CCN Traffic Optimization for IoT

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Outline

1. Introduction
2. CCN Background
3. Problem Definition
4. Solution
5. Evaluation
6. Conclusion

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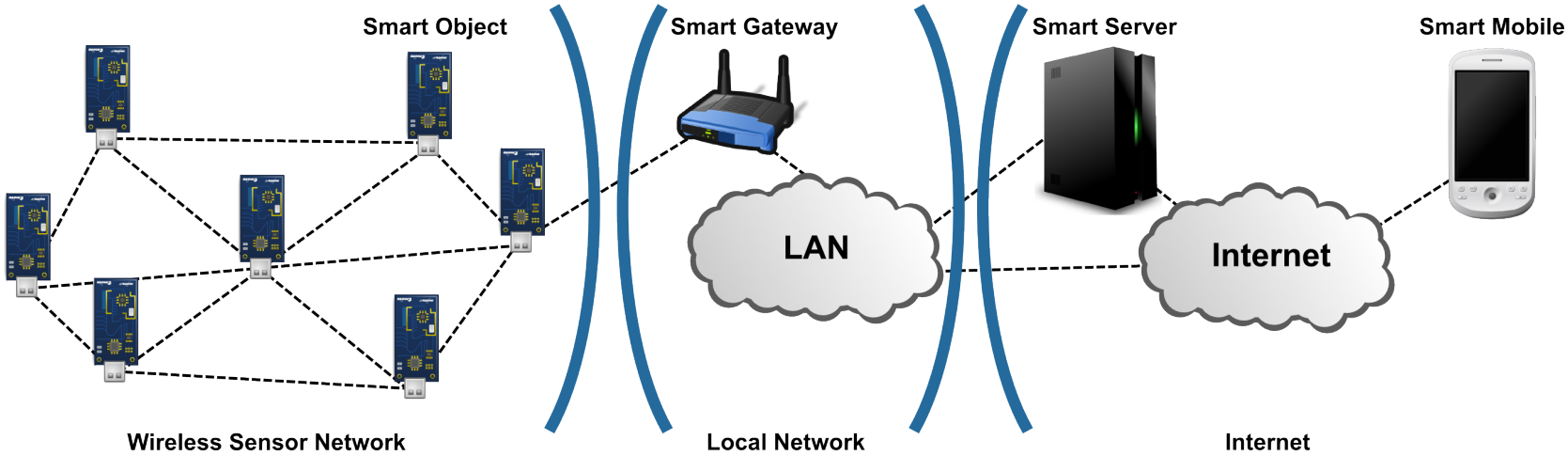
Context

- Internet of Things
  - multi sites network with sensors and gateways
  - shared infrastructure of multiple owners for multiple service providers
  - reliability, security, privacy... requirements



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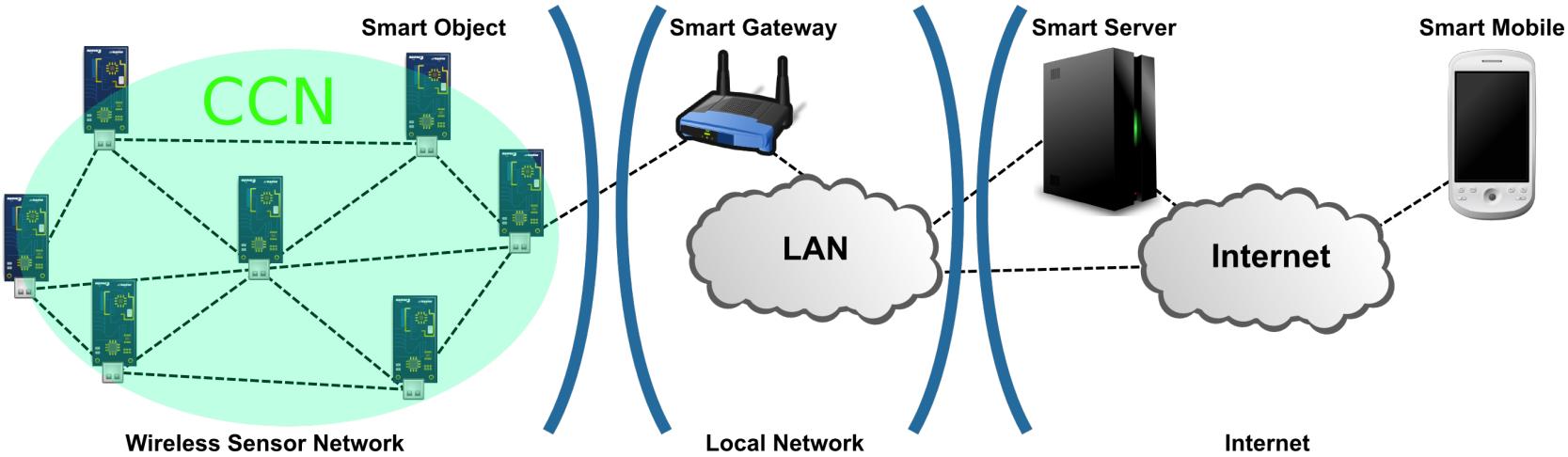

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CCN for Sensors

- Why?
  - CCN designed for distributed networking → scalability
  - ICN/CCN provides already many required basic functionalities (security, naming)
  - → alleviates the need of additional protocol, *e.g.* resource discovery protocols
  - Contiki implementation available
- but:
  - CCN: pull-based mode (on demand information retrieving)
  - many IoT use cases where: push based model for sensor (regular sensing or event based)
- → can we still use CCN for sensor communications on a push based manner?

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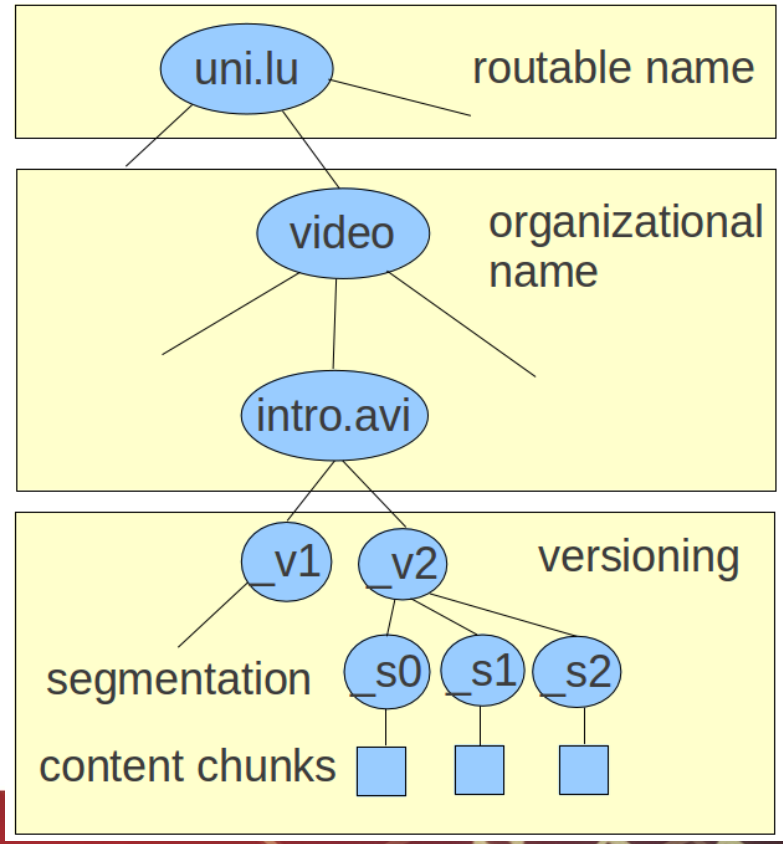
Basics

- Key ideas
  - Data as a name, not a location
  - Data is directly requested at the network level (no more DNS: more security; less delay)
  - Anybody with the data can answer
  - Data is authenticated, not the connections it traverses
  - + caching at intermediate routers
- 2 types of packets *Interest* and *Data*
  - Consumer driven: broadcast Interest, waits for Data
  - Data transmitted in response, consumes the Interest

Hierarchical naming

- Routable prefix, persistence of the names
- Hierarchical aggregation for fast routing and forwarding
- Dynamic generation of content
- Context-aware resolution (*/ThisRoom/projector*)



Message sequence

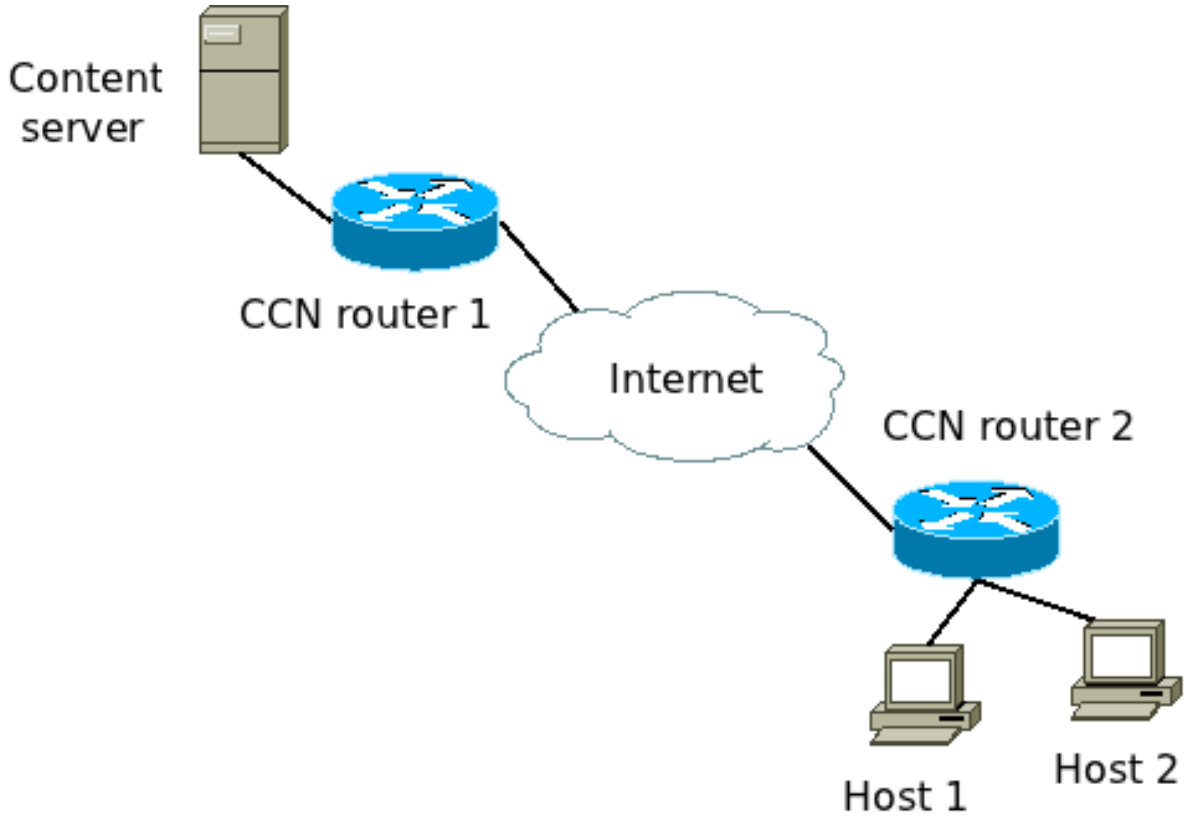
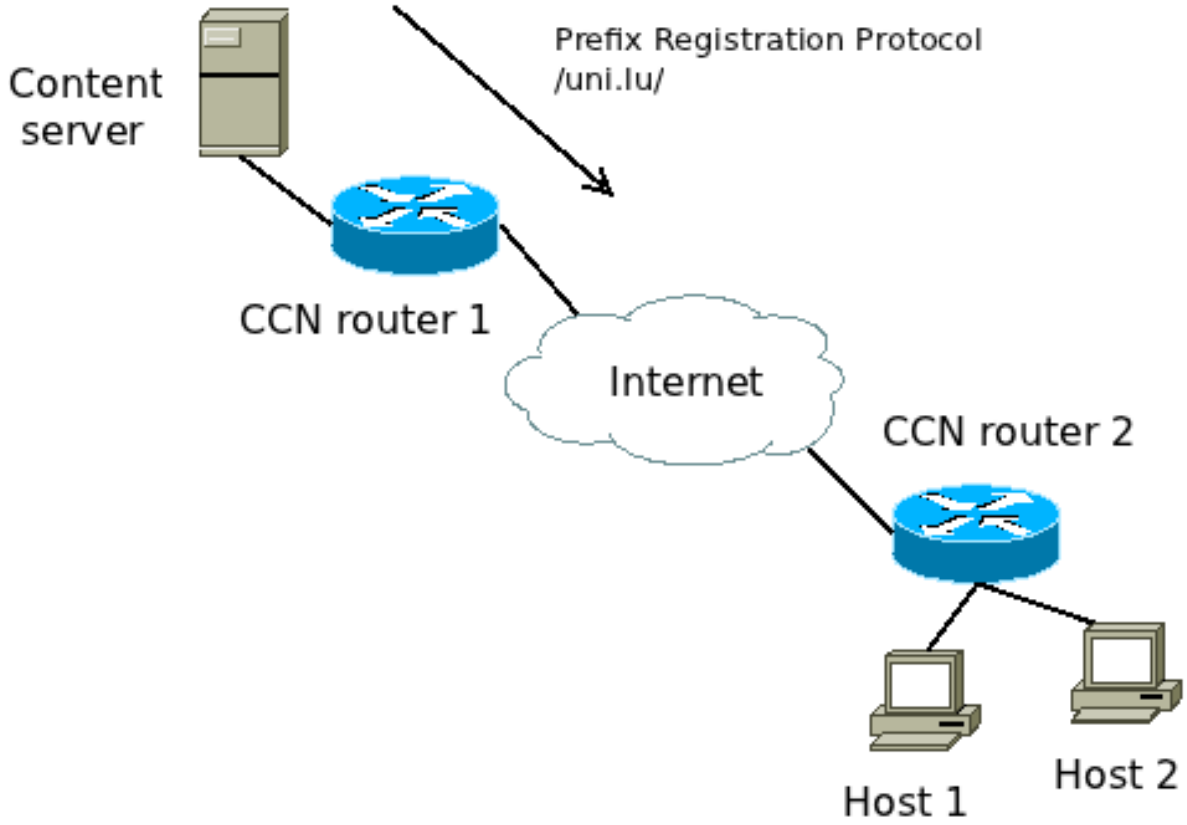


Figure: Scheme of a minimal Content-Centric network

Message sequence



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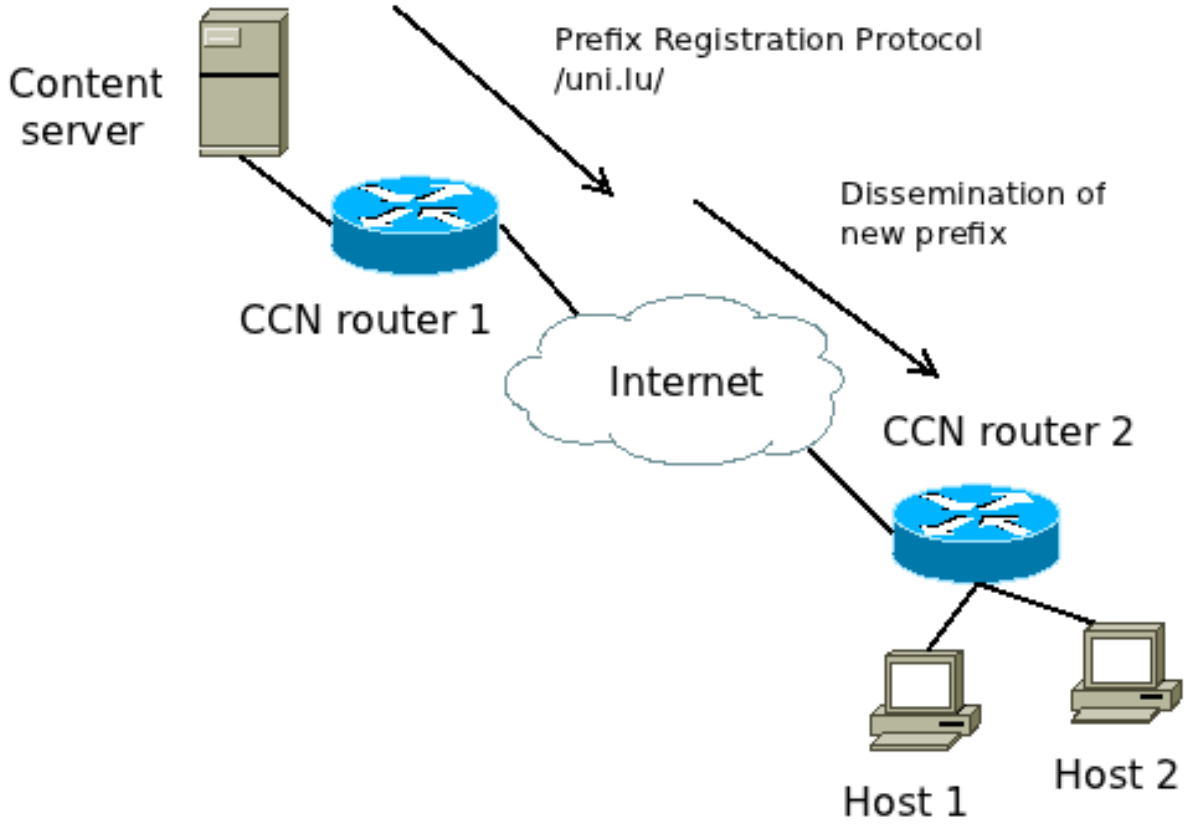

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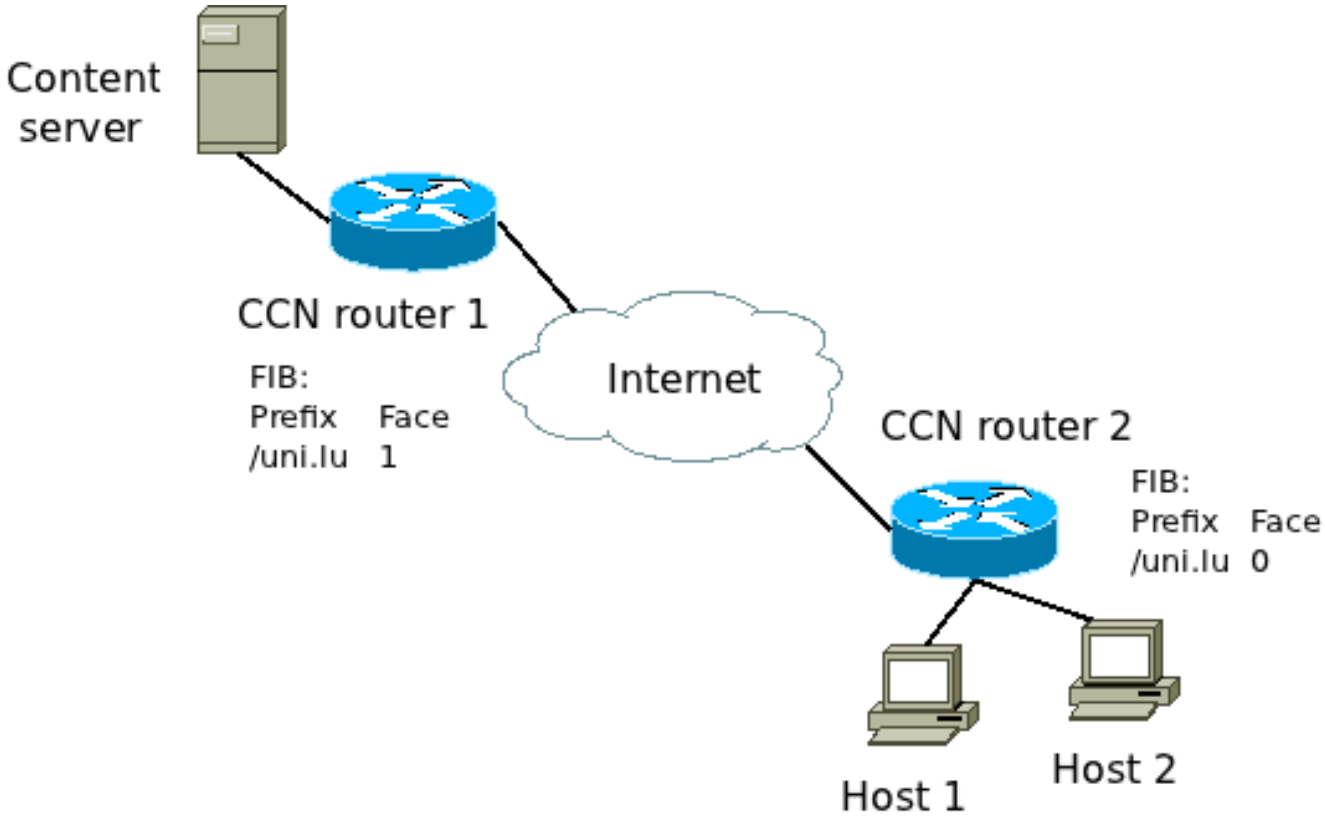

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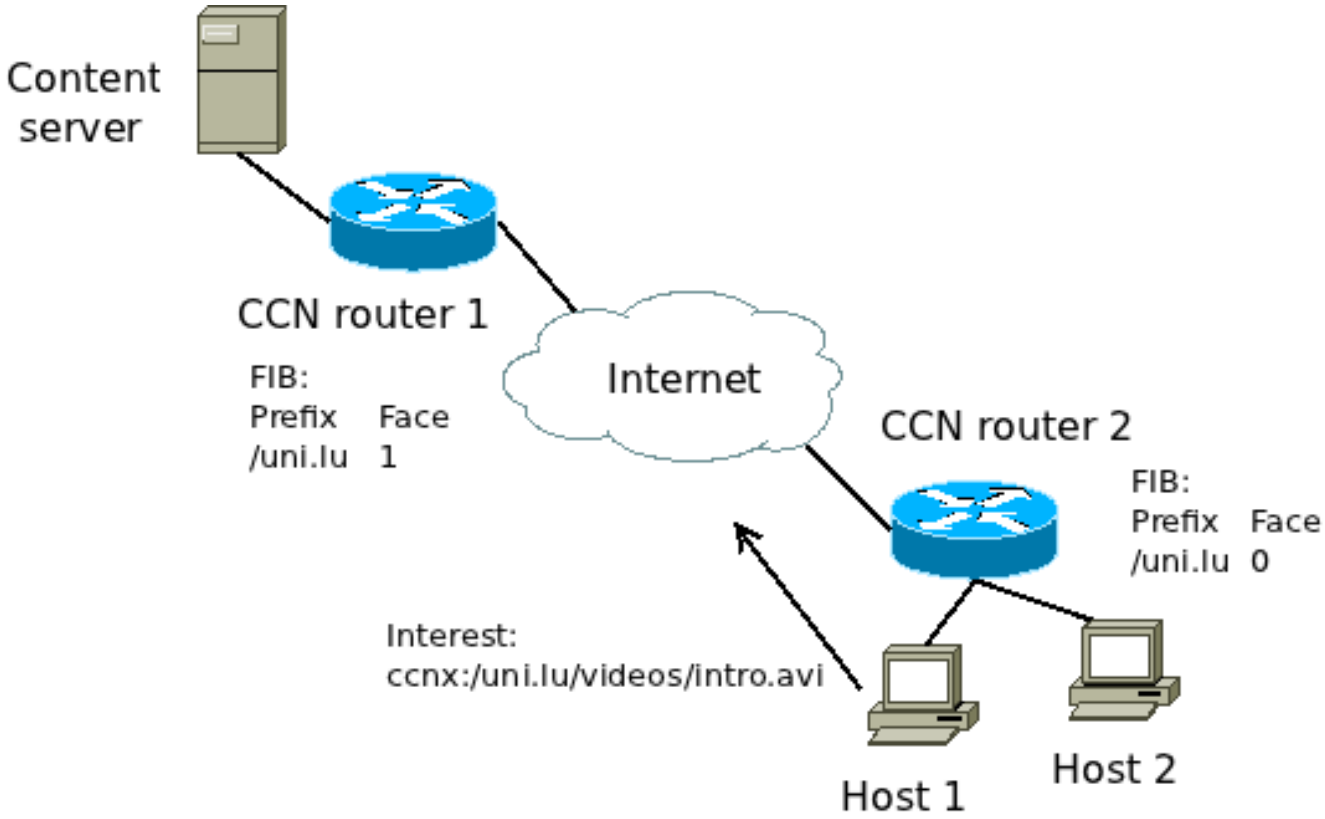

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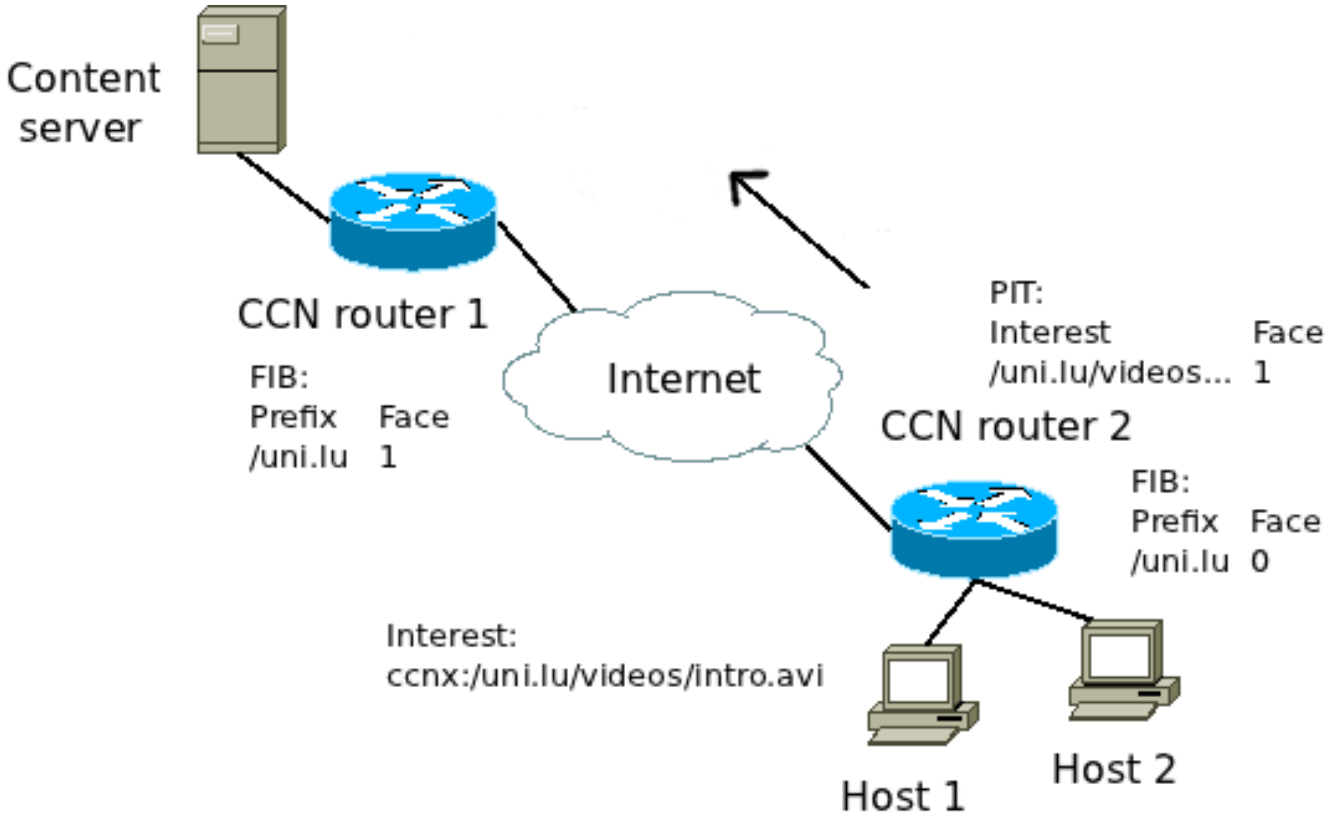

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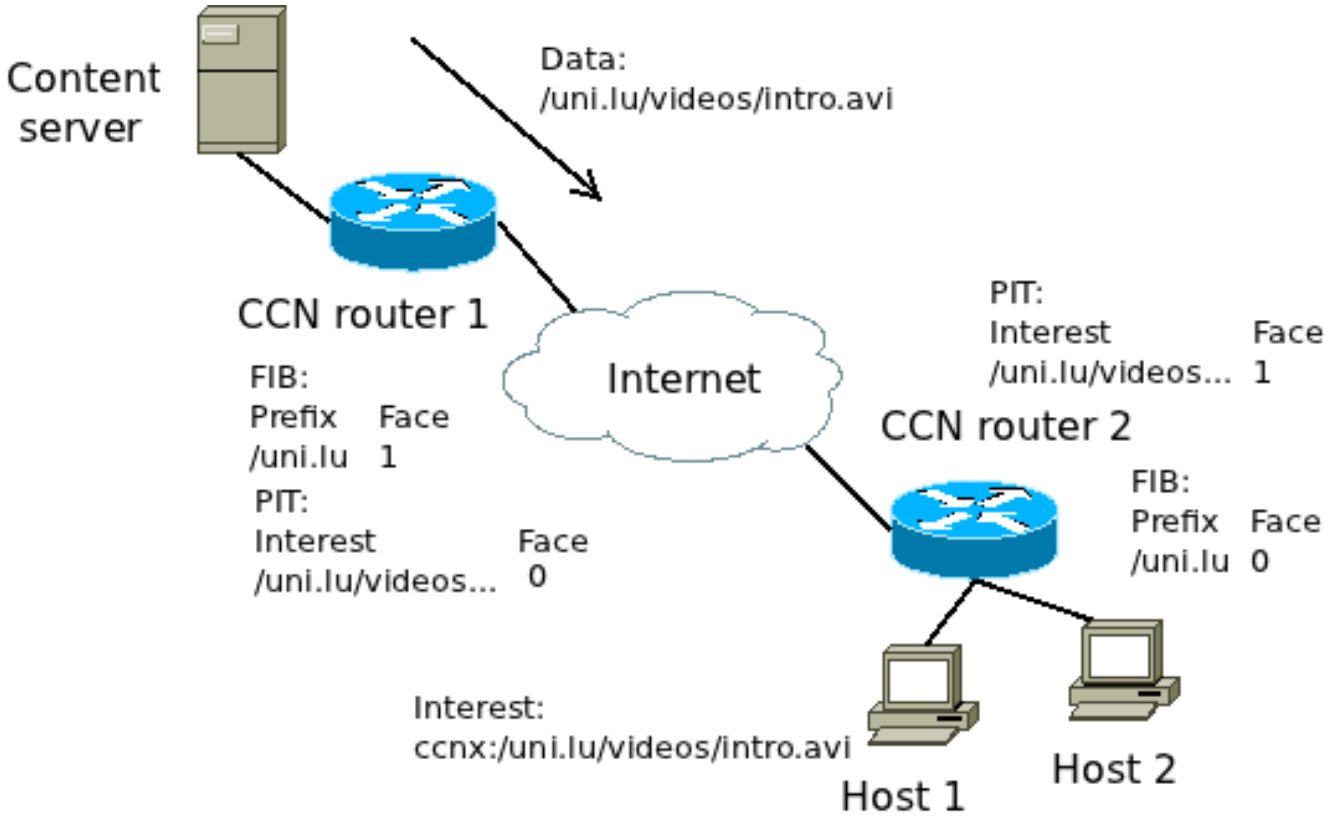

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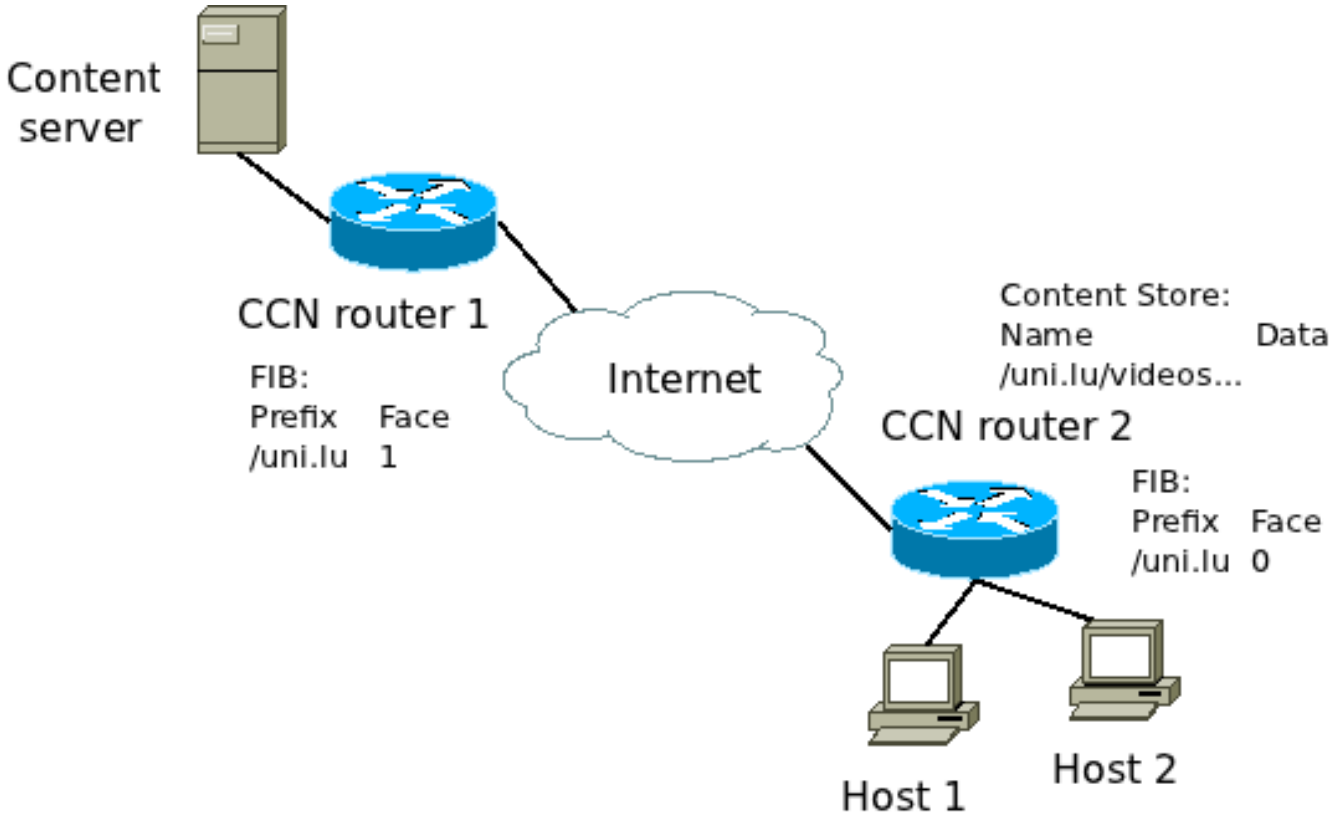

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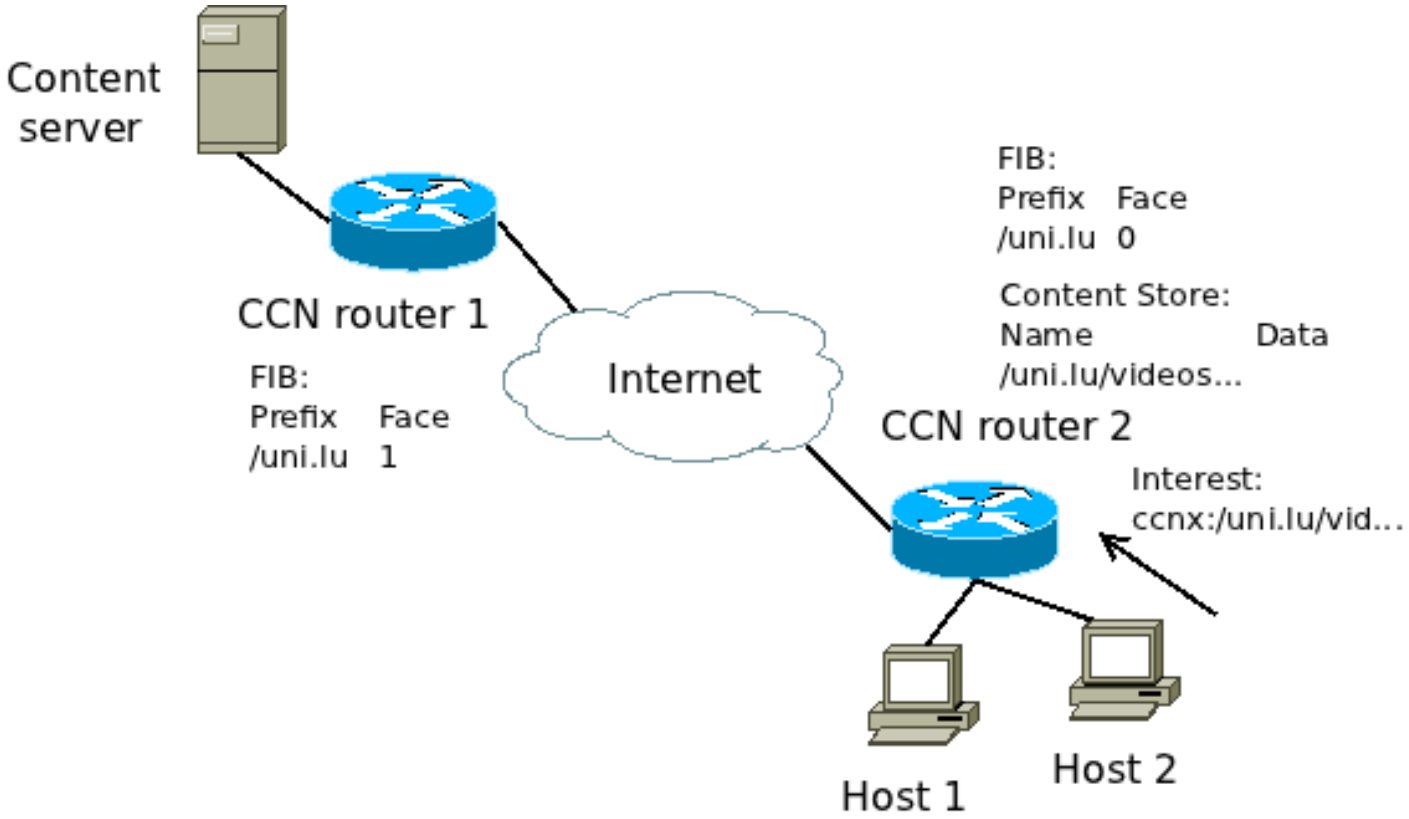

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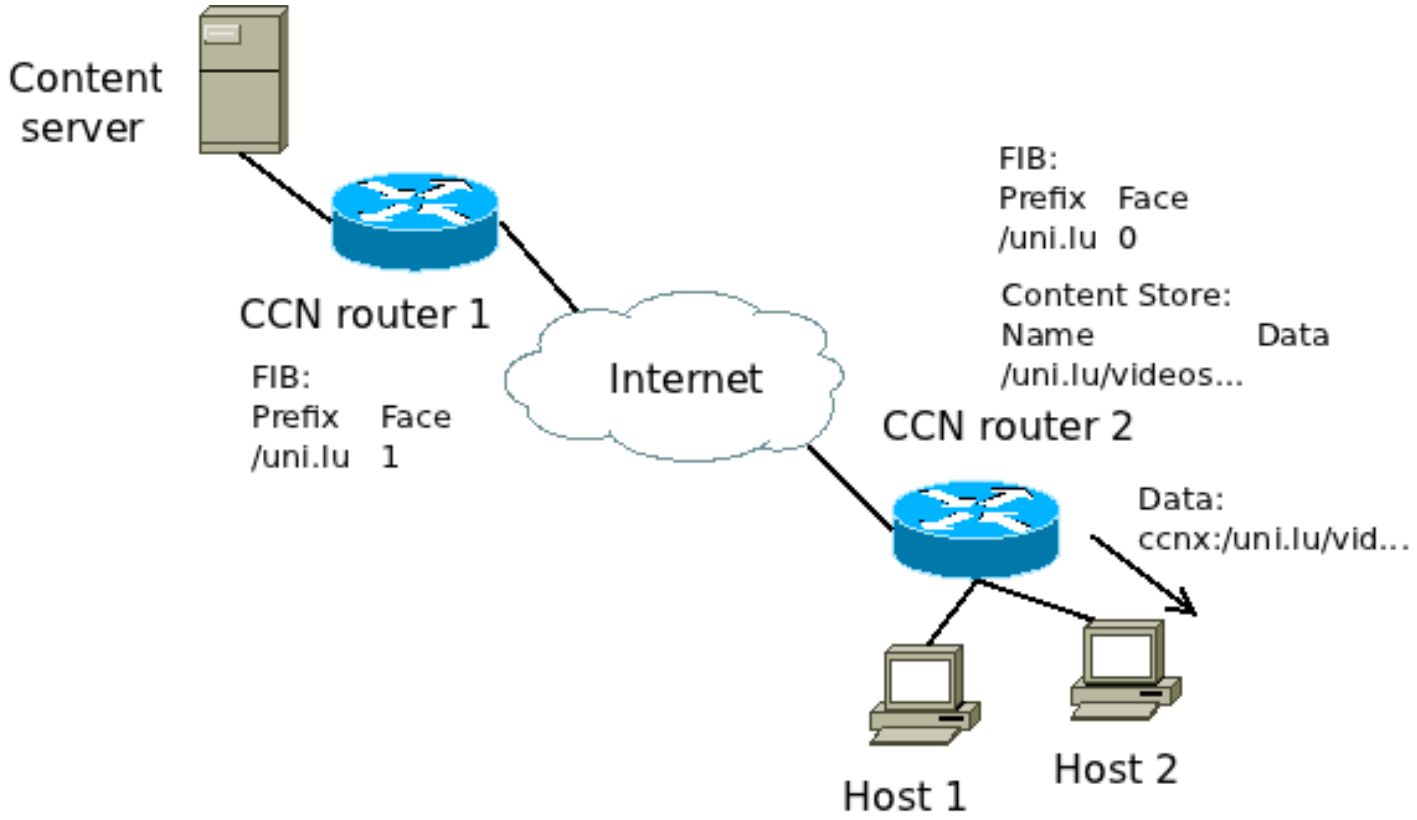

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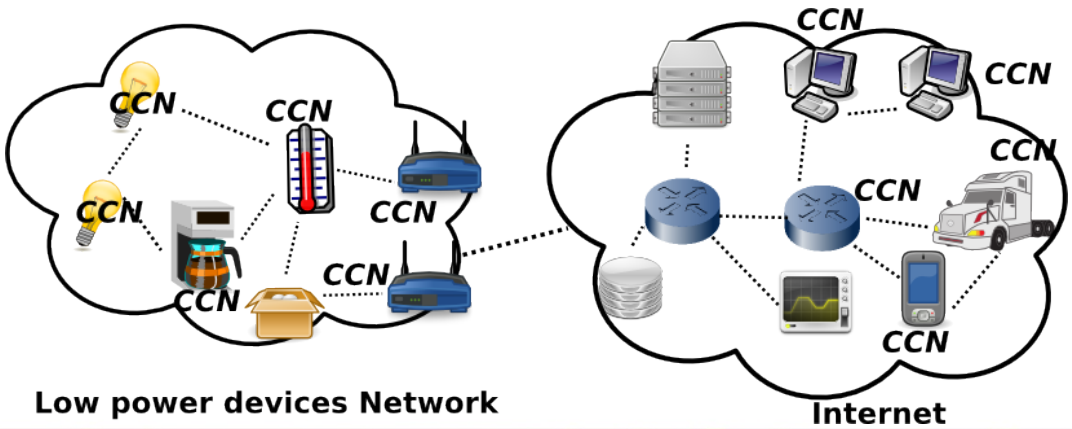
CCN deployment

- CCN faces → transparent IP network transversal
- CCN at all sides: sensors, servers, user devices
- context of this work = sensor communication optimization (low power devices)
- → retrieved sensed information
  - push based communication
  - regular updates (every 10 sec, 5 minutes)
  - multiple consumers (with different update frequencies)



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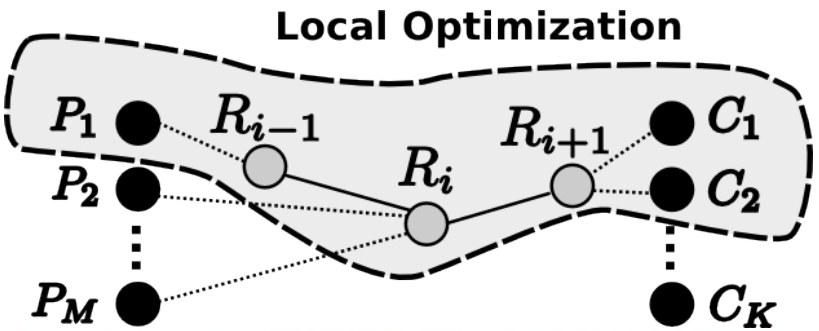
Formal problem

- Limited resources (CPU, memory, energy...)
  - no broadcast / no multicast to every consumer at every time unit
  - example: temperature update every 10 sec, service need update every 5 minutes → overhead = 29 messages
- Problem definition
  - M producers, K destinations, CCN routers
  - Disjoint sensed information → local problem
    - 1 producer, N consumers $C = c_1, \ldots, c_N$ with sampling periods i_j
    - R_i: Cap_i (available ressources)
    - objective: $min(msg(R_i))$



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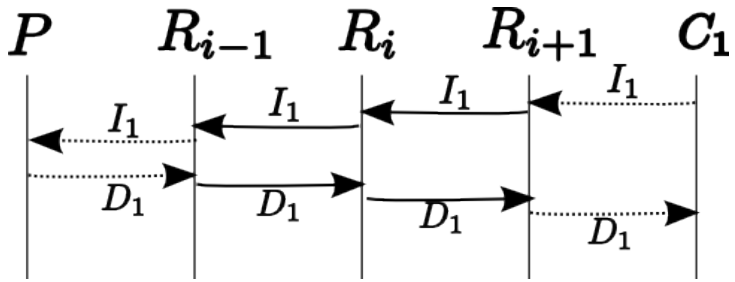
Push-based communication

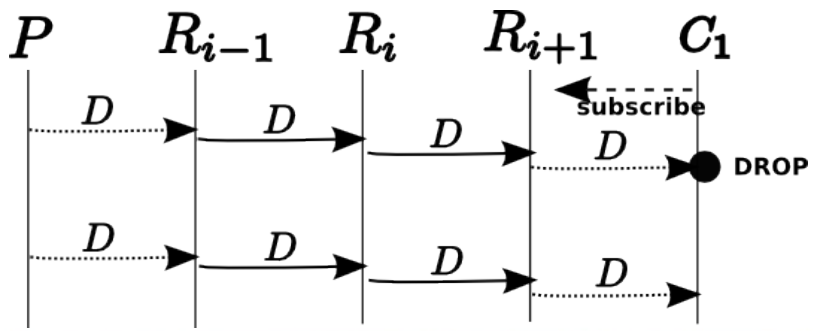
- CCN data forwarded when an interest is emitted = pull model



- SotA propositions
  - Jacobson *et. al*, ACM ReArch 2009: creation of a rendez-vous point → transaction model, individual demand from the producer (no subscription mechanism)
  - Carzaniga *et. al*, ACM SIGCOMM ICN 2011: dissemination of ephemeral messages → a new unicast table (no multicast) based on IP routing for avoiding routing loops

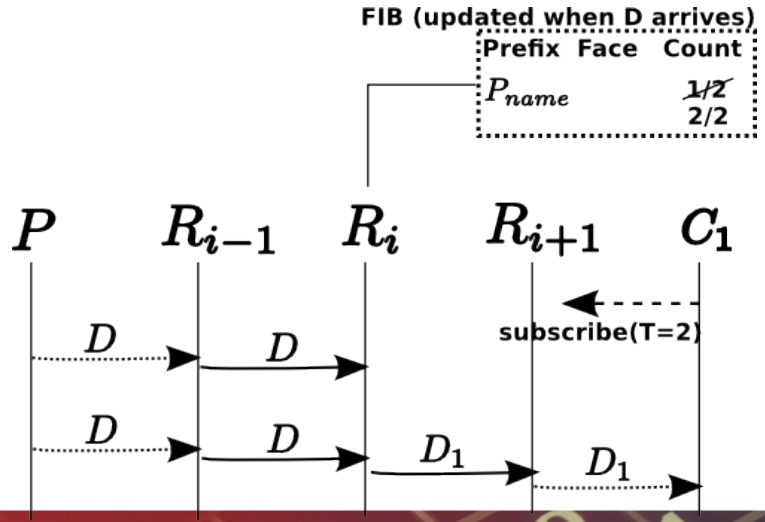
Push-based communication

- Approach overview
  - subscription = content publications
  - sensor value disseminations
    - → use the standard FIB to disseminate sensor value
    - interest message towards the consumer content name prefix + value as its suffix
    - */roomA/thermometer/value/20*
    - → but does not work as there is no content in the other way
    - use FIB for forwarding not requested content → no PIT update
    - → routing loop (interests are not consumed anymore → *last_seen* flag in FIB



Simple filtering

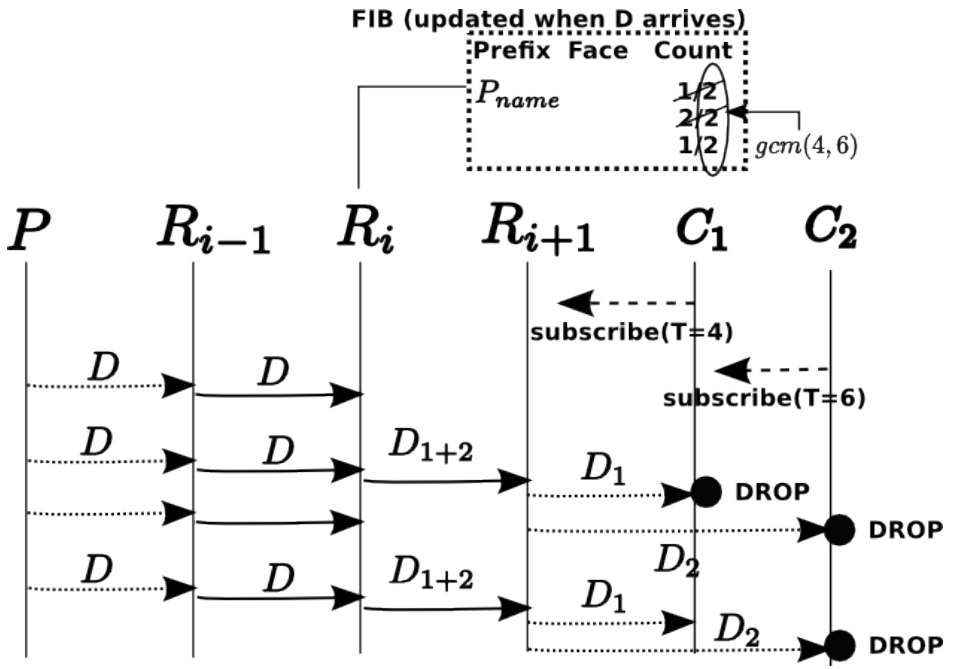
- Avoid sending useless dropped messages
  - simple filtering
    - the router only forwards data to C_i at the period t only if the consumer C_i has expressed its interest regarding this period
    - $\rightarrow$ t is a multiple of the sampling period i_i
    - $\rightarrow$each C_i has to specificity its sampling period to R_i (smart router)
    - need a counter in the FIB, one counter per subscriber = optimal strategy



Smart forwarding – gcd

- Use a limited number of counters Cap_i
- Extreme case $Cap_i = 1$
  - apply partially simple filtering
  - some packets still dropped $\rightarrow$ minimize it

- remove identical subscribed periods i_i
- if multiples in subscribed periods and keep the smallest, *e.g.* $i_1 = 2$ and $i_2 = 4 \rightarrow$ forward packets every 2
- extend the previous concept using the GCD (Greatest Common Divisor)



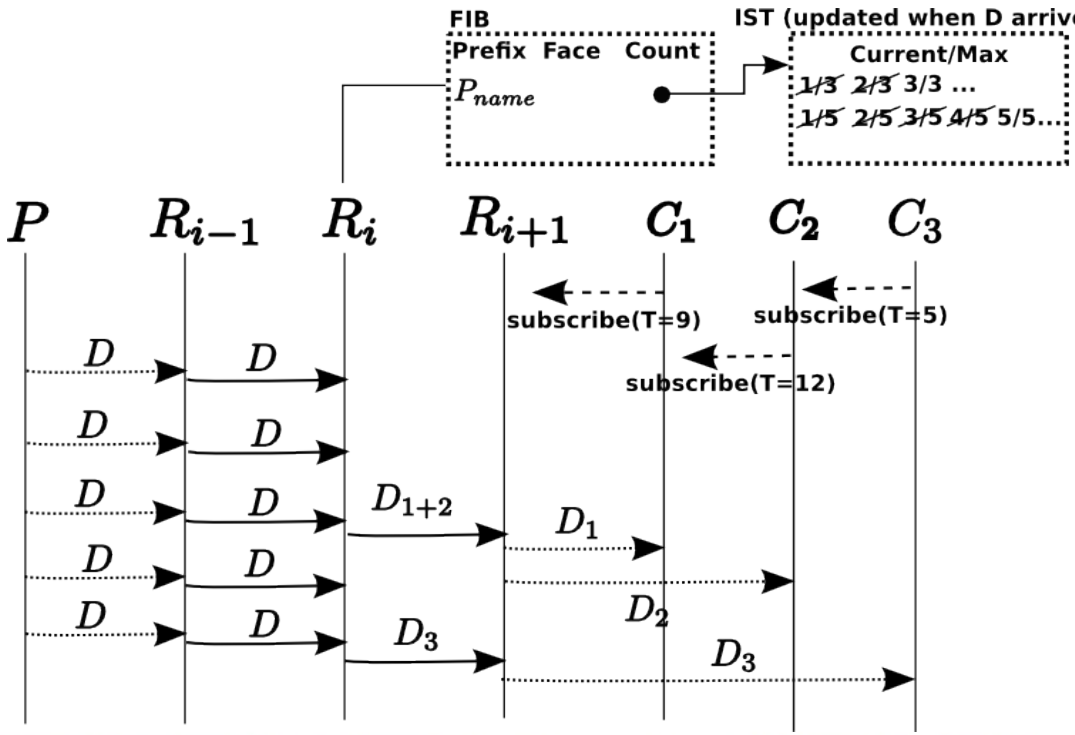
Smart forwarding

- More counters, $Cap_i > 1$
  - IST (Information Sampling Table) for tracking multiple counters
  - guarantee that each C_i receives the packets as subscribed or more
  - $\rightarrow$ select $G = \{g_1, \ldots, g_{Cap_i}\}$ such that:

$$\forall C_i \in C, \exists g_k \in G, \alpha \in \mathbb{N}, g_k \times \alpha = i_i$$

- incremental IST updates
- heuristic: maximal GCD between two i_i

1: T: new registered interval
2: $G.append(T)$
3: **if** $|G| > Cap_i$ **then**
4: $g\_select \leftarrow g_i \in G, \forall g_k \in G, gcd(g_i, T) \geq gcd(g_k, T)$
5: $G.replace(g\_select, gcd(g\_select, T))$
6: **end if**



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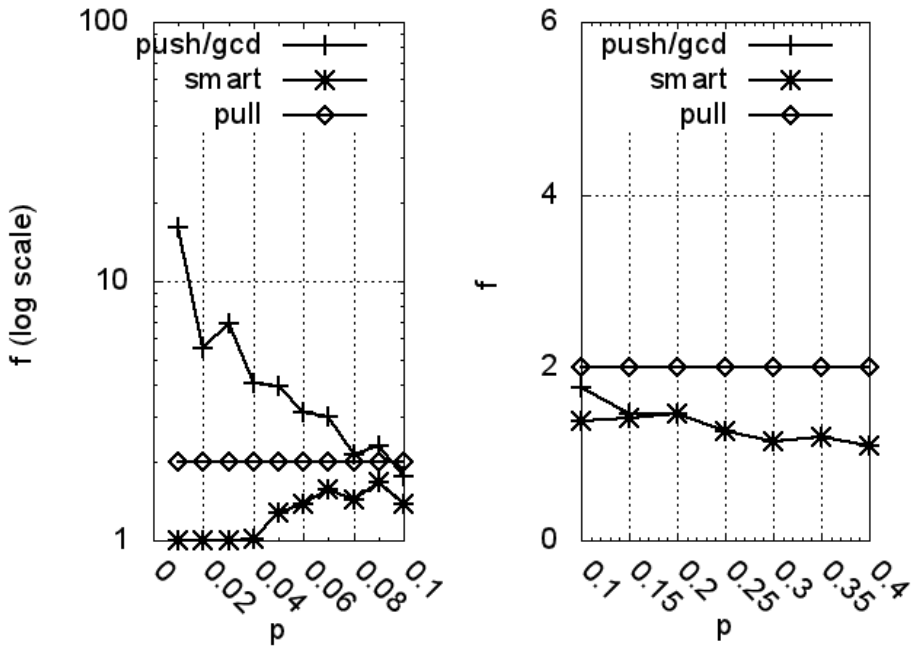
Methodology

- Basic simulator
  - limited functions necessary to assess our approach
  - no PIT or Content Store, no physical layer...
- Parameters
  - MAX_T: maximal sampling interval that a consumer can subscribe to,
  - p: number of consumers with a unique sampling interval expressed as a proportion of MAX_T
  - $\#counters$: number of available counters,
  - $\#steps = 5 \times MAX\_T$ the number of simulation step, 1 step = the initial sampling period of the sensor
- Strategies
  - $s \in \{pull, push, optimal, gcd, smart\}$
  - message overhead: $f_s = msg_s / msg_{optimal}$
- i_i chosen randomly
- simulation executed 10 times

Number of consumers

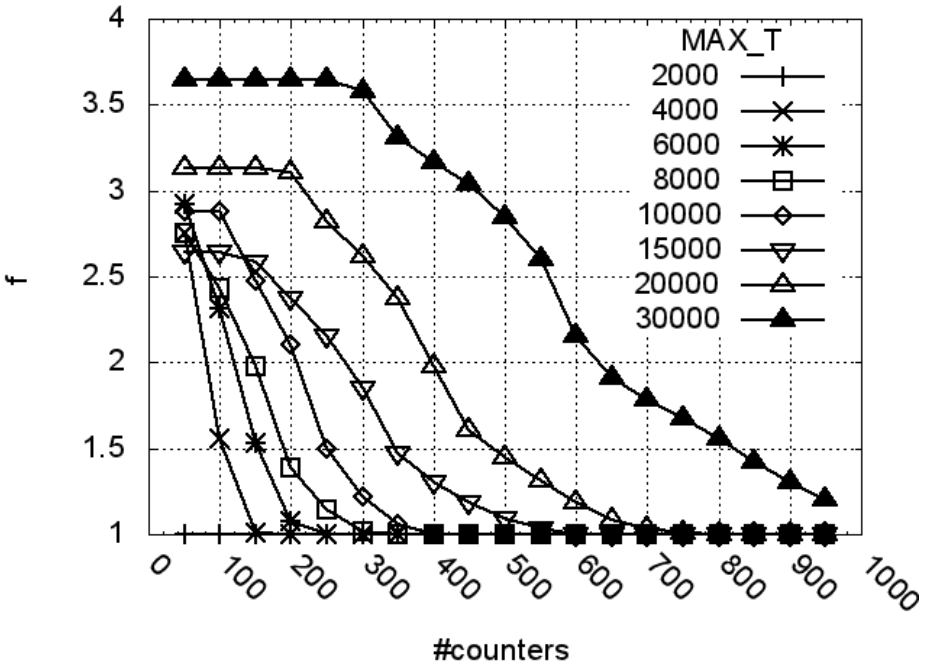
- $MAX\_T = 3000$, $\#counters = 100$
- *pull* strategy $\rightarrow$ 2 messages (1 interest + 1 data)
- prime numbers $\rightarrow$ $gcd = 1$ $\rightarrow$ $gcd \sim push$ (forwarding every packet)
- when p increases
  - more consumers $\rightarrow$ higher chance to have low i_i including 1
  - $\rightarrow$ all strategies tends to 1
- smart forwarding benefit
  - $1 < f_{smart} < 1.67$
  - $p < 0.04$ a unique counter per i_i (equivalent to *optimal*)
  - worst case: 240 unique subscribed periods ($p = 0.08$)



Number of consumers

- $p = 0.05 \times MAX\_T$
- smart forwarding strategy
- $\#counters$ and MAX_T vary

- when $\#counters$ increases $\rightarrow$ overhead reduces faster with less subscribers (lower MAX_T)
- fine tuning of Cap_i during the design phase of the sensor
  - assumption: a maximal overhead, a number of subscibers
  - $\rightarrow$ number of counters



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Conclusion

- CCN for distributed IoT communication
- Context: producers (sensors) regulary updating consumers
- A new push based mechanism to limit the message overhead based on subscription requests
- Smart forwarding is close to the optimal forwarding and always better than the standard pull based communication of CCN
- Future work: multiple-content producers

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