse path
- Reactive Optimistic Name based routing
  - To flood initial interest message
  - Unicast subsequent messages over the path automatically configured on FIB, on the way back
  - Ex: for accessing /riot/text/a, there is an entry /riot/text/* that will later match /riot/text/b or /riot/text/c
  - It is also considered optimistic because it assumes that all the content is stored on a single node

Results Single Consumer



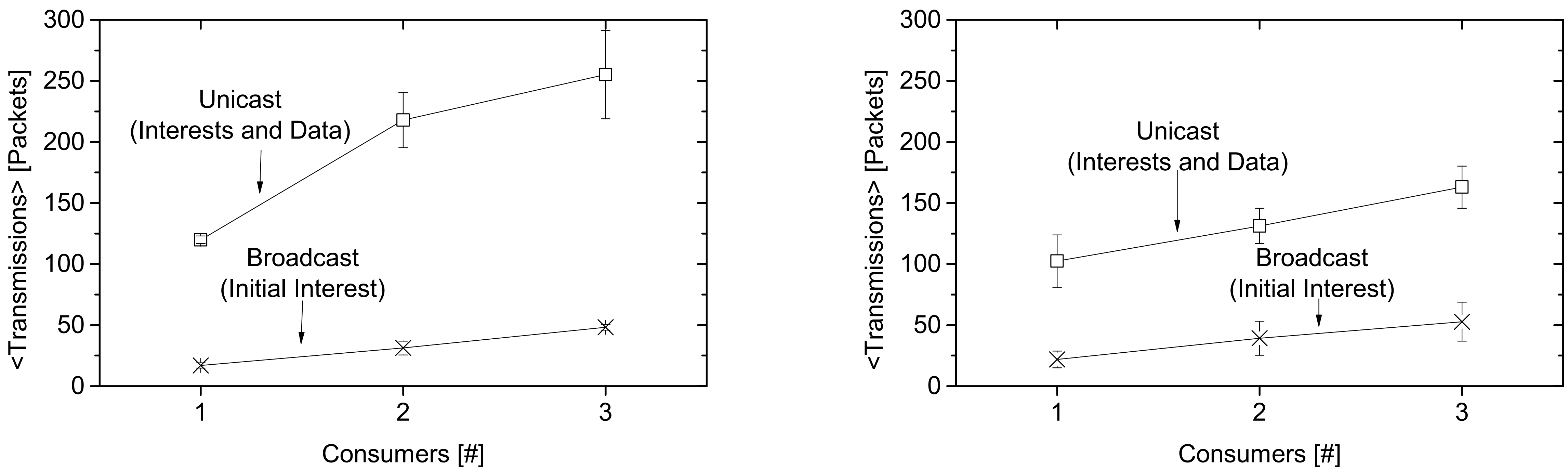
(a) Vanilla Interest Flooding

(b) Reactive Optimistic Name-based Routing

Figure 3: Single-consumer scenario. NDN performance for different routing schemes. Average number of packets transmitted in a network of 10 nodes to fetch content of various size.

Results Multiple Consumer + Cache

- 20 chunks accessed by 1, 2 or 3 nearby consumers (pairwise 1 hop)
- cache capacity 20 chunks all nodes (2% of RAM)



(a) Without caching (b) With caching

Figure 4: Multi-consumer scenario. NDN performance for RONR and different content cache schemes. Average number of packets transmitted in a network of 20 nodes with a variable number of consumers.

Standardisation Efforts at the IETF

Efforts at the IETF

Information-Centric Networking: Baseline Scenarios. http://tools.ietf.org/html/rfc7476

Applicability and Tradeoffs of Information-Centric Networking for Efficient IoT. draft-lindgren-icnrg-efficientiot-03. (expired, January 7, 2016)

ICN Research Challenges. draft-irtf-icnrg-challenges-04. https://tools.ietf.org/html/draft-irtf-icnrg-challenges-04. (active)

ICN based Architecture for IoT - Requirements and Challenges. draft-zhang-iot-icn-challenges-02. https://tools.ietf.org/html/draft-zhang-iot-icn-challenges-02. (expired, February 29, 2016)

Baseline Scenarios

Social Networking

Real-Time Communication

Mobile Networking

Infrastructure Sharing

Content Dissemination

Vehicular Networking

Delay- and Disruption-Tolerance

Opportunistic Content Sharing

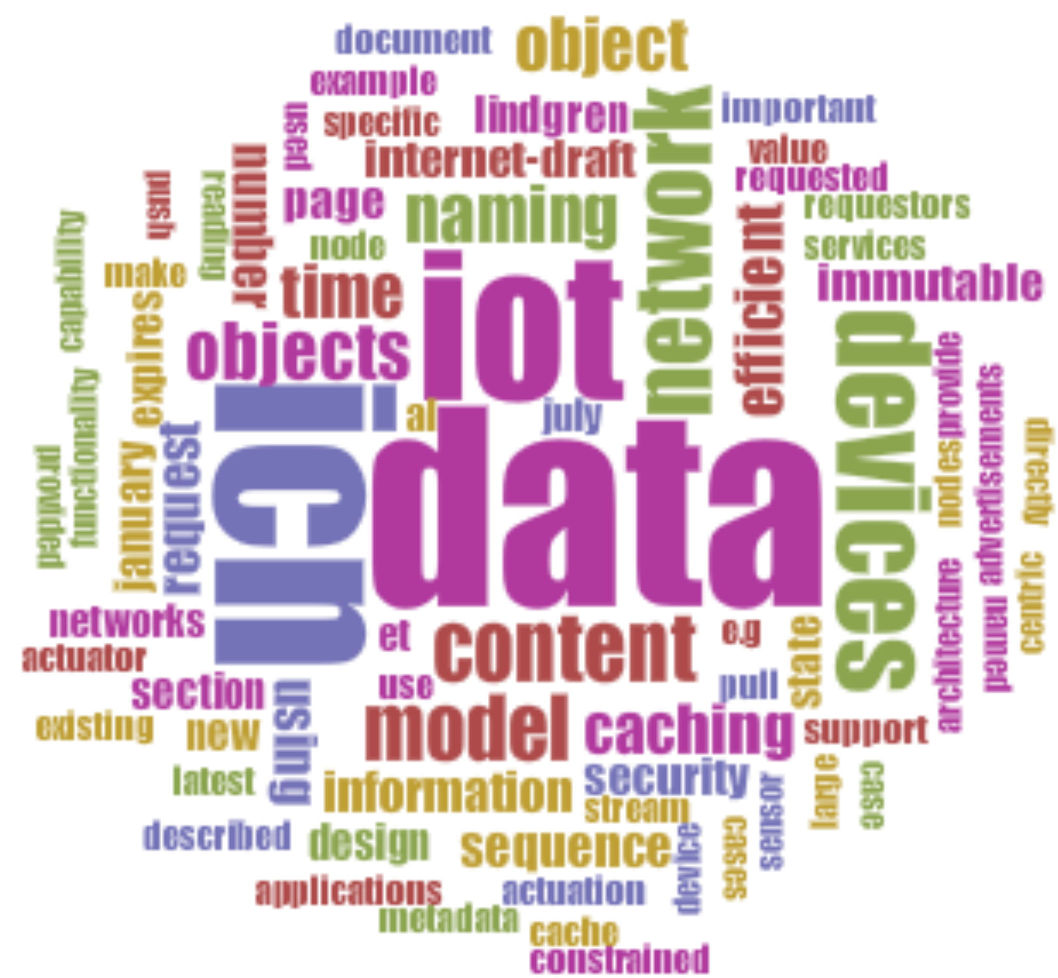
Emergency Support and Disaster Recovery

Internet of Things

Smart City

Applicability and Tradeoffs

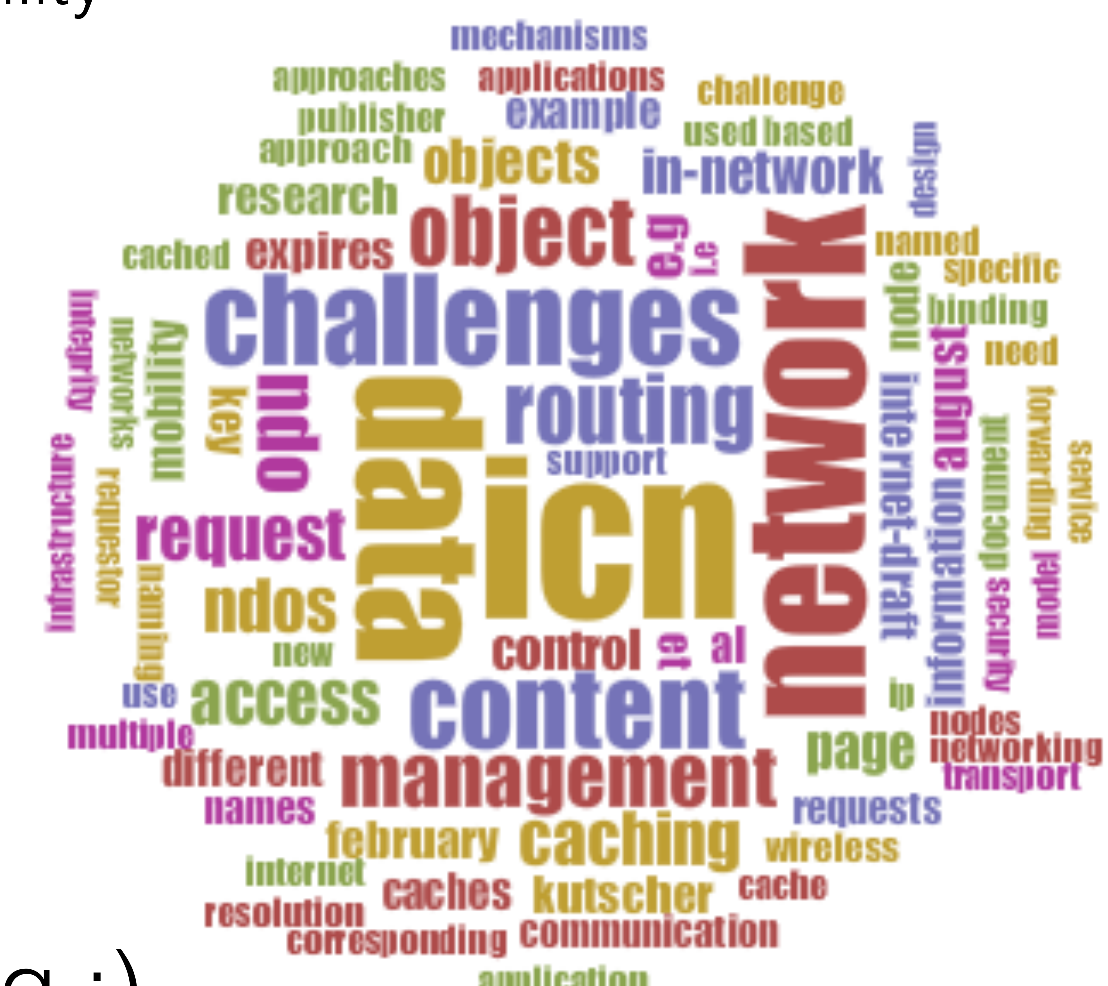
- The importance of time
- Handling actuators in the ICN model
- Role of constrained IoT devices as ICN nodes



Applicability to IoT data, naming, devices :)

Research Challenges

- Naming, **Data** Integrity, and **Data** Origin Authentication
- Security
- Routing and Resolution System Scalability
- Mobility **Management**
- Wireless **Networking**
- Rate and Congestion Control
- In-Network Caching
- ICN applications



Data ICN Network Routing :)

ICN based Architecture for IoT - Requirements and Challenges

IoT Architectural Requirements

. Naming

. Scalability

. Resource Constraints

. Traffic Characteristics

. Contextual Communication

. Handling Mobility

. Storage and Caching

. Security and Privacy

. Communication Reliability

. Self-Organization

. Ad hoc and Infrastructure Mode

. Open API

ICN Challenges for IoT

. Naming and Name Resolution

. Caching/Storage

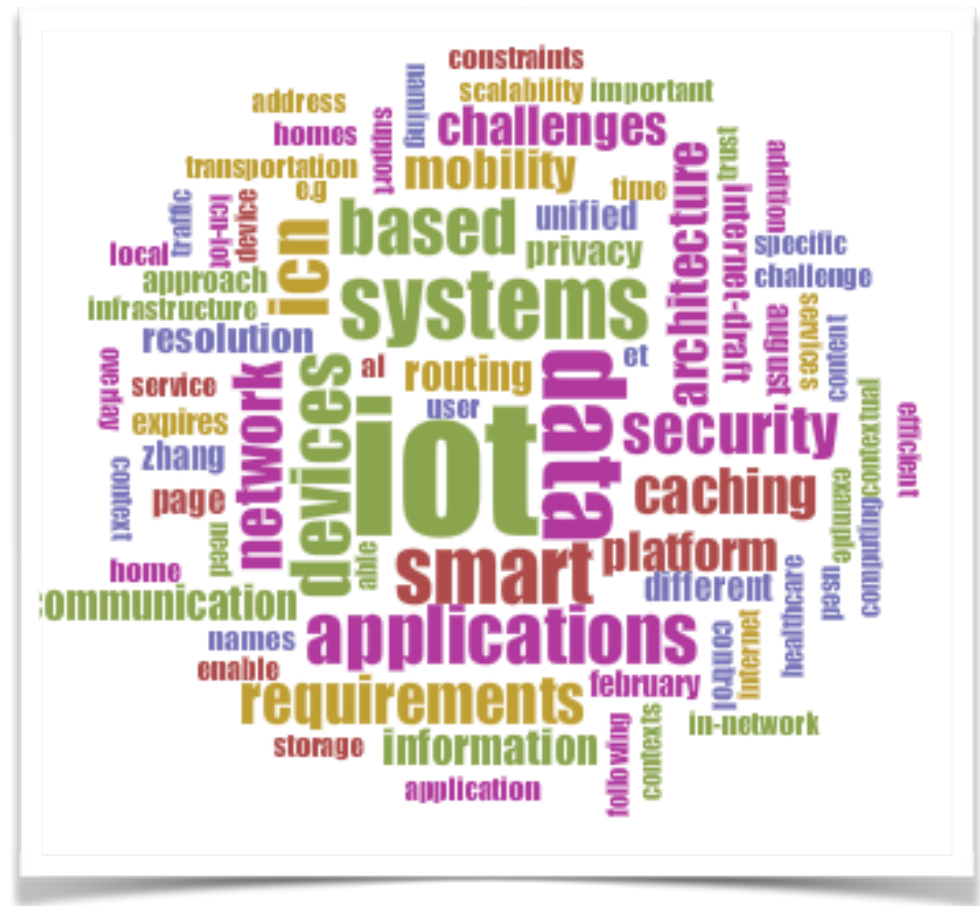
. Routing and Forwarding

. Contextual Communication

. In-network Computing

. Security and Privacy

. Energy Efficiency



requirements and challenges for:
systems, data, security, applications

References

[Song et al., 2013] Song, Y., Ma, H., and Liu, L. (2013). Content-centric inter-networking for resource-constrained devices in the internet of things. In Communications (ICC), 2013 IEEE International Conference on, pages 1742–1747.

[Baccelli et al., 2014] Baccelli, E., Mehlis, C., Hahm, O., Schmidt, T. C., and W¨ahlisch, M. (2014). Information centric networking in the IoT: Experiments with NDN in the wild. In Proceedings of the 1st International Conference on Information-centric Networking, ICN ’14, pages 77–86, New York, NY, USA. ACM.

[Waltari, 2013] Waltari, O. K. (2013). Content-centric networking in the internet of things. Master’s thesis, University of Helsinki.