ITU Kaleidoscope 2015

Trust in the Information Society

Proactive-Caching based Information Centric Networking Architecture for Reliable Green Communication in ITS

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Introduction

Waseda University

- **Problem statement and research motivation**

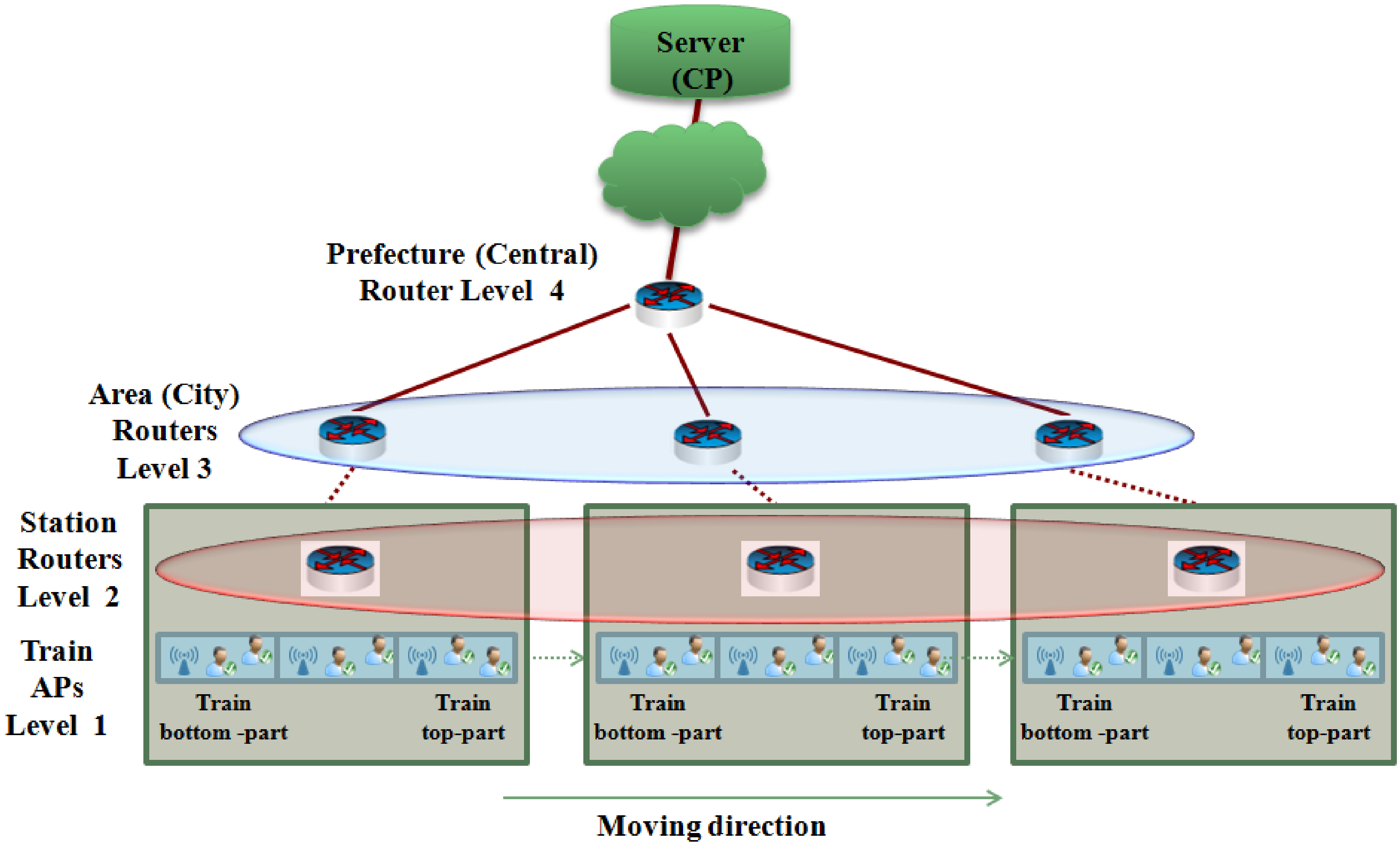
  In this research, the train system is stated for the case of ITS.
  - Nowadays, train is a popular public transportation vehicle.
  - The train's commuters also have high tendency to use their mobile devices for getting their interested information from Internet during the time they spend on train.
  - Motion of a commuter can be predicted from path of a train line and the moving direction, stopping time along with the moving time between two stations can be pre-determined.
- **Proposal goal**

  Construct a concrete model as a prototype of energy-efficient and reliable DAN (Data Aware Networking) based wireless communication technology **within the context of ITS.**

NOTE: In ITU (standardization) documentations, ICN (Information Centric Networking) concept is reflected as DAN (e.g. ITU-T, "Recommendation ITU-T Y.3033: Framework of data aware networking for future networks," 2014).

Proposed DAN Network Topology for ITS

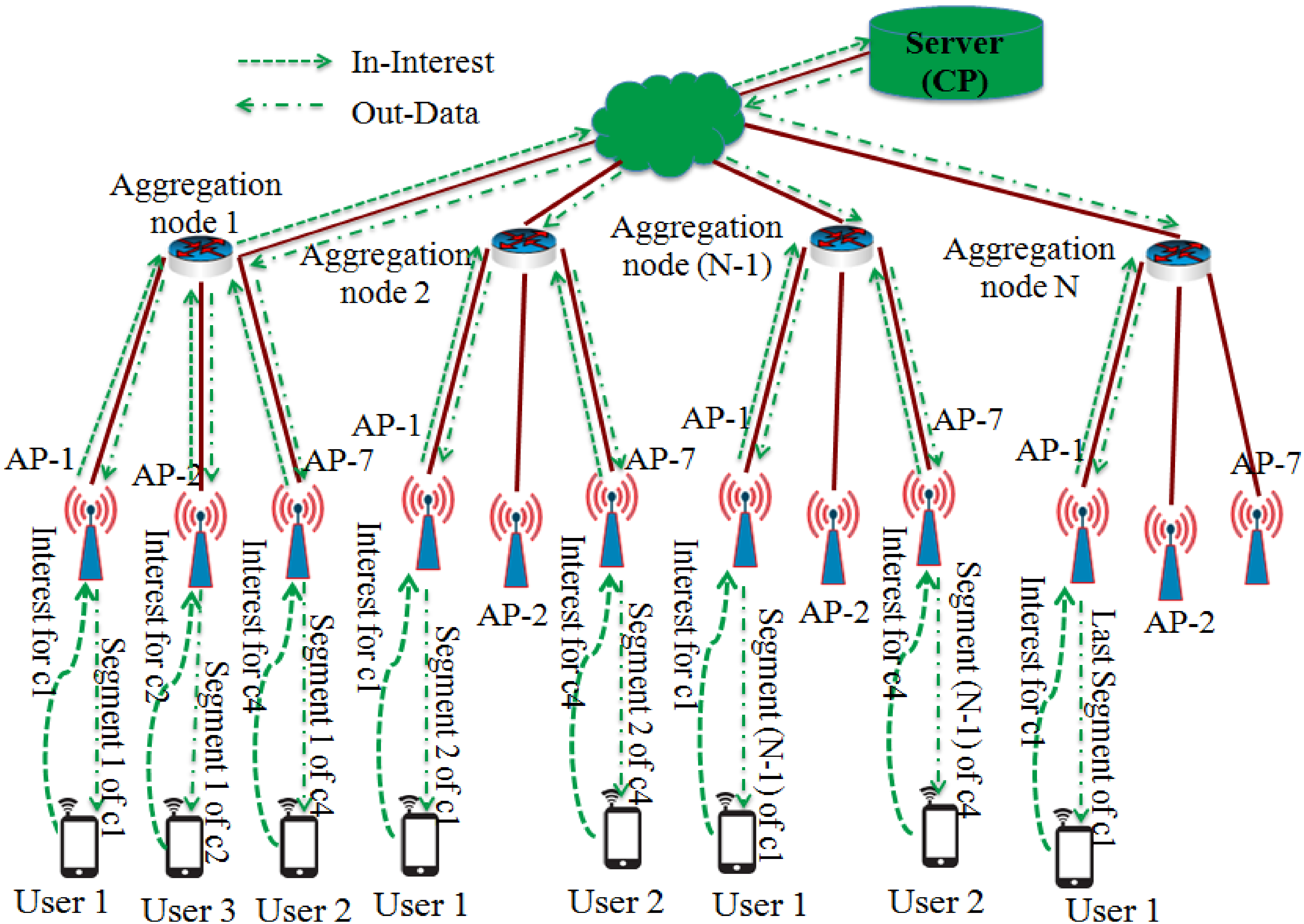
- **5-level tree based topology** with server as root node



Proactive-caching scheme and smart scheduler

- **Proactive-caching based scheme**
  - **Choose aggregation points (Station CRs at level 2) as the location of proactive caching** for enhancing the scope of sharing of the content.
  - **Mechanism:** When the CP receives an interest asked for a content, that content data is divided into several segments then is pre-cached to N Aggregation nodes (expected number of stations that one commuter stays on the train).
- **Smart scheduler**
  - **decides** the **appropriate location** (station) for pre-caching and **calculate** amount of content segment should be cached.
  - the system **generates fake interest** (for same content) from the neighbor Aggregation node. **Moreover**, the pre-caching process for a suitable segment of content c to station N's CR **only happens in case** station (N-1) still get the interest for content c at that time → **prevent redundant content traffic.**

Proactive-caching base scheme for ITS

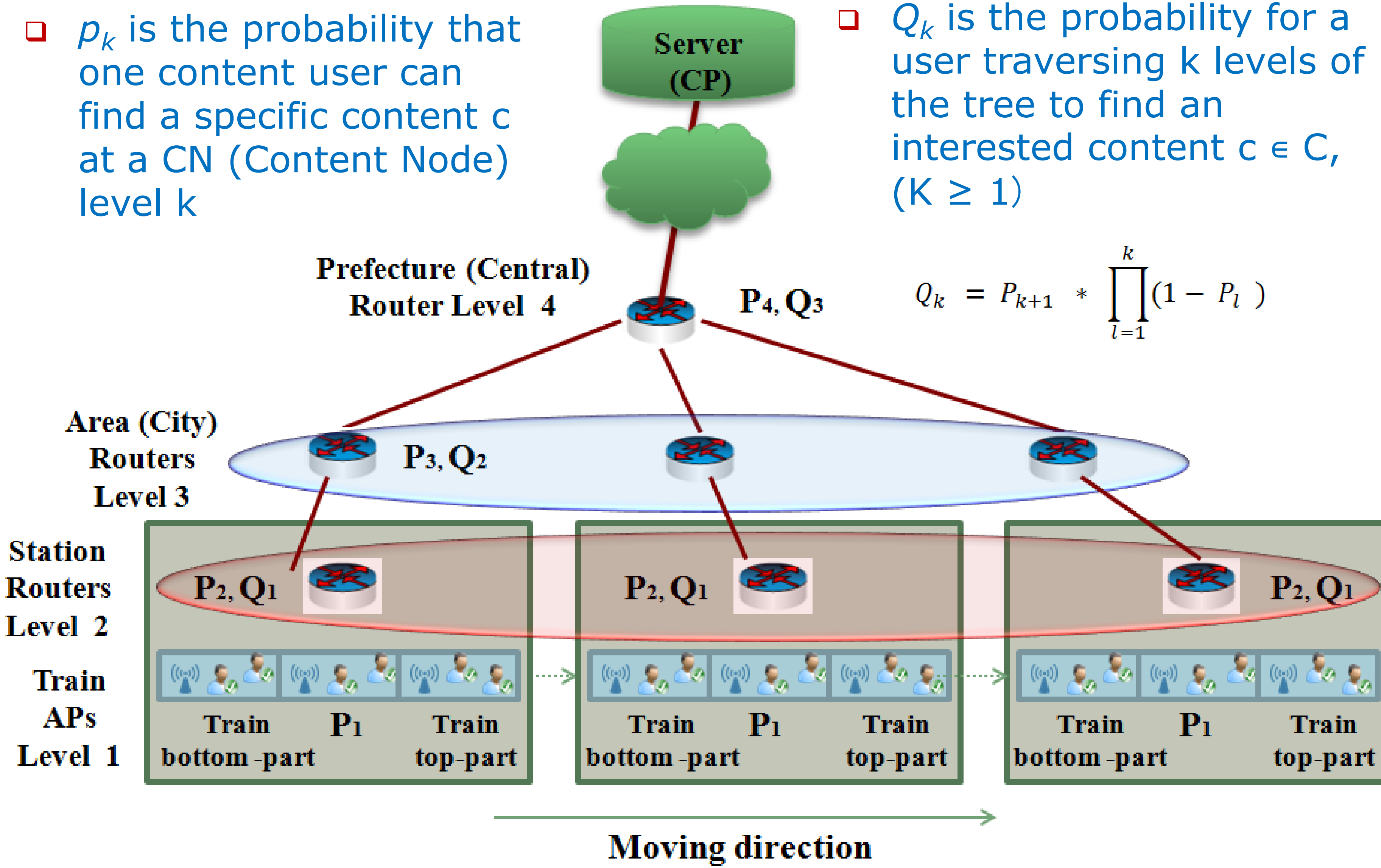


Green ICN Architecture for ITS

- p_k is the probability that one content user can find a specific content c at a CN (Content Node) level k

- Q_k is the probability for a user traversing k levels of the tree to find an interested content c ∊ C, (K ≥ 1)

$$Q_k = P_{k+1} * \prod_{l=1}^{k} (1 - P_l)$$



Content Node Rate Adaptive Scheme for Green Networking in DAN

- **CN Rate Adaptive scheme**
  - Let R_k be the link rate enter on level k CR for a content c ∊ C and R_{ICN} is the link rate with caching in the conventional ICN network, then maximum load in first level

$$R_1 = R_{ICN} \text{ and } R_1 > R_k\ (\forall\, k > 1)$$

  - Let S_k be the set of content come to a level k router and S is maximum number of contents that each ICN routers can cache
    → *Enhanced* R_k $(1 < k \leq 4)$

❑ In case there is at least one popular content is asked

$$Optimized\ R_{k,ICN} =$$
$$\alpha\, \{ R_{ICN}\ \ [1 - \min\,(P_{1c} + \textstyle\sum_{l=1}^{k-2} Q_{lc})]\}$$
$$\forall Content\ c \in S_k\ and\ |S_k| \leq S$$

❑ In case only unpopular content(s) are asked

$$Optimized\ R_{k,ICN} =$$
$$\alpha\, \{ R_{ICN}\ \frac{\max P_{1c}}{T_P}\ [1 - \min\,(P_{1c} + \textstyle\sum_{l=1}^{k-2} Q_{lc})]\}$$
$$\forall Content\ c \in S_k\ and\ |S_k| \leq S$$

where ɑ is the proportional coefficient of link rate and power consumption of Content Nodes (APs and CRs) and ɑ ≥ 1.

→ **the Enhanced Link Adjusting Factor E_A is defined as**

$$E_A = \frac{Enhanced\ R_{k,ICN}}{R_{ICN}}\ (0 < E_A \leq 1)$$

Mathematical model for energy consumption evaluation

$$E_{IP} = N\ E_{R-IP} + E_S$$
$$= N\ P_{R1-IP}\ T_w + N_1\ P_{R2-IP}\ T_w + N_2\ P_{R2,AP-IP}\ T_w + (P_{S1}\ T_w + P_{S2}\ T_w + P_{S3}\ T_w)$$

where $E_{R\text{-}IP}$, E_S are the energy consumed by a IP router and energy consumed by the server; $P_{R1\text{-}IP}$, $P_{R2\text{-}IP}$, $P_{R2,AP\text{-}IP}$ are the embodied power of a network node (router/AP), working power of a IP router, and working power of an AP, respectively; N_1, N_2 and N are the number of routers, number of APs, and number of CNs respectively ($N_1 + N_2 = N$) and P_{S1}, P_{S2}, P_{S3} are the embodied power, power for server storage and operating power of a server (same value for both ICN and IP based network system), respectively. Besides, T_W is the working time of the whole network system.

$$E_{ICN} = N\ E_{R-ICN} + E_S = N\ (P_{R1-ICN}\ T_W + P_{R3-ICN}\ T_W) + N_1\ P_{R2-ICN}\ T_w + N_2\ P_{R2-ICN,AP}\ T_w$$
$$+ (P_{S1}\ T_w + P_{S2}\ T_w + P_{S3}\ T_w)$$

where $P_{R1\text{-}ICN}$, $P_{R2\text{-}ICN}$, $P_{R3\text{-}ICN}$ are the embodied power, working power and power to cache memory of a ICN CN (CR/AP), respectively. For the purpose of power consumption evaluation, both the current IP-based network system and conventional ICN system share the same power consumption for servers, whereas a ICN node consumes slightly higher power compared to a normal IP node because of the CN's caching function.

$$Proposal\ E_{ICN} = \sum_{k=1}^{N} Enhanced\ \ E_{R-ICN,r_k} + Enhanced\ \ E_{S-ICN}$$

$$\textstyle\sum_{k=1}^{N} Enhanced\ \ E_{R-ICN,r_k} = N\ (P_{R1-ICN}\ T_W + P_{R3-ICN}\ T_W) + \sum_{k=1}^{N} Enhanced\ P_{R2-ICN\ ,r_k}\ T_{Or_k}$$
$$Enhanced\ \ E_{S-ICN} = (P_{S1}\ T_w + P_{S2}\ T_w) + [P_F\ T_{O_s} + P_I\ (T_w - T_{O_s})]$$

where T_{Or_k} is the operating time of CN r_k with proposed ALR design, and T_{O_s} is the operating time of server S. Besides, assume that systems user server (CP) with 2 specific state: Idle mode when no content interest send to server and Full mode otherwise (there is at least one interest come to CP). Then let P_F *and* P_I are working power of Full mode and Idle mode, respectively.

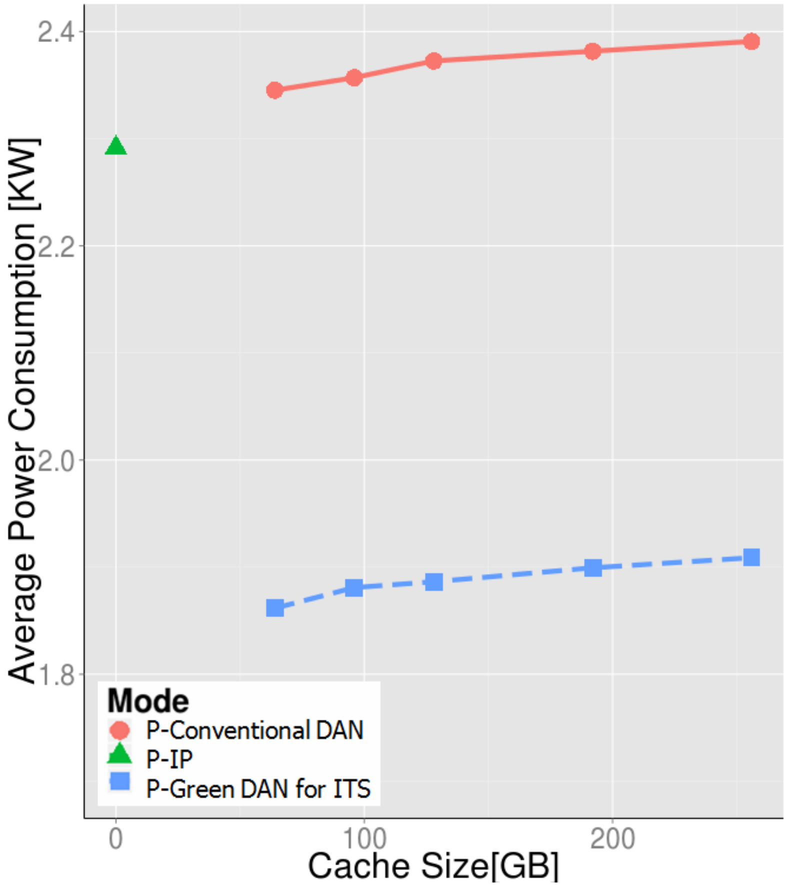
Proposal Evaluation

- **Simulation parameter** (in ndnSIM)

Simulation Parameters	
Connection bandwidth	1Gbps
Content size	1000MB
Payload size (Content Chunk size)	1024 bytes
Content Store Size	20,000 objects
Number of Station CRS (Aggregation Node)	4
Numbers of child nodes which each "parent" has	2
Content request rate	25% of network utilization
Content Popularity distribution	Zipf Distribution (similar to Zip-like distribution)
L. Breslau, P. Cao, L. Fan, G. Phillips, and S. Shenker. Web Caching and Zipf-like Distributions: Evidence and Implications. In Proc. Of INFOCOM, 1999	
Time stay at each Station &Time move between 2 stations	18s & 90s

Proposal results and discussion

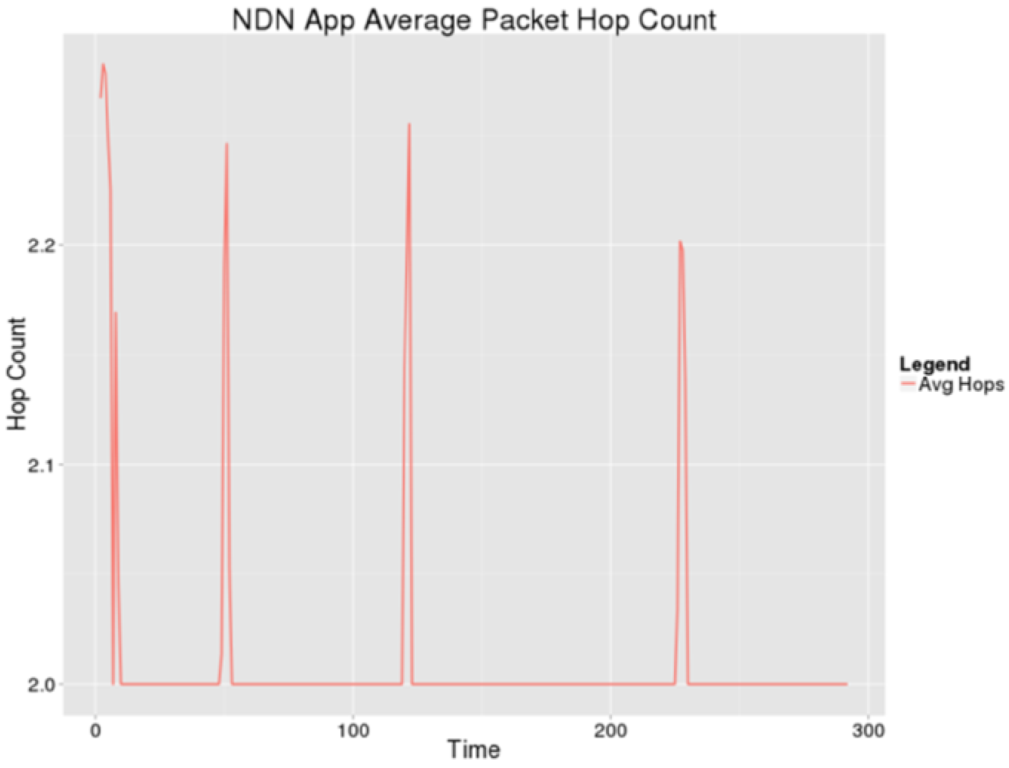
- **Power consumption comparison in case of different cache size (GB)**



- Though the conventional ICN (DAN) system consumes slightly more power than the current IP-based system, simulation with tree topology proves the efficiency proposed Green ICN system compared to the IP-based system **(about 20% power saving with suitable hardware support).**

Proposal results and discussion

- **Performance evaluation for Average Hop Count of ITS**



❑ The Average Packet Hop count is kept stable at value of 2 with the simulation time as shown, except the cases that the Mobile Node (MN) is involved in the Hand-offs period when it move to change the Point of Attachment (PoA). This is the **result of proposed proactive caching strategy.**

Conclusion and Future work

- In this paper, we **propose and evaluate a cross-layer wireless content access model in ICN (DAN) for ITS (train/railway system)**
  - **Integrate both green networking and innovated proactive-caching based scheme in ICN mobility together** to raise energy efficiency and effectiveness for the goal of green mobility in ICN.
  - **The simulation results corroborate theoretical idea and prove the efficiency of proposed scheme**, compared to both current IP-based network and conventional ICN design.
    → **propose our work for DAN standardization process of ITU** for a reliable and safe human-centric system toward an ubiquitous intelligent and trusted society.
- **Future work**
  - **Extend** our proactive caching scheme in ICN **with various practical use-cases with different kinds of content services**, such as: VoIP, Multimedia Services, etc in larger scalability **for Future Mobile Communication**.
  - **Conduct the scheme under field experiment** to further evaluate proposal's efficiency.

Thank you very much for your kind attention!

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