Green ICN

Toward Green Information Centric Networking

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Outline

- GreenICN
  – Architecture and Applications of Green Information Centric Networking
  - GreenICN at a glance
  - Objectives and Goals
  - Architecture
- Research Activities at Osaka University & KDDI R&D Labs.

GREENICN
– ARCHITECTURE AND APPLICATIONS OF GREEN INFORMATION CENTRIC NETWORKING

GreenICN at a Glance

- GreenICN
  – Architecture and Applications of Green Information Centric Networking
- Duration: 3 years (1 Apr 2013 – 31 Mar 2016)
- Website: http://www.greenicn.org

EU Coordinator:	JP Coordinator:
Prof. Xiaoming Fu	Mr. Shigehiro Ano
University of Göttingen	KDDI R&D Labs
Germany	Japan

SEVENTH FRAMEWORK PROGRAMME

Project Consortium

European Partners	Japanese Partners
EU Coordinator Georg-August-Universität Göttingen (UGO, Germany) **Contact:** Xiaoming Fu <fu@cs.uni-goettingen.de>	**JP Coordinator** KDDI R&D Laboratories Inc. (KDD, Saitama) **Contact:** Shigehiro Ano <ano@kddilabs.jp>
NEC Europe Ltd. (NEE, UK)	NEC Corporation (NEJ, Tokyo)
CEDEO (CED, Italy)	Panasonic Advanced Technology Development Co., Ltd
Telekomunikacja Polska (Orange Labs, Poland)	University of Tokyo (UTO, Tokyo)
University College London (UCL, UK)	Waseda University (UWA, Tokyo)

Existing Project Basis

EU

ICN related:

- FP7 COMET (UCL)
- FP7 CONVERGENCE (CNI, CED)
- 4WARD (NEE, OLP)
- SAIL (NEE)

Others:

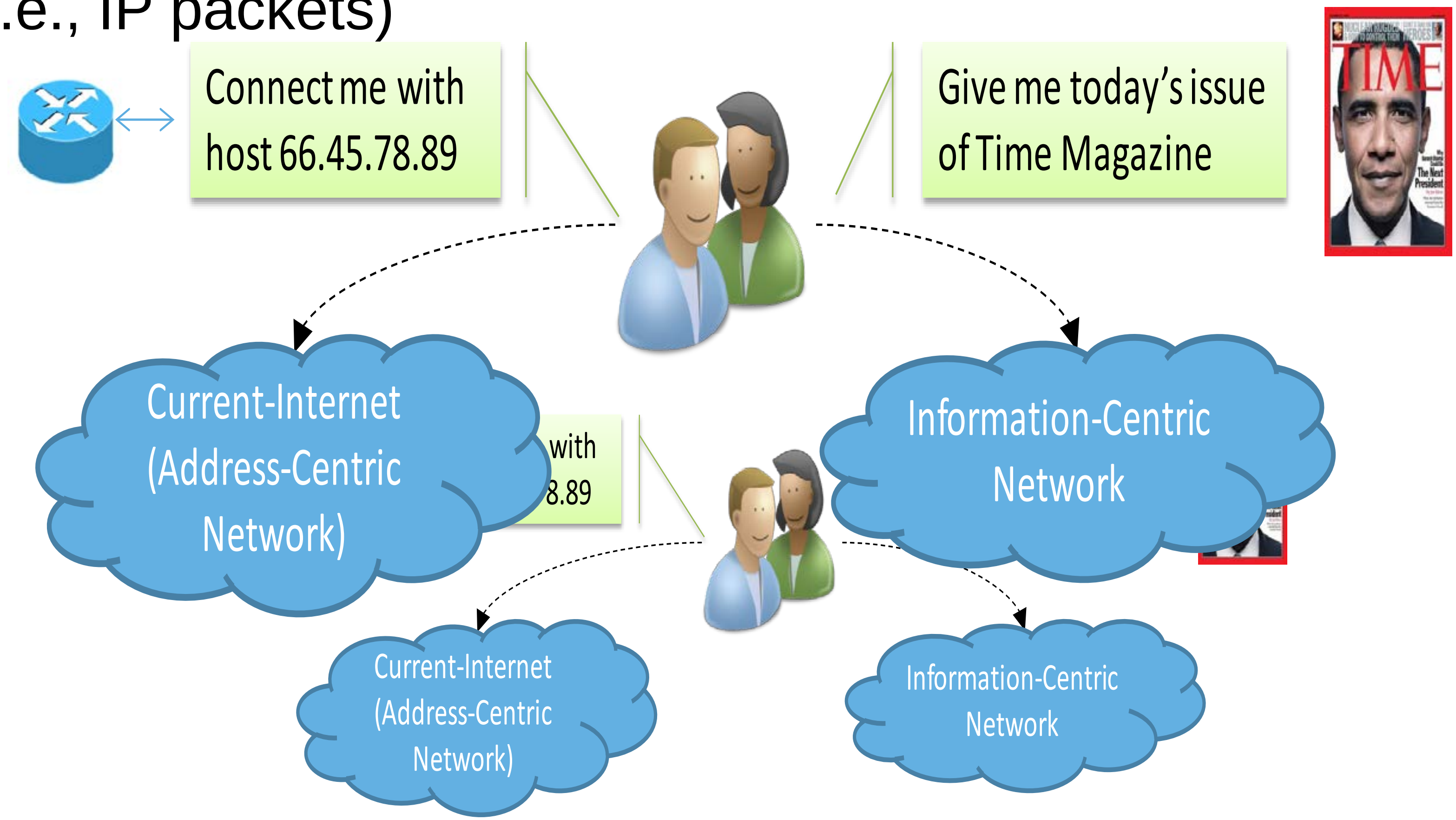
- FP6 ENABLE (UGO)
- FP6 Daidalos (NEE, UGO)

JP

- KDDI NICT projects
- NEJ NwGN projects
- UTO NEDO projects on energy efficient networking and disaster
- UWA MIAC & TAO projects on disaster security etc
- UOS JST projects on rescue management

ICN (Information Centric Networking)

- In ICN, network transfers individual, identifiable (named) content chunks, instead of unidentifiable data containers (i.e., IP packets)



GreenICN Objectives

- ICN: A new networking paradigm where the network provides users with named content, instead of communication channels between hosts.
  - **Many issues stay open:** naming, routing, resource control, security, privacy and migration path from today's Internet
  - **Missing seamless support of content-based publish/subscribe** for efficient information dissemination
  - Existing solutions do **not** sufficiently **address energy efficiency**.
- GreenICN 's scientific aim:
  - Develop innovative methodologies and approaches to optimize ICN paradigm in a highly-scalable and energy-efficient manner
  - Support two use scenarios: **disaster recovery**; **video delivery**

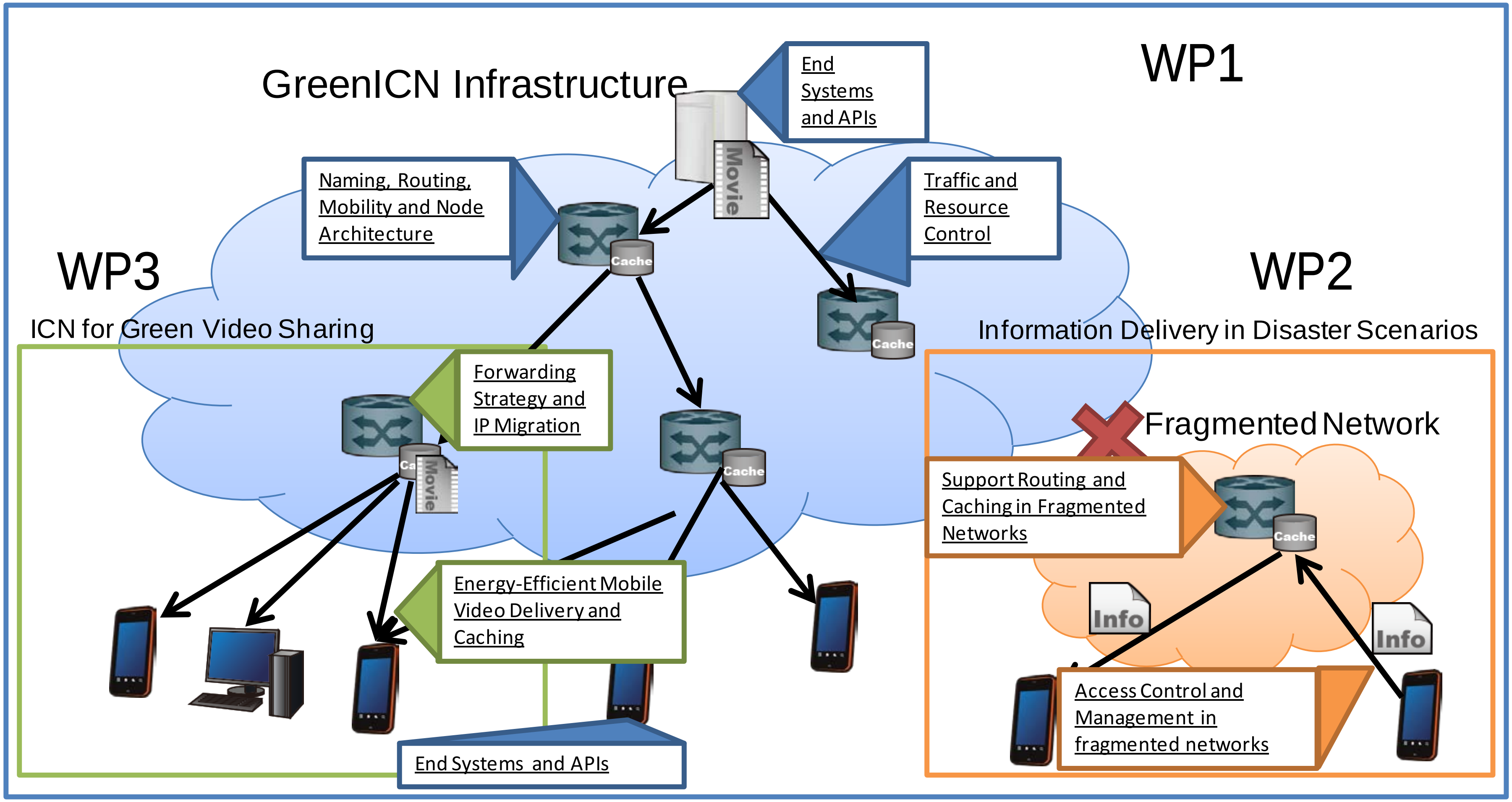
Goals

- Requirement 1: 20% Reduction of Power Consumption of GreenICN for Normal Days
  - EU announced that the total energy consumption of all EU countries should be decreased by 20%.
  - Japan announced a reduction of energy consumption of 30% by 2030, compared to that in 2003.
- Requirement 2: At Least 40% Reduction of Power Consumption of GreenICN (including end-user devices) for Disasters
  - In 2011, people in Tohoku area suffered 3 days of blackout because of the East Japan Earthquake.
  - The 40% reduction aims to make the communication services and related base stations able to operate 3 days in such a scenario.

Goals (Continued)

- Requirement 3: Seamless Services before and after a Disaster
  - The lesson learned at the 2011 East Japan Earthquake is that terminals and services specifically designed for disasters were useless, and that people wanted to use the same terminals and services used in their everyday life.
- Requirement 4: Migration Path
  - GreenICN should friendly coexist with the current IP network.
- Requirement 5: Scalability and size of the served contents and related names
  - GreenICN should be able to serve at least current Web contents with off-the-shelf technology.

GreenICN Architecture



Requirements and Architecture for Green Information Delivery

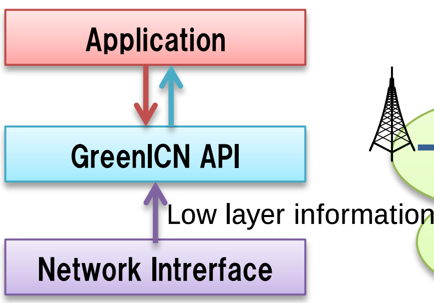
- **The objective is the identification of use scenarios and requirements and the definition of the GreenICN architecture.**

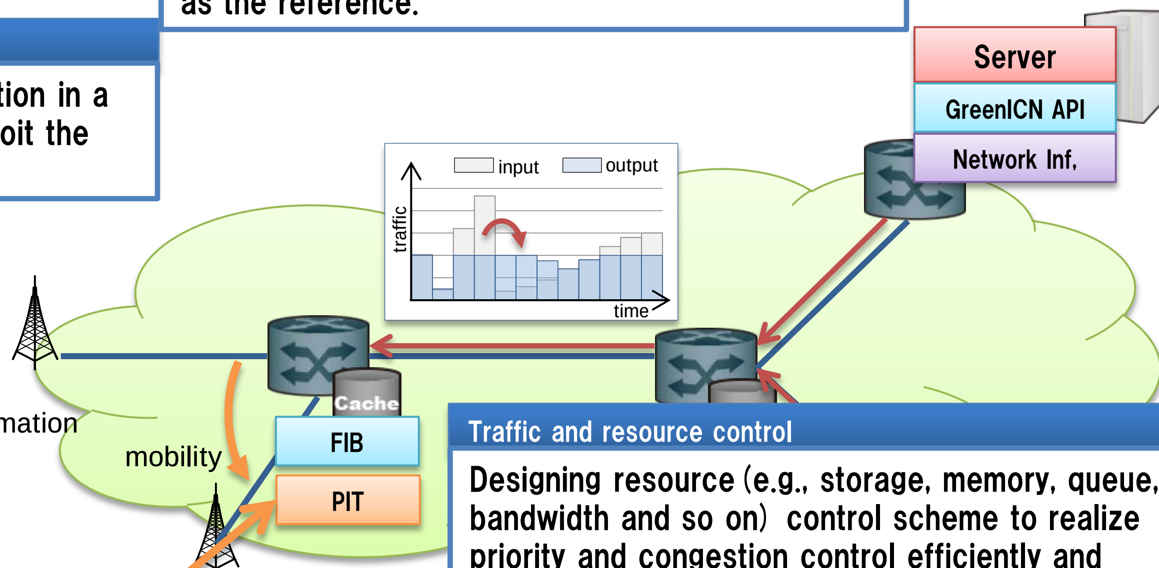
Use scenarios and requirements

Defining the overall GreenICN architectural framework, which will be used by the other WPs as the reference.

GreenICN end systems and APIs

Developing and specifying their instantiation in a middleware that makes it to optimal exploit the GreenICN features.





Traffic and resource control

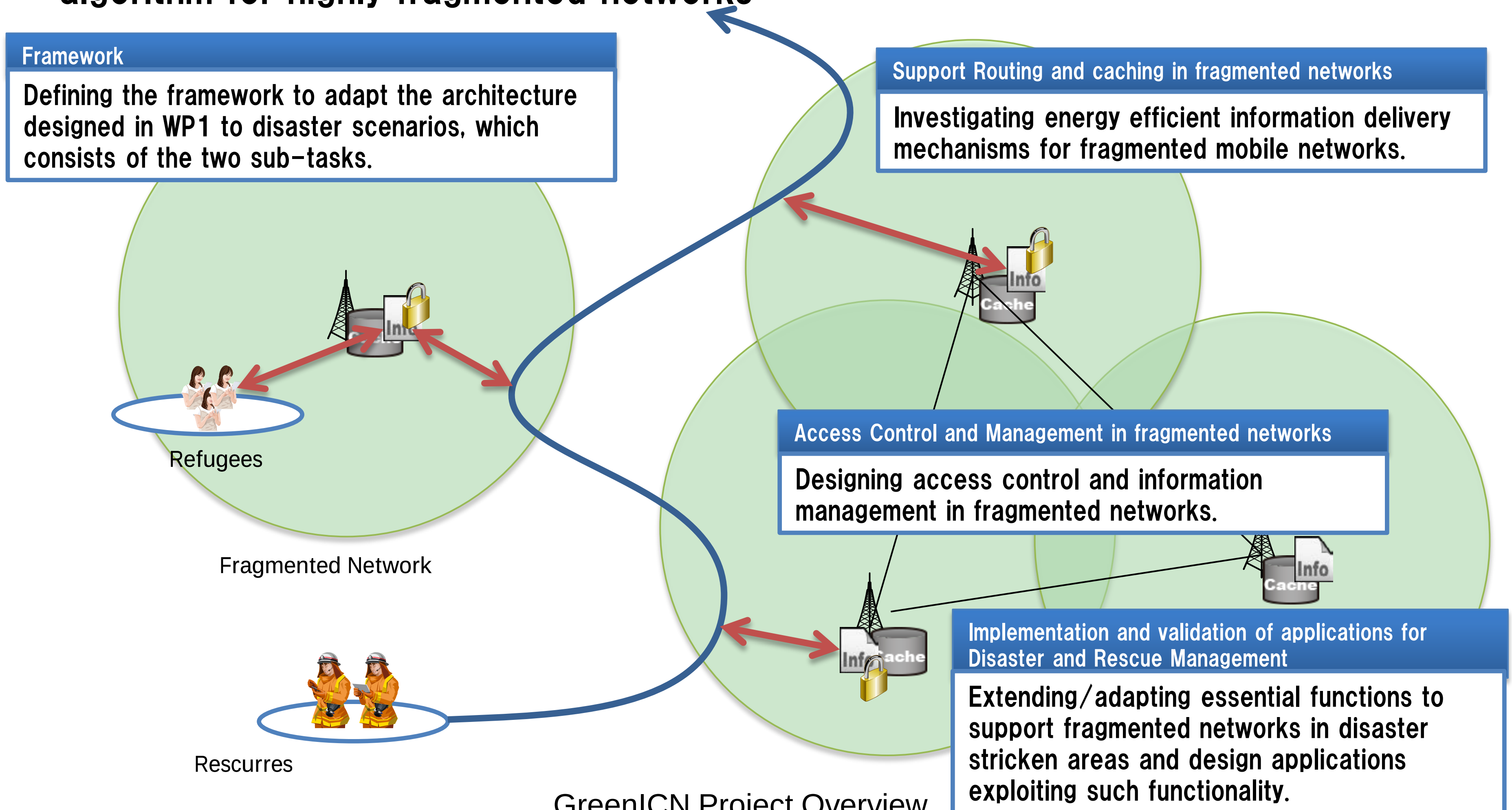
Designing resource (e.g., storage, memory, queue, bandwidth and so on) control scheme to realize priority and congestion control efficiently and robustly.

Routing and Forwarding Strategies

Designing the routing, forwarding, naming, mobility and the overall GreenICN node architecture for green information delivery networking.

Green Disaster Information Delivery and Rescue Management

- **Provide support for large-scale energy-efficient disaster information delivery for fragmented/disrupted mobile networks, including routing and cache management algorithm for highly fragmented networks**

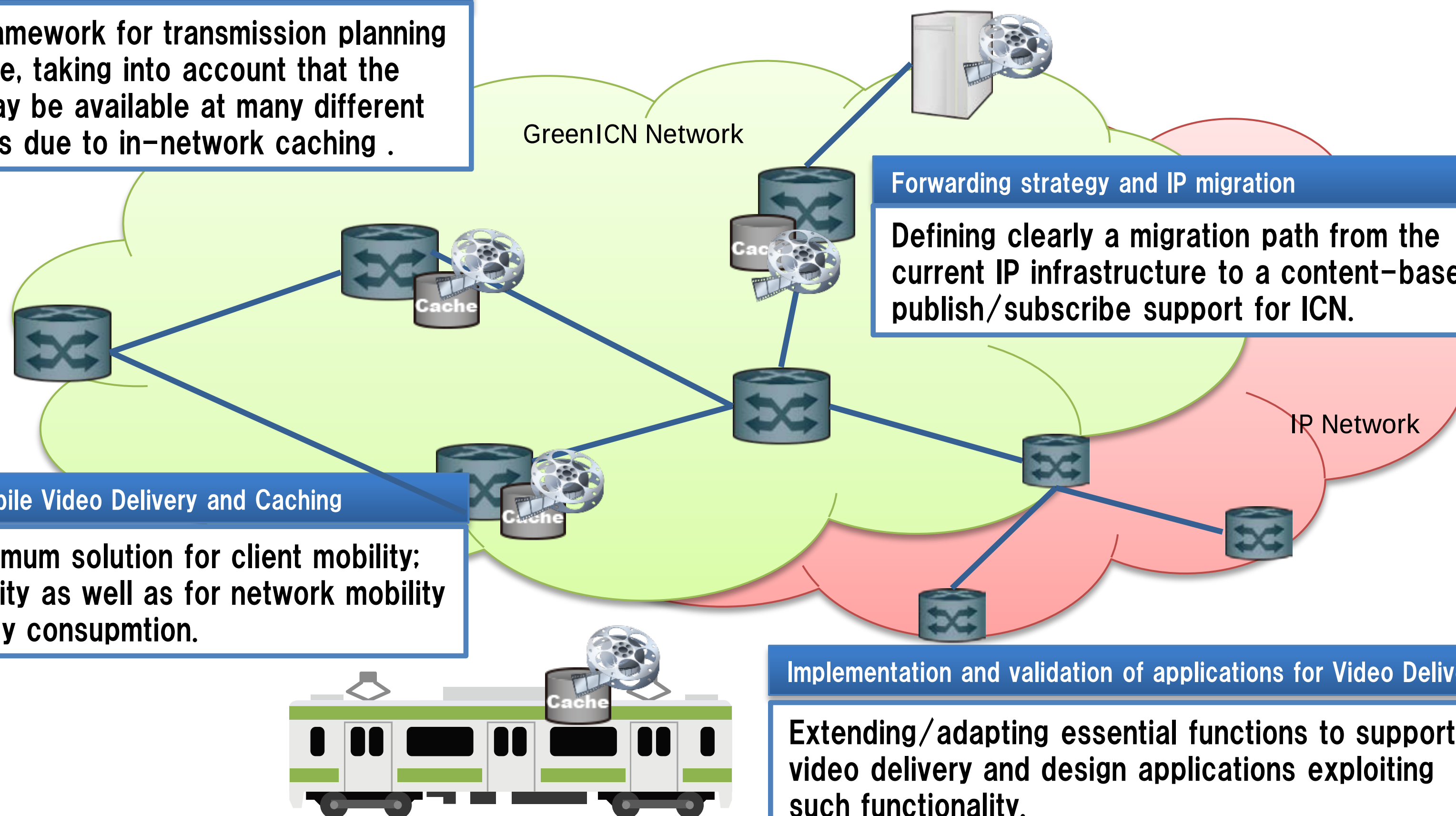


ICN for Green Video Sharing

- **Define a framework for collaboration and sharing incentives in order to achieve energy-efficient video delivery towards the access network**

Framework

Designing the framework for transmission planning in space and time, taking into account that the same content may be available at many different network locations due to in-network caching .



Forwarding strategy and IP migration

Defining clearly a migration path from the current IP infrastructure to a content-based publish/subscribe support for ICN.

Energy-Efficient Mobile Video Delivery and Caching

Investigating optimum solution for client mobility; for content mobility as well as for network mobility in terms of energy consupmtion.

Implementation and validation of applications for Video Delivery

Extending/adapting essential functions to support video delivery and design applications exploiting such functionality.

Status

- EU-JP Kick-off meeting in NEC Europe, Heidelberg, Germany, 13-15th May 2013
- WP1 (Use scenarios, requirements, problem statement, architecture) in good shape
- WP2-WP5 (Solutions) being intensively investigated:
  - E.g., UGOE&UCL's papers got accepted in SIGCOMM ICN 2013
- Liaison with US NSF NDN project being established
- Liaison with MPEG Forum being established

RESEARCH ACTIVITIES AT OSAKA UNIVERSITY & KDDI R&D LABS.

Issues

This talk's topic

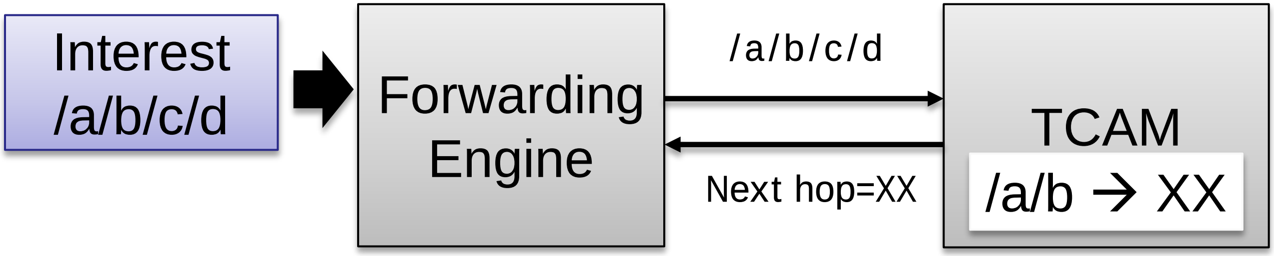
- Which architecture is GreenICN based on?
  - Human-readable names or self-certified names?
- What are benchmarks compared with GreenICN?
  - Standard ICN or IP networks (Current networks)
- What principles are taken for reducing consumed energy?
  - Define the energy consumption model to
    - Identify energy-intensive ICN operations such as prefix search and cache access which are bottlenecks to reduce energy consumption
  - Design mechanisms to
    - Revise such energy-intensive ICN operations to consume less energy
    - Allocate such energy-intensive ICN operations to some portions of ICN routers so that all of them need not always do such operations

CCN (Contents Centric Networking) router performance

- CCN router components
  - Content Store (CS)
  - Pending Interest Table (PIT)
  - Forwarding Information Base (FIB)
- We focus on FIB performance
  - Longest prefix matching (LPM) is mandatory
  - FIB needs to store even inactive name prefixes
  - Backbone router's FIB store numerous prefixes
    - Reference requirement: 620 million name prefixes
    - Number of web server host names of today
  - LPM is a both time and energy consuming task

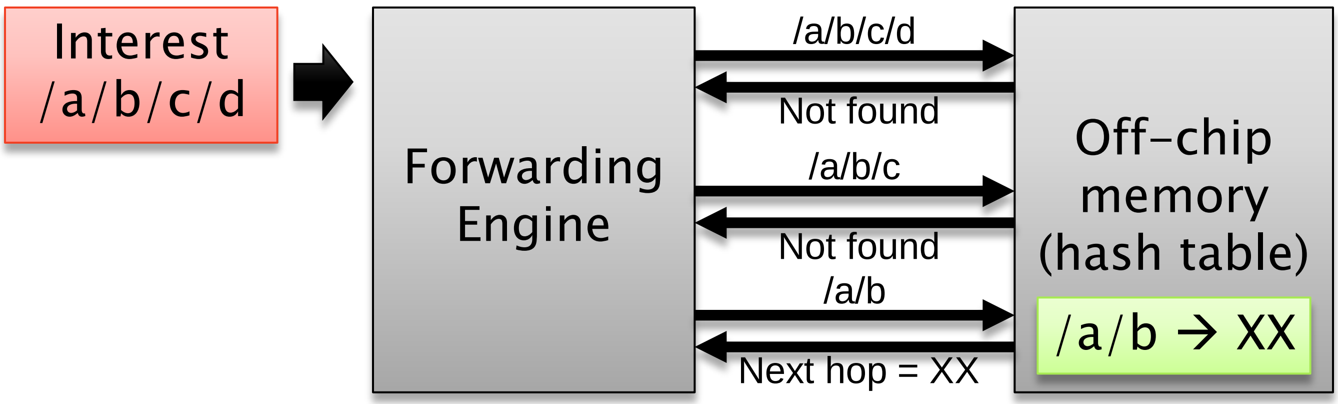
M. Fukushima, A. Tagami and T. Hasegawa, "Efficiently Looking Up Non-Aggregatable Name Prefixes by Reducing Prefix Seeking," Proceedings of IEEE NOMEN 2013, April 2013.

Existing solution for LPM:TCAM(Ternary Content Addressable Memory)



- Very fast and constant time lookup
- Limited capacity, high energy consumption
- Feasible to store 0.43 million IP prefixes
- Infeasible to store 620 million name prefixes

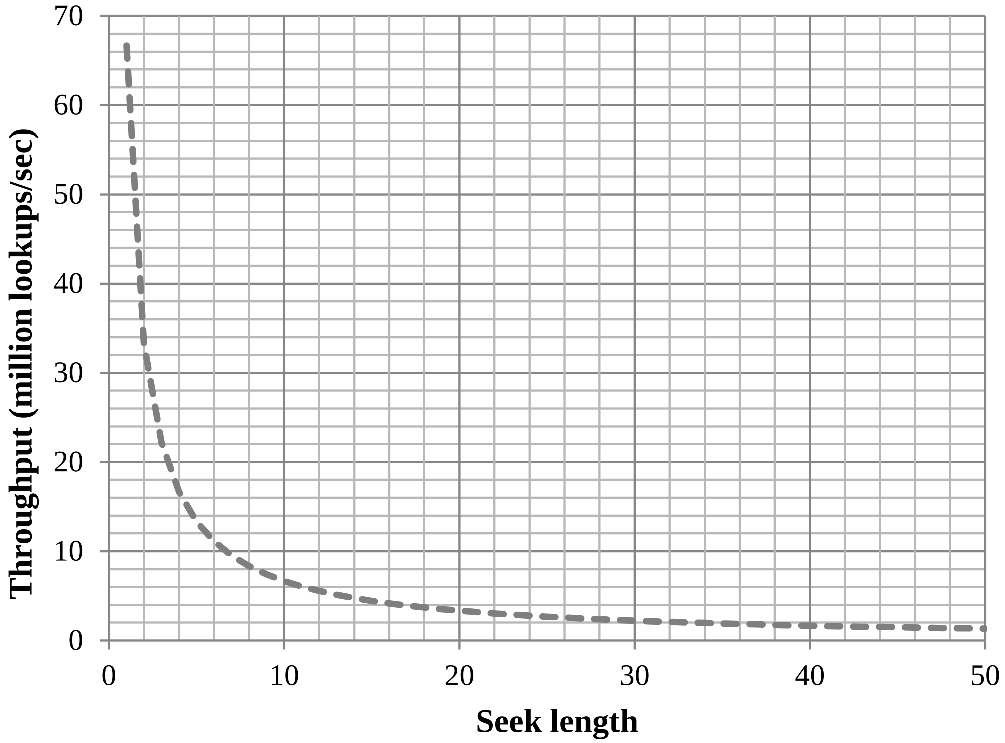
Existing solution for LPM:Off-chip memory(1/2)



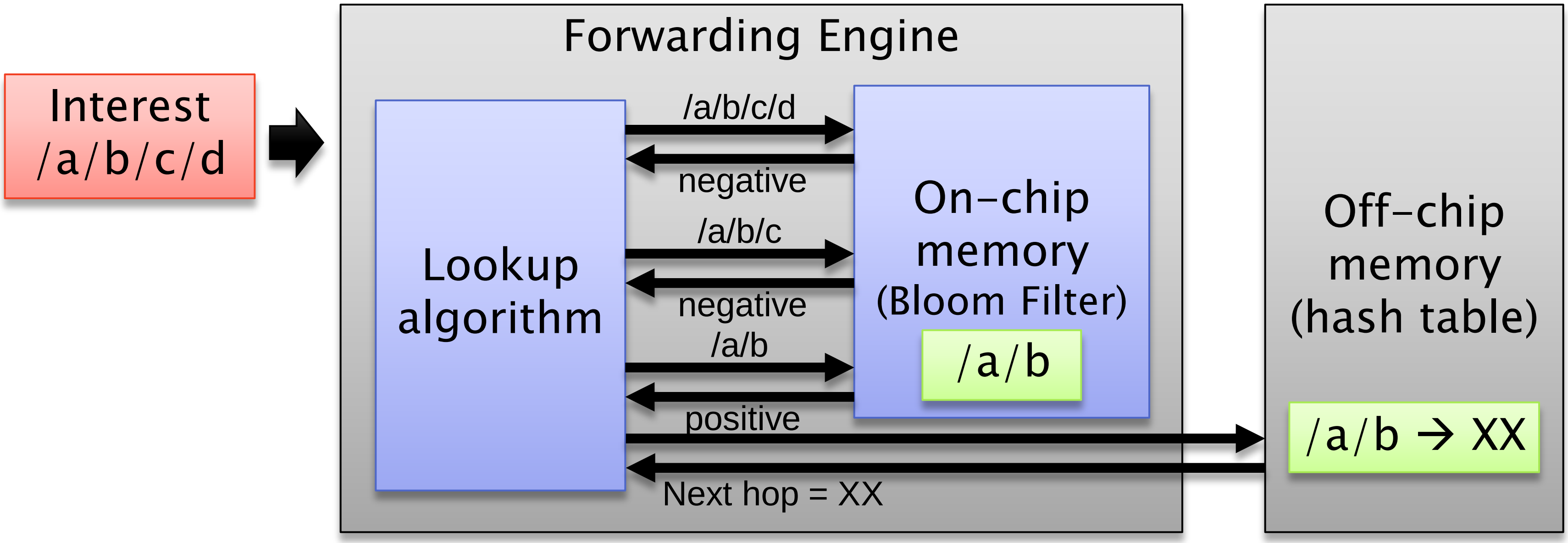
- Off-chip DRAM is the only feasible memory technology to store 620 million prefixes
- Need to seek for the longest matching prefix through all candidate prefixes (prefix seeking)
- Seek length: the number of prefixes required to be probed (e.g., it is 3 in the above example)

Existing solution for LPM:Off-chip memory (2/2)

- Throughput severely degraded for long names
  - Memory latency: 15 nsec (Reduced Latency DRAM)
  - Throughput is inversely proportional to seek length

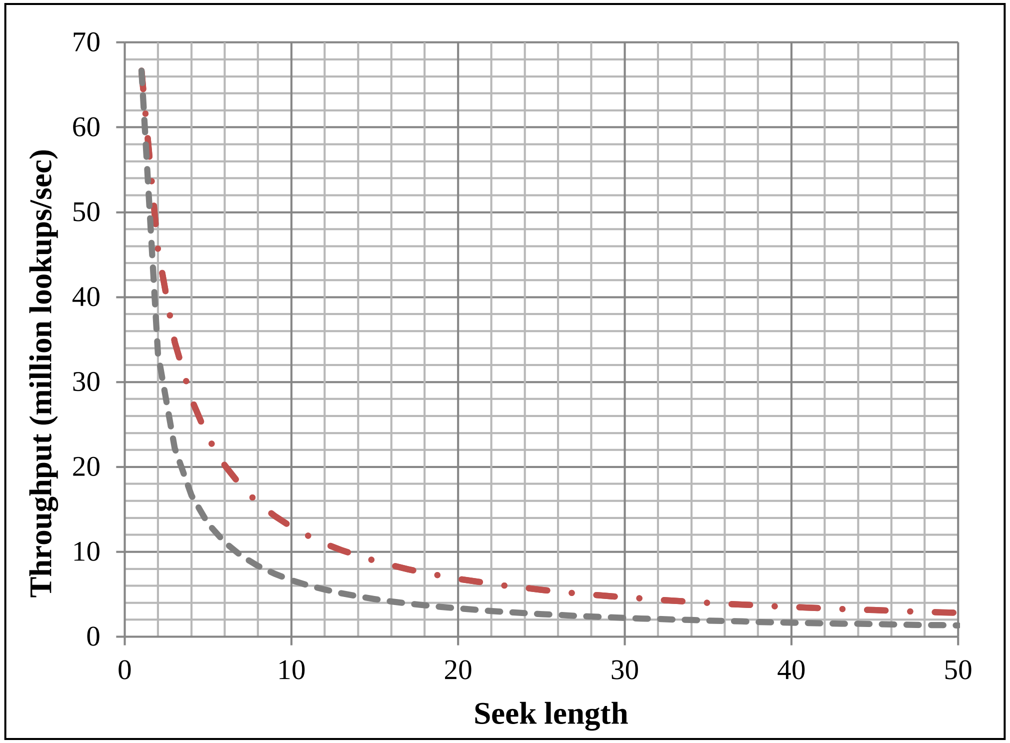


Existing solution for LPM:Off-chip/on-chip memory (1/2)



- Off-chip hash table with on-chip Bloom filter
  - Proposed for IP forwarding by Dharmapurikar, et al.
  - Applied to name-based forwarding by Perino and Varvello
  - Performance depends on the false positive probability of Bloom filter

Existing solution for LPM:Off-chip/on-chip memory (2/2)

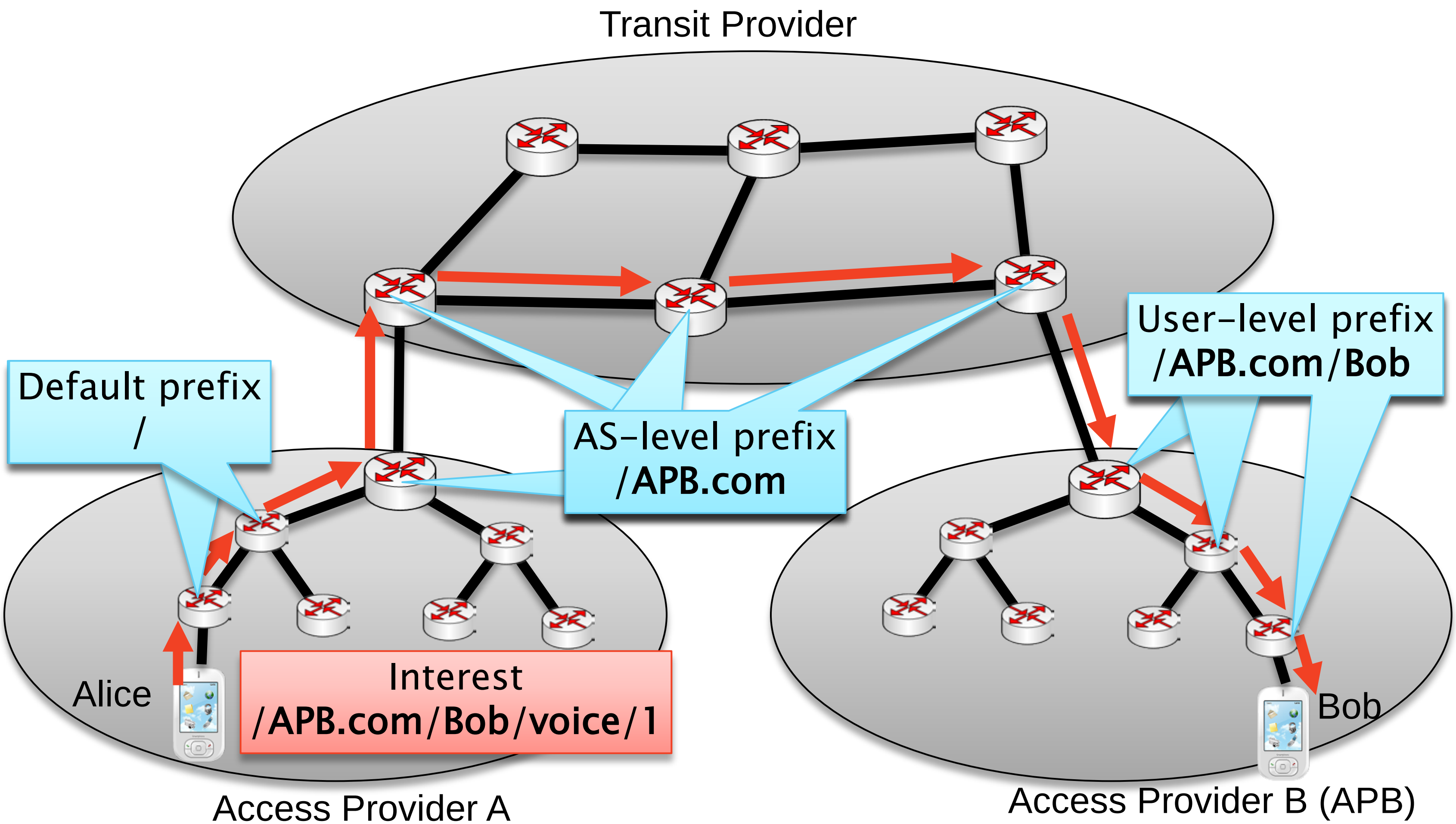


- On-chip memory is too small for 620 million prefixes
  - False positive probability
    - 96 % (68 Mbits on-chip memory, currently largest available on FPGA)
    - 54 % (1 Gbits on-chip memory, expected in future)

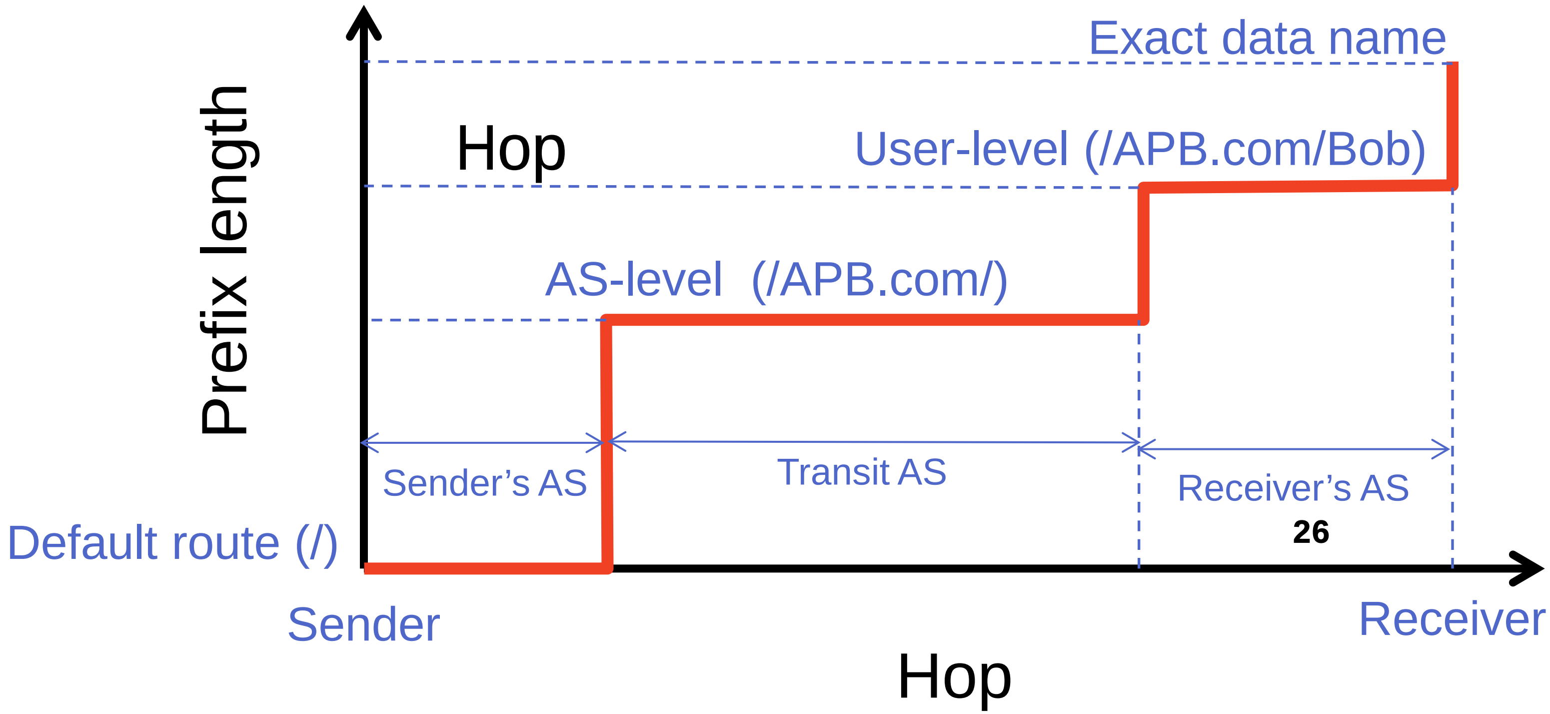
Observation

- If FIB size is very large, further speedup of prefix seeking is difficult
  - The bottleneck is simply memory latency
  - Off-chip memory latency improvement is slow
  - On-chip memory capacity is too small
- Can we avoid prefix seeking, instead of trying to speedup it?
  - Assumption
    - minor modification of protocol is acceptable
    - Typical usage of prefix is given

Typical forwarding path of Interest



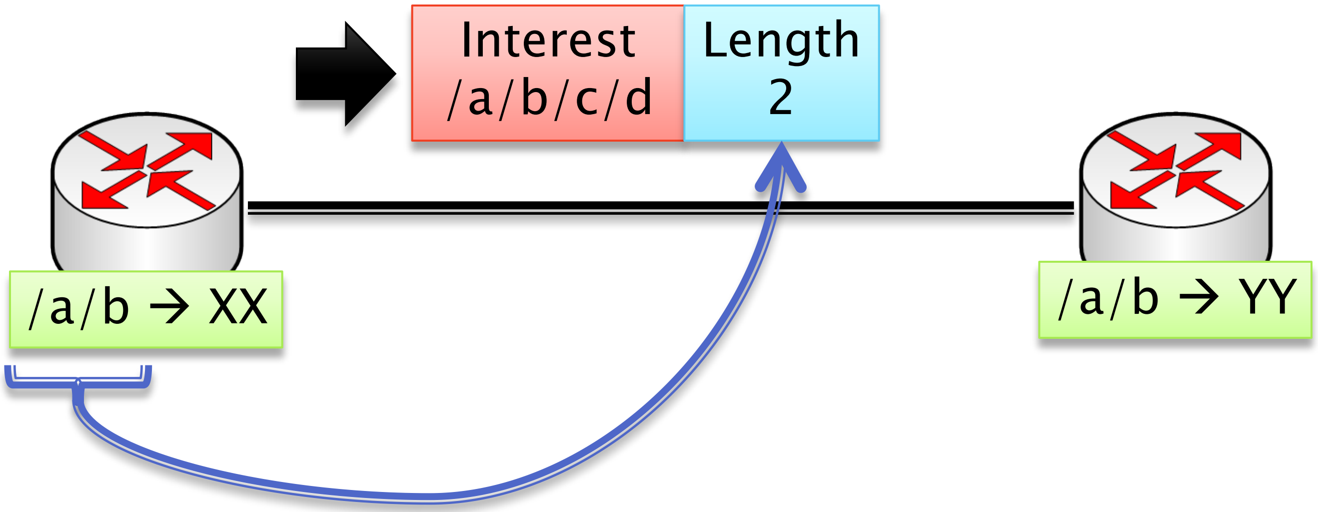
Prefix length is a step function



- Prefix length (i.e., routing granularity) does not change at most hops
- When it changes, prefix seeking is inevitable
- When it does not change, prefix seeking is redundant

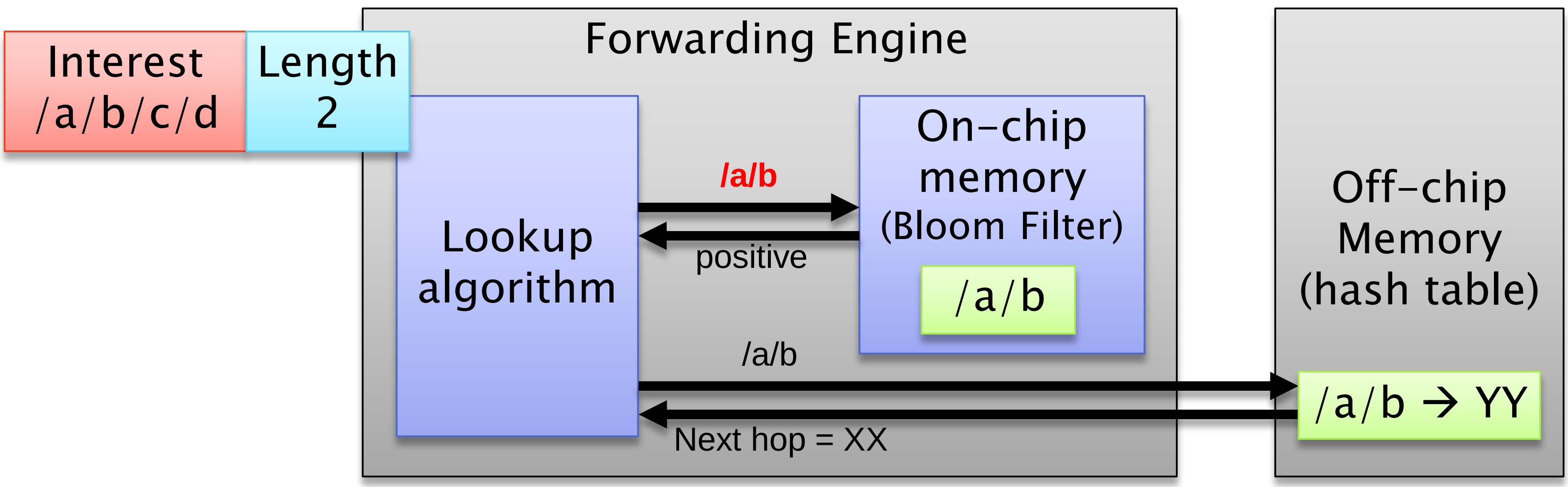
Proposed solution (1/2)

- Avoid redundant prefix seeking if possible!
- Firstly, the sending router insert a shim header carrying matching prefix length



Proposed solution (2/2)

- Secondly, the receiving router lookup the prefix of the same length
  - If it is found and has no child prefix (no more-specific prefix), it is the longest matching prefix
  - Otherwise, fallback to the conventional lookup scheme



How to decide the prefix of the same length is the longest matching prefix

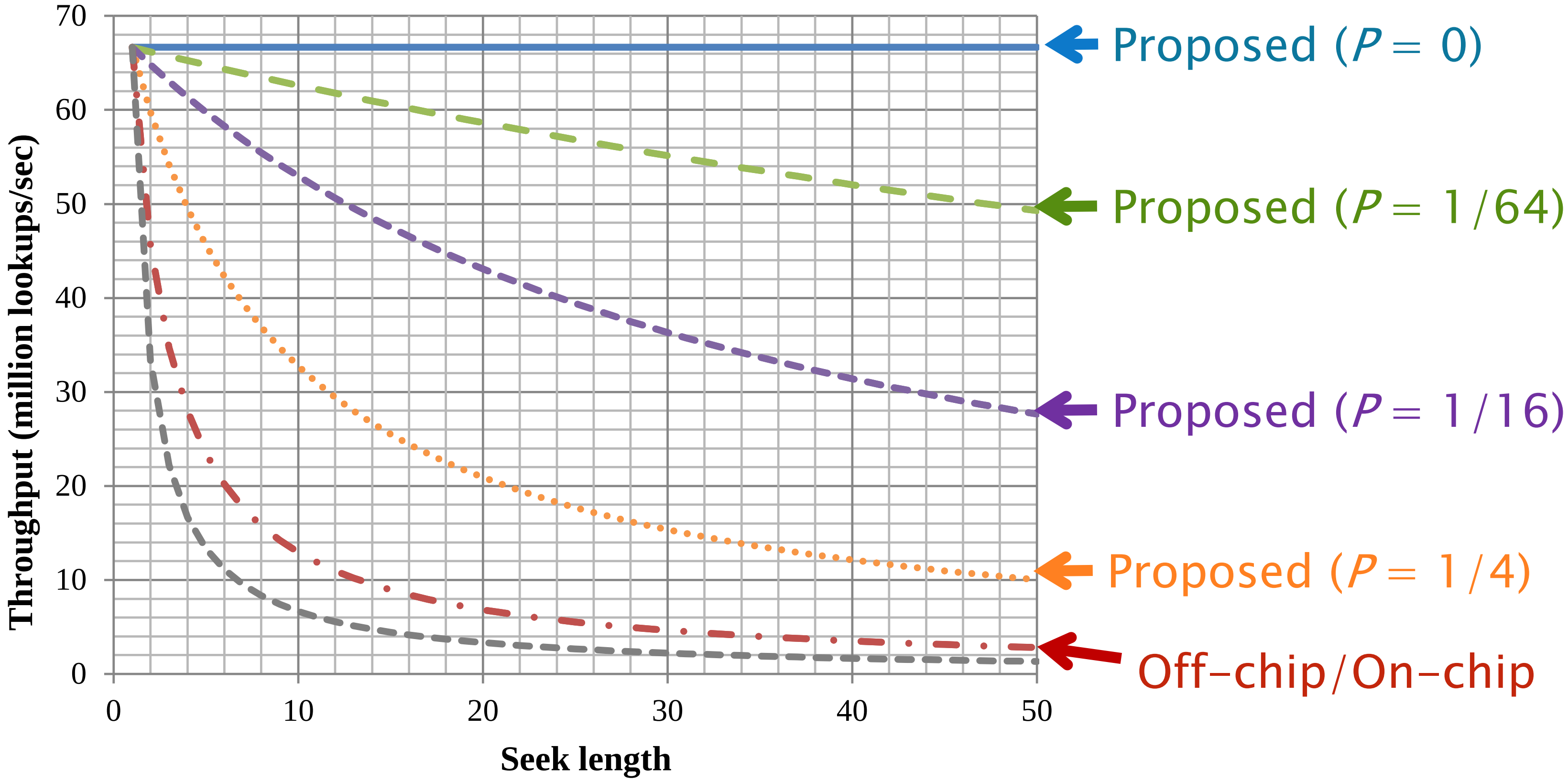
- Add a num_child field to each hash table entry
- Simple rule
  - If the prefix of the same length has its num_child == 0, it is the longest matching prefix
- Conservative results
  - If the prefix is surely the longest, skip prefix seeking
  - If the prefix may or may not be the longest, fallback
- Need to update num_child field when FIB is update

Pros and cons of proposed solution

- Advantages
  - Little forwarding overhead
    - Inserting a tiny link-local shim header
    - Checking num_child field
  - No need to modify network layer protocol
  - ISPs can locally deploy this scheme in a link-by-link manner
- Drawbacks
  - Performance depends on FIB contents
  - Security concern

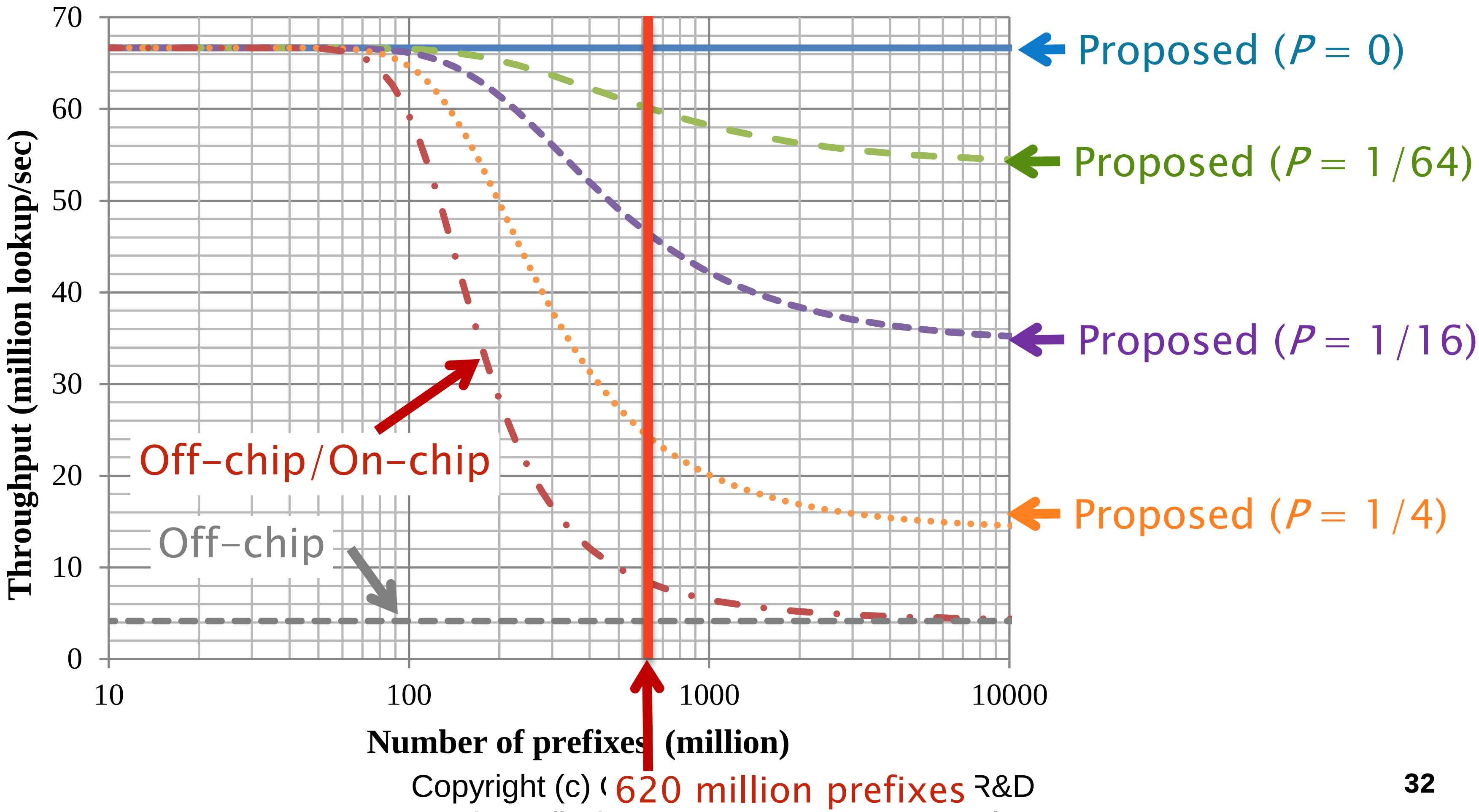
Evaluation: Impact of seek length

- P : the probability that a router cannot skip prefix seeking
- FIB size = 620 million prefix



Evaluation: Impact of FIB size

- P : the probability that a router cannot skip prefix seeking
- Seek length = 16



What is realistic value of P ?

- Depends on topology, router’s location, traffic matrix, etc.
- No real CCN dataset is available
- Preliminary estimate: 15%
  - PoP-level topology from Rocket Fuel dataset
  - Synthesize PoP-level traffic matrix
  - Route traffic by shortest path routing
  - Prefix length is determined by source and sink of traffic
  - Average over all PoP-level backbone routers

Security concerns

- If applied only to intra-domain links
  - No security concern
  - No performance improvement at domain border
- If applied to inter-domain links
  - Passive attack (misuse of observed prefix length)
    - E.g., longer prefix length might imply some business relationship between ISP and content provider
    - Can be mitigated by sending a fake prefix length
  - Active attack (sending incorrect prefix length)
    - It is not likely, because the proposed solution is a link-local protocol and the attacker can be easily identified

Summary of Prefix-seek Reduction

- Conclusion
  - Seeking for longest matching prefix incurs high off-chip memory latency
  - Most of prefix seeking is redundant
  - Proposed a solution to eliminate this redundancy, and improve FIB throughput
- Future work
  - More thorough evaluation and parameter validation
  - Application for energy efficiency

Summary

- ICN: a new paradigm for future Internet
- GreenICN:
  - an EU-Japan collaborative effort
    - Design of innovative architectures and applications for green ICN
    - Fusion of ideas from leading academia and industry partners
    - Demonstration and evaluation through implementation
  - The work has been carried out in the framework of the FP7/NICT EU-JAPAN GreenICN project.
- Research activities at Osaka University and KDDI R&D Labs.
  - Energy consumption model and efficient prefix seek

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The research leading to these results has received funding from the EU-JAPAN initiative by the EC Seventh Frame-work Programme (FP7/2007-2013) Grant Agreement No.608518 (GreenICN) and NICT under Contract No. 167.