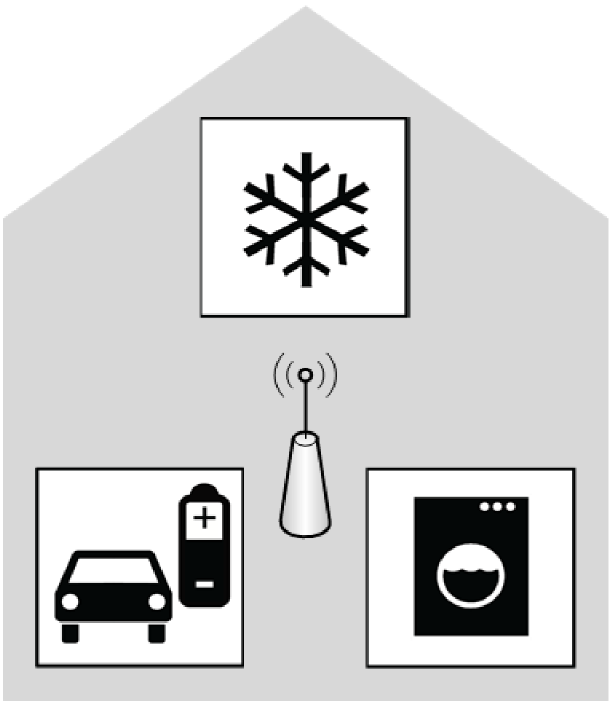
Information Centric Networking in the IoT

Experiments with NDN in the Wild

Emmanuel Baccelli[1], Christian Mehlis[3],
Oliver Hahm[1], Thomas C. Schmidt[2],
Matthias Wählisch[3]

INRIA[1]
HAW Hamburg[2]
Freie Universität Berlin[3]

The Beauty of ICN in the IoT



- Simplified, natural API
  - Example: Get “/paris/cordeliers/amphi_farabeuf/temperature”
- Increased robustness by caching
  - Lossy wireless links in the IoT
- Ease data fusion by hop-wise replication
- Reduced network layer
- Inherent auto-configuration
  - IoT devices w/o user interface

The Ugly of ICN in the IoT

Additional states

- Constrained devices are prevalent in the IoT

Long names

- IoT link layer technologies usually support short MTUs

Do the benefits outweigh
the challenges of ICN in the IoT?

What is this Talk About?

- Explore basic feasibility and tradeoffs of ICN in the IoT
- Report about experiments in real world testbed
- Propose interoperable ICN enhancements for the IoT

Agenda

- IoT Model
- A Priori Challenges
- Enable ICN in the IoT
- Experiments
- Summary

IoT Model in this Talk

Constrained devices

- Power consumption in mWatt compared to Watt
- Computations in megaFLOPS compared to GigaFLOPS
- Memory in Kilobytes compared to Gigabytes

Multi-hop wireless communication

- MTUs between 30 bytes and 40 bytes

Standardized interconnection

- Connect with Internet-devices

⇒ **We look on the very low end IoT devices in the global (future) Internet!**

Challenge: Limited Memory

Implications on caching capabilities

- Small-sized content doable
  - Example: Temperature value 12 bytes => 85 sensor values
- Medium-sized content requires distributed chunk caching

Implications on overlay applicability

- ICN should work directly on link-layer

Implications on routing approaches

- Constant routing states preferred
- Minimal control traffic

Implementing ICN in the IoT: Network Stack

Which ICN implementation?

- NDN (before the CCN/NDN split ;)

Which operating system for IoT?

- RIOT

Porting CCN-Lite to RIOT

- 1,000 lines of C code
- Required ROM 16 kBytes
- Required RAM 5 kBytes

Basic Routing with Vanilla Interest Flooding (VIF)

Idea

- Flood all content interests

Advantages

- Does not rely on additional control traffic
- Requires no additional states

Disadvantages

- Does not scale with many nodes
  - Network transmissions are costly in terms of energy

Optimized Routing with Reactive Optimistic Name-based Routing (RONR)

Idea

- Assumption: Whole piece of content is stored on a node
- Flood only the first interest for a content name
- Subsequent interests for chunks are unicast

Advantages

- Reduces the number of radio transmissions, saves energy
- Still, no control traffic and minimal states

Disadvantage

- Content delivery can be delayed

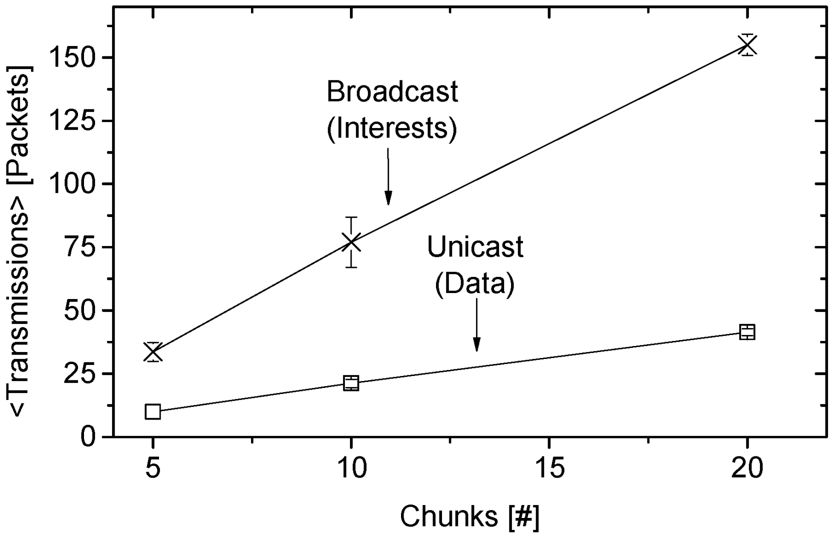
Experimental Setup

- Deployment of ICN/IoT implementation in the FU testbed
  - 60 nodes distributed in several rooms and floors
  - Each node with CC1100 radio chip, CPU 868 MHz
  - Maximum link layer frame size 64 bytes

- Basic configuration of the experiments
  - Size of name length 12 bytes
  - Consider single and multi consumer scenarios
  - Consider ICN with and without caching
  - Chunk size set to 58 bytes
  - Content size aligned to prevent fragmentation

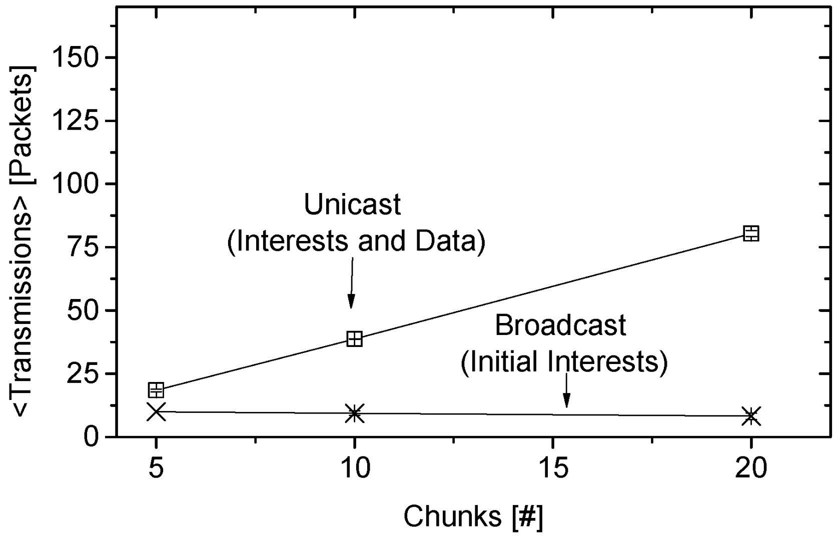
Results - Single Consumer Scenario

Vanilla Interest Flooding



- It worked!
- Relatively large interest signaling overhead

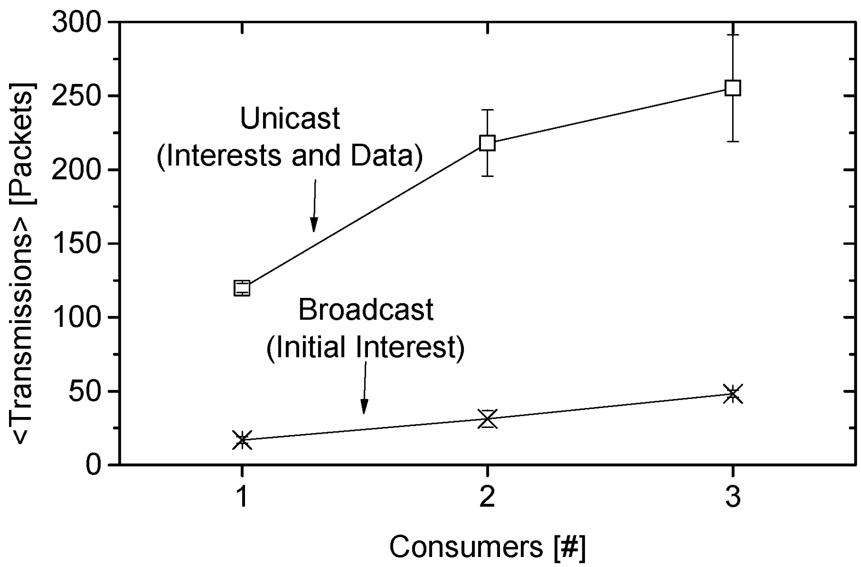
Reactive Opportunistic Forwarding



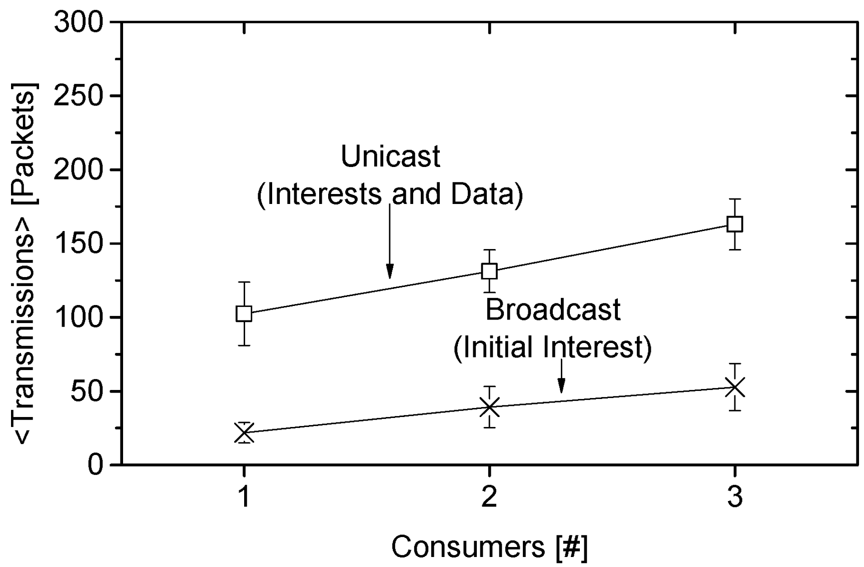
- 50% less radio transmissions compared to Vanilla flooding
- In particular, less broadcasts

Results - Multi Consumer Scenario for RONR

Without Caching



With Caching



- Scales almost linearly with the number of consumers

- Cache accommodates 20 chunks
  - 2% of 96 kBytes of RAM
- 50% less radio transmissions
- Unicast benefits from caching

Comparison with Common IoT Protocols

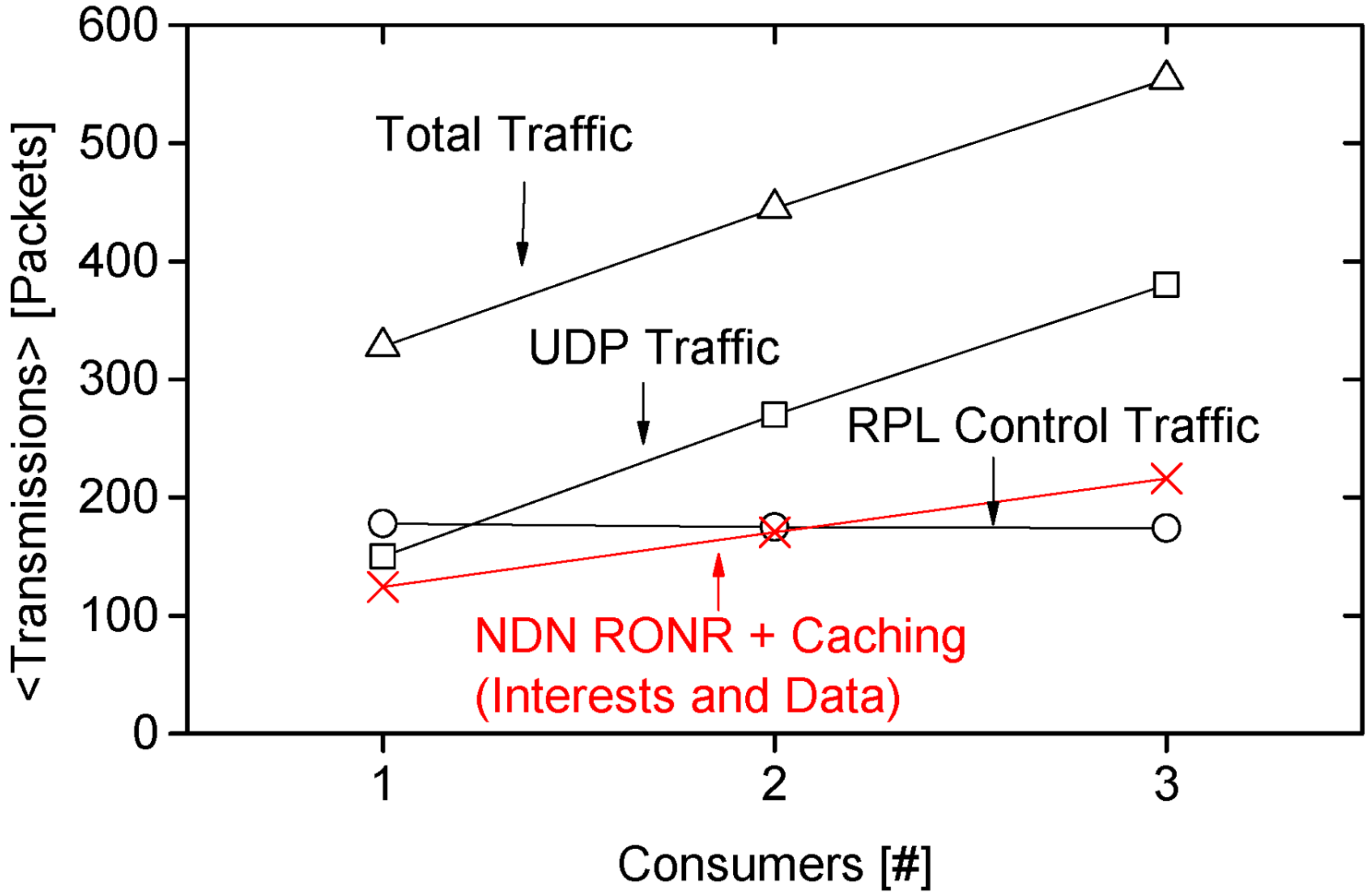
- Common IETF protocol suite for IoT: 6LoWPAN + RPL
- Comparing required memory for protocol stack

Module	ROM	RAM
RPL + 6LoWPAN	~52 kBytes	~27 kBytes
CCN-Lite	~16 kBytes	~5 kBytes

⇒ ICN requires 70% less ROM, and 80% less RAM

We now perform the same
multi-consumer experiment with caching.

RONR Compared with 6LoWPAN/RPL Stack



Summary & Outlook

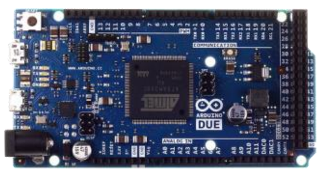
We started from very basic scenarios and simple mechanisms

- ICN is applicable in the Internet of Things
  - NDN/CCN implementation available with low memory footprint
- Caching and opportunistic forwarding help to reduce packet loss and energy consumption
  - ICN may outperform current IoT protocols

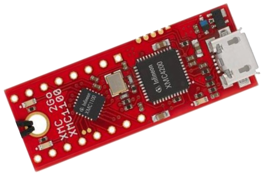
In the future

- Deal better with typically small frame sizes
  - Header compression and fragmentation layer below NDN
- IoT-specific content replication and cache replacement
- Additional communication models
- Short naming schemes optimized for constrained devices

Let’s Rock IoT with ICN!







RIOT

- Download, extend, and experiment
- http://github.com/RIOT-OS/RIOT
- http://www.riot-os.org

FIT IoT-lab

- Over 2,700 wireless sensor nodes across six sites
- RIOT and thus ICN runs in IoT-LAB
- Open for external researchers