ICN and IoT

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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

![Diagram showing the process for 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

PIT, FIB

Repository

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

ThereGate

ccnr

ThereCore

ccnd

pb-ccnx

sensor mesh
Specifics of pb-ccnx

JSON for CO of a temperature sensor

linked list (n = curr = prev+1)

access: `ccnx://my/temperature/n`

`ccnx://my/temperature/n+1`

pulls special names and control data
Tests Performed (reviewed)

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

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

Table 1: Comparing memory resources for common IoT operating systems and hardware.
4.2 Vanilla Interest Flooding (VIF)

Considering the maximum link layer frame headers and names fit in a single link layer frame, both with size of 12 bytes including the chunk identifier. The simplest routing approach that requires minimal state is MDR (Multi-hop Delegation Routing), whereby each node in the network repeats interest flooding. In general, in a network of $n$ nodes, and for each chunk triggers an interest, which requires network-wide broadcasting. The consumer could fetch the content, Figure 3(a) shows that, compared to its size, many packets were transmitted to fetch the content. This is due to the fact that the interest floods to the producer, which can then send the content on the reverse path. VIF fits the constraints of IoT devices as discussed in Section 5.1.

4.3 Reactive Optimistic Name-based Routing

To analyze the effects of NDN for typical radio packets 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.

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

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)

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


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

[Word cloud with terms like ICN, data, objects, network, device, etc.]
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 :)

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**ICN applications**

- Object
- Network
- Challenges
- Routing
- Content
- Data
- Management
- Support
- Applications
- Examples
- Challenges
- Social media
- Security
- Network
- Research
- Design
- Services
- Use
- Multiple
- Access
- Pages
- Use
- Multiple
- Access
- Pages
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

