Information-Centric Networking for the Internet-of-Things

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Outline

- ICN for the IoT: observations and vision
- I-CAN: Information-Centric Access Networks (GR)
- POINT: IP Over ICN - The Better IP? (H2020 project)
  - CoAP over ICN
- MMlab Research & People
- Pub-Sub Internetworking (PSI): overview & unique features
A vision for the IoT

- many consider the IoT as an extended WSN
- need to move one step further!
  - fully exploiting connected things
    - smart things
  - & things with no computational power whatsoever
    - dumb, but potentially ‘dynamic’; indirectly connected
      - their state changes; observed or set by others
        - proxies...
- focus on *information*, not things
  - application independent
    - no silos!
    - information obtained for one app (silo) to be available to another (originally unexpected) app
      - under user/owner control...
ICN for the IoT

- **Opportunity!**
  - Unsettled technologies/architectures
  - Vertical (silo) applications/technologies \(\rightarrow\) interoperability… lacking
  - ICN could enable interoperability
    - play the role of middleware … in cleaner & leaner way

- **Access Control!**

- **Privacy?** Potential for ‘privacy attacks’ so widespread…
  - Privacy: through access control in *rendezvous* architectures
ICN + IoT

Many recent publications... research...

- ACM SIGCOMM ICN 2014

- ICNRG
  - Information-centric Networking: Baseline Scenarios -- “2.8. Internet of Things”
  - Requirements and Challenges for IoT over ICN
  - Proposed Design Choices for IoT over Information Centric Networking

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Why ICN for the IoT

- integrate (vertical application) silos into an Internet of Things
- ICN semantics: pub/sub, asynchronous...
- better/easier network resource management
  - multicast, multi-homing, caching
- easier network attachment and “thing” configuration
- easier “QoS” management
  - explicit naming of traffic (information/content)
    @ the (inter-)network layer
IoT Challenge: Naming

- ... as the integration enabler
  - identifiable → potentially accessible
    - compound names?
- a name (+? metada...) should identify
  - the thing’s identity
    - RFID, QRCode, Barcode
      - @ type level
      - individual thing
  - the thing’s owner & context
  - properties...
- related issues
  - information authentication and provenance verifications
  - manageability, revocability
  - group names

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ICN-IoT Semantics

- ICN semantics
  - pub/sub, asynchronous, in either order…
  - persistent interests, group communication
  - metadata
    - facilitate service discovery, service composition…

- (IoT) application (protocol) semantics
  - … the same… consider CoAP…
  - easier to implement CoAP, MQTT… over ICN
    - their semantics match better
  - leaner/more efficient protocol stacks
  - multipoint, across domains & apps
    - multicast, anycast, multi-homing
  - caching: allows separation/disconnection of things
Better/more Flexible Resource Utilization
... with an ICN approach

- better/easier network resource management
  - multicast, anycast, multi-homing, caching
- easier network attachment and “thing” configuration
- easier “QoS” management
  - explicit naming of information/content at the (inter-)network layer
- smaller ICN stack (than IP) => simpler implementations
  - energy efficiency, cost (maintenance etc.) reduction
- easier to create in network security mechanisms
  - filtering, application layer firewalls
More IoT Challenges:

- **Contextual Information Lookup**
  - Name, metadata, user context…
  - API hides the complexity of the underlay topology and architecture

- **Information Forwarding**
  - Delay tolerance, mobility
  - Permanent and ephemeral subscriptions

- **Trust**
  - Limited (or no!) computational power
  - Things can be tampered with; software on things not easily updated
  - Transitive trust and trust delegation
  - Eliminate the need for CA?
Motivation: Mobility presents new challenges and opportunities

- Mobiles have multiple wireless interfaces
- Different wireless access technologies have different characteristics

Objectives: investigate

- ICN requirements & features for mobile/wireless access networks
- multi-source, multi-path, multi-interface
- in-network and proactive caching
- privacy support

Nationally funded project – ARISTEIA II

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I-CAN Architecture Features

- **Publication proxies**
  - store and advertise content on behalf of content owners
    - content remains available even when owner is offline

- **Subscription proxies**
  - send subscriptions on behalf of actual receivers
    - beneficial if users are mobile and have disconnections
    - can exploit proactive caching

- **Future content & persistent subscriptions**
  - can reduce **signaling overhead** in cellular and contention-based access networks

- **Use case-scenario: D2D (multimedia) content sharing**
  - *(provider controlled)* sharing of content among clients
    - e.g., travelling on a train
      - 1st copy (maybe) obtained over cellular
      - train cache may also participate...
  - content (chunk) naming facilitates operation
    - can be adapted to work with IP (& D2D/P2P) technologies
**POINT: IP Over ICN - The Better IP?**

- **Project:** Running: 1/1/2015-31/12/2017
- **Partners:**
  - Aalto U (co-ordinator), ELL-i (FI)
  - Intracom Telecom, AUEB (GR)
  - RWTH Aachen (DE)
  - Primetel (CY)
  - CTVC Ltd, Interdigital, U Essex (UK)
- **Trials in Cyprus (@Primetel)**
- **Concept: IP over ICN (PSI) over SDN**
  - Premise: IP apps can do better over ICN
    - Need to define what “better” means
  - Better utilisation in HTTP streaming scenarios
  - Better privacy of personal data and metadata
  - Better management of virtual network paths
  - Better (fairer) content distribution
Focus
- 1 ISP
- User Equipment (UE): no changes (required)
  - i.e. IP
- ICN used internally in the network
- NAP: Network Access Point
- ICN could be exposed to UE
Blackadder +

- Application-facing abstractions
  - HTTP, CoAP,…

- Novel dissemination strategies
  - For access networks

- Integration with SDN
  - ICN over SDN

- Flexibly-grained QoS
  - per abstraction

- Key target protocols/services
  - HTTP
  - CoAP
  - IP

Fine-grain QoS abstraction

LIPSIN | MSBF | POINT Alternative 3

ICN-over-SDN shim layer

SDN

L2 Transport Networks
The **POINT** IoT story

- **IoT / IP**
  - CoAP over ICN
  - CoAP handler at the NAP
  - UE: no changes (required)
    - i.e. **IP**

- **IoT / ICN**
  - native ICN
An IoT reference architecture

- Caching
- Aggregation
- …

CoAP Client

Host #1

FW-Proxy

GW #1

Host #2

Thing #1

GW #2

RD/GW #1

RD/GW #2

RD/GW #3

Network #1

Network #2

Network #3

CoAP Server

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A POINT rendition of the IoT reference architecture

- Network #1
  - RD/GW #1
  - NAP
  - Network #1

- Network #2
  - RD/GW #2
  - NAP
  - Network #2

- Network #3
  - RD/GW #3
  - NAP
  - Network #3

- Host #1
  - GW #1
  - NAP

- Host #2
  - GW #2
  - NAP

- Thing #1
  - GW #2
  - NAP
Scenario #1: Coincidental multicast (async requests, coap-observe RFC 7641)
Scenario #2: One-to-Many Requests
(group-communication RFC 7390)

CoAP GET all.networks/Purple

lookup all.networks

A.B.C.D

CoAP GET all.networks/Purple

JOIN A.B.C.D

RD/GW #1 #2 #3

Network #1 #2 #3

Host #1

GW #1

FW-Proxy

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Scenario #3: Service Composition

GW #1

CoAP GET AVG/Purple

AVGer

RD/GW #1

RD/GW #2

AVG/Purple

Purple

Purple

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CoAP over ICN

- **CoAP ~ ICN**
  - asynchronous communication
  - persistent interests
  - group communication

- **advantages (to CoAP application developers & operators)**
  - applications do not have to deal with IP multicast
  - no modifications to DNS
  - state overhead moved from the (constrained) endpoints to the network
    - for requests to … not yet available resources & “observe” extension
      - the CoAP server receives a single request
      - all other requests are suppressed by the NAPs
  - (~operator): CoAP and CoAP “observe” create opportunities for multicast
    - the network then uses multicast to handle bursts of traffic

- **CoAP over DTLS**
POINT IoT Experimentation

- ‘things’ with Power over Ethernet
- Connected at the edges of the POINT testbed

POINT Testbed (w/ Blackadder)
- Tunneled over the Internet

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Observations

• ICN has some common key features across architectures
  - Content distribution has been the initial key motivation for ICN (CCN)
  - Information dissemination and access (on the IoT) might be the real application
• ICN is well positioned to provide for the IoT
  - caching: client-provider (thing) separation, asynchrony, energy efficiency
  - multihoming: access/unify multiple separate networks/applications
  - traffic management: exploiting explicit information naming in the network
  - mobility support: where relevant—many things are mobile
  - security: new models, new attempts, new problems…
  - privacy: through access control in rendezvous architectures

• Outlook
  - Scalability, efficiency, acceptance, deployment …
  - Security and privacy
● **MMlab Faculty**
  - George C. Polyzos, Director
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  - Giannis Marias
  - Vasilios A. Siris
  - Stavros Tountpis
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  - Yannis Thomas
  - Charilaos Stais
  - Christos Tsiolopoulos

● **MSc students**

● **Researchers**

● **Undergraduate students**

● **Alumni…**
  - Dinos Katsaros, PhD (@UCL)
  - Pantelis Frangoudis, PhD (INRIA, Renes)
  - Vaggelis Douros, PhD (@Orange)

http://mm.aueb.gr/
Thank you!

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Selected MMlab ICN Publications


Our ICN-related Research Projects

- **PSIRP**: Publish Subscribe Internet Routing Paradigm
  - FP7 ICT STREP, 2008-2010
    - the basis
    - focus on (inter)-networking
- **Pursuit**: Publish Subscribe Internet Technologies
  - FP7 ICT STREP, 2010-2013
    - extending, above & below the Internet layer
    - optical, wireless, mobility, transport…
- **Euro-NF**: Anticipating the Network of the Future—From Theory to Design
  - FP7 ICT Network of Excellence, 2008-2012
    - ASPECTS, GOVPIMIT, E-key-nets
- **EIFFEL**: Evolved Internet Future For European Leadership
  - FP7 ICT SSA, 2008-2010; Think-Tank continued
  - June 2011 TT @ **MIT**: Information-Centric Networking
- **φSAT**: The Role of Satellites in Future Internet Services
  - European Space Agency funded
  - 2011-2013
- **I-CAN**: Information-Centric Future Access Networks
  - NSRF (Greece), 2014-2015
- **POINT**: iP **Over ICN**- the betTer IP
  - H2020 ICT STREP, 2015-2017
- **SatNEx IV**, ESA, 2015-2016
  - Y1 WI 5: ICN over MAC
  - Y2, WI 4: Caching
Publish-Subscribe Internetworking (PSI)
Publish-Subscribe Internetworking (PSI) Key Functions and Components

- publish – subscribe – rendezvous
  - Rendezvous ID: hash of content (/name)
    - asynchronous and multicast
    - restores the imbalance of power sender/receiver(s)
    - + Scope ID: aggregation, policies…
- PSI Basic Functions: RTF
  - Rendezvous: Matches publications with subscriptions and initializes forwarding
  - Topology: Monitors the network and creates information delivery paths
  - Forwarding

PSI Identifiers
PSI Unique Features

- **Fast forwarding**
  - Bloom filter based forwarding (→ forwarding identifiers)
    - simple, stateless, fast forwarding
    - incl. for multicast
  - path (‘source’) routing
    - path as compact Bloom filter carried on packets

- **Centralized – ‘SDN compatible’ approach**
  - (intra-domain) routing/resource allocation
  - topology discovery/management

- **‘recursive’ use of pub/sub …**
  - object level
  - chunk/packet level…
    - pull transport, error control, rcvr flow control
      - = slow & fast rendezvous
  - topology formation: handover = subscribe to network…
Secure Publisher Proxy

- Combines
  - Identity Based Encryption (IBE)
  - Proxy re-encryption
- The content owner encrypts content using a (different) symmetric encryption key
- Each symmetric key is encrypted using
  - IBE with the owner’s identity

- To access encrypted content, the subscriber needs to
  - decrypt the symmetric encryption key
  - by having the proxy re-encrypt the symmetric key and
  - derive $C_{\text{Subscriber}}$ from $C_{\text{Owner}}$