An Energy-efficiency Assessment of Content Centric Networking (CCN)

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Motivation and Introduction

- Content-Centric Networking (CCN) [1] is a new networking architecture aimed at accommodating content distribution needs of the future Internet.
- CCN can potentially reduce bandwidth usage and improve scalability.
- Our goal is to compare the energy usage of CCN and current IP-based networks.
- We modeled CCN to perform a cost analysis in a video streaming scenario.
- We consider two types of costs (energy consumptions).

1. Energy required to manufacture the network devices. (one time cost).
2. Energy required to operate the network devices for streaming the video.

Network Modeling

- The client in CCN tries to get content (movie) from the nearest hop.
- Q_k is the probability of a client traversing k hops to find content (Fig.1).
- Probability Q_k of a given router is the same for all the routers on that level.
- P_k is the probability of content being present on the k^{th} hop .

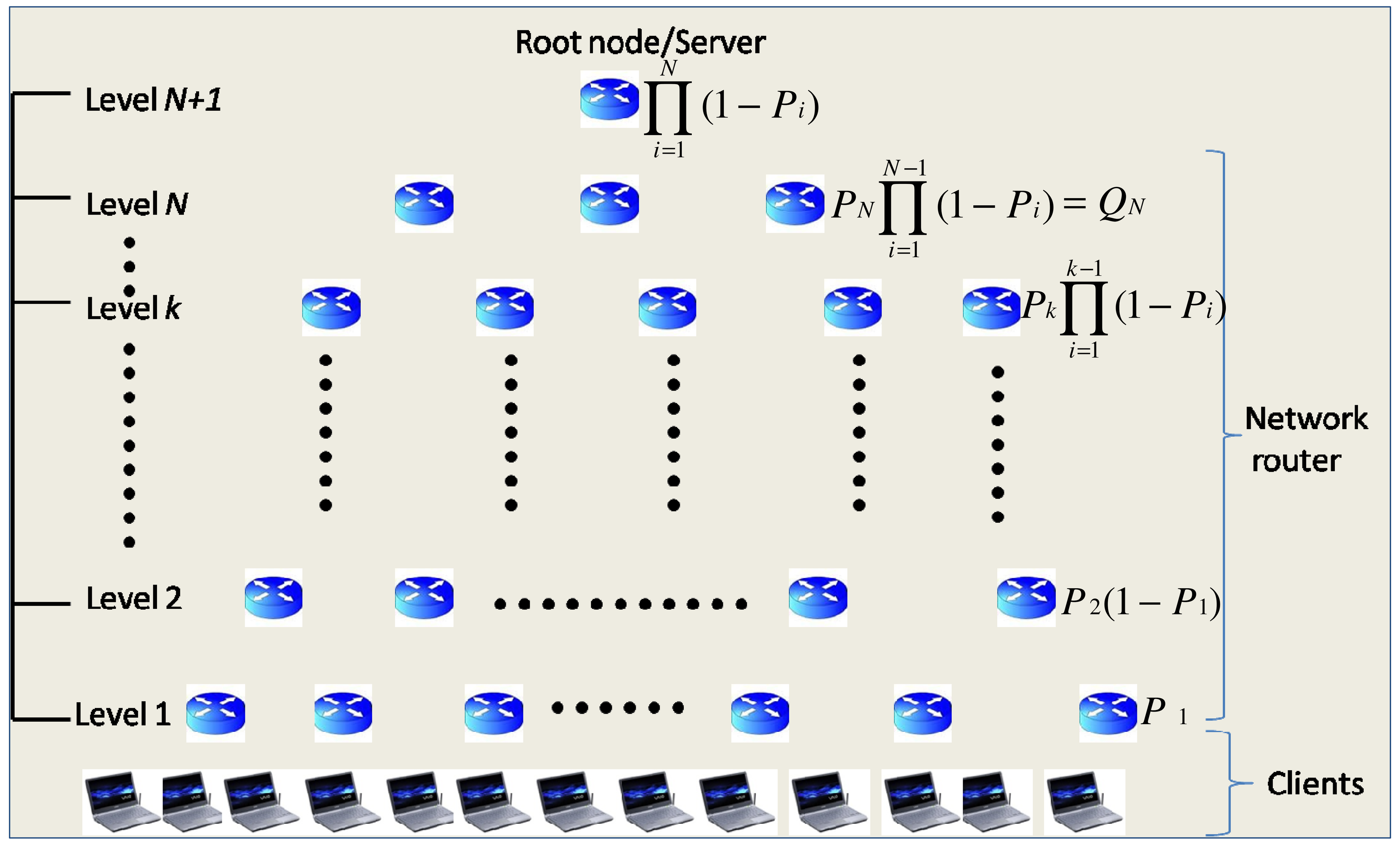


Fig. 1: The layered topology showing probabilistic model for CCN

- We perform a steady state analysis.

Define the following parameters .

- $p \in (0,1)$: the probability of finding content at the first level. It captures the notion of popularity of content.
- $\alpha \in (0,1)$: it captures the popularity variation across levels and depends on the network density.
- The probability of finding the content at any level '*k*' is modeled as

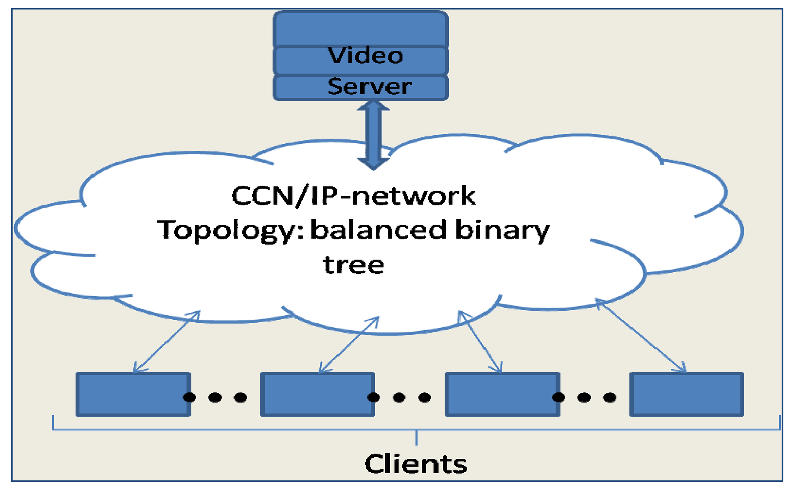
$$P_k = 1 - (1-p)e^{-(k-1)\alpha}$$

- The expected number of routers (hops) traversed to retrieve each piece of content is then:

$$E(hops) = \sum_{k=1}^{N+1} kQ_k$$

- For CCN $E(hops)$ a function of content popularity and the number of hops.

Analysis



We calculate manufacturing cost and operation cost for the devices used for the streaming service.

L : life cycle of the devices 3 x 365 days.
T : number of movies streamed 10^3/day.
S : server cost 59054 MJ.
C_S: energy required to power memory associated to the server for L *days* 900KJ.

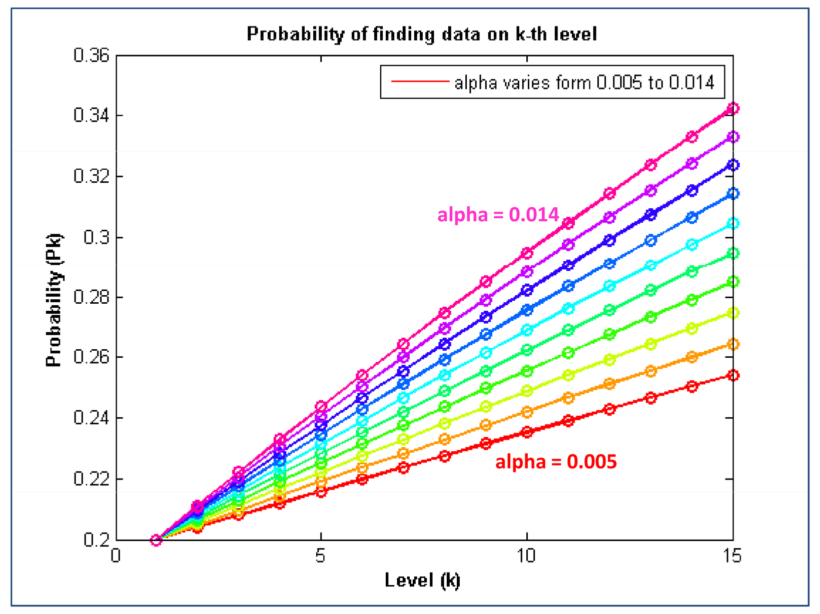
Fig. 2: Dedicated video streaming scenario

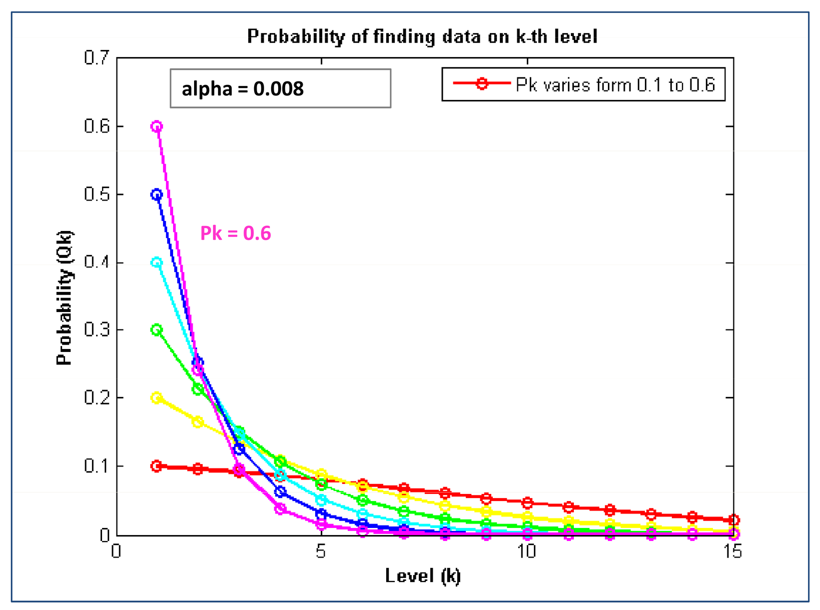
K : aggregate number of nodes across layers 2^{N+1} - 1.
M_{IP} : manufacturing cost for an IP router 5345 MJ .
M_{CCN} : manufacturing cost for a CCN router 6222 MJ .
O_{IP} : operation cost of an IP router while streaming a single video. 251 J.
O_{CCN} : operation cost of a CCN router while streaming a single video 812 J.
C_M : total energy required to power the cache memory for L *days* 548 KJ.
N : total number of hops.

$$EnergyCost_{IP} = KM_{IP} + S + C_S + LTO_{IP}N$$

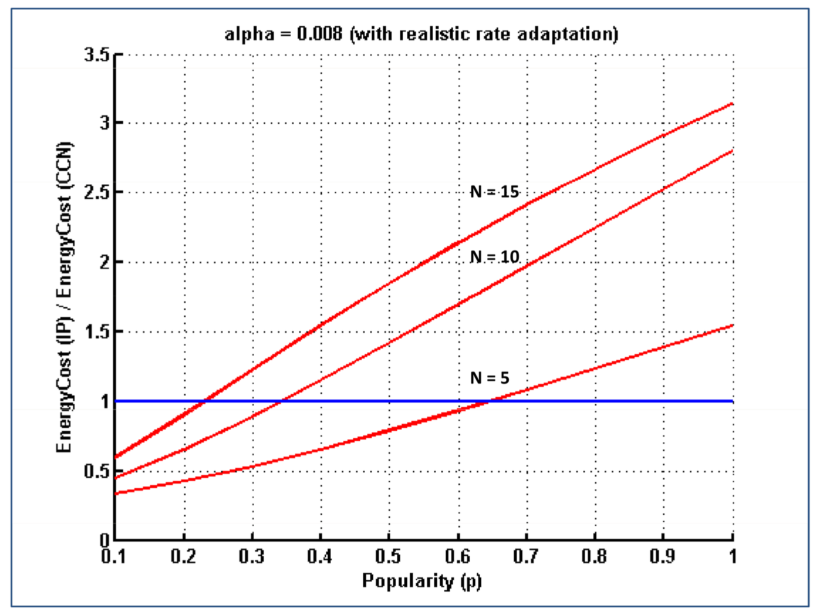
$$EnergyCost_{CCN} = KM_{CCN} + S + (K-1)C_M + C_S + LTO_{CCN}E(hops)_{CCN}$$

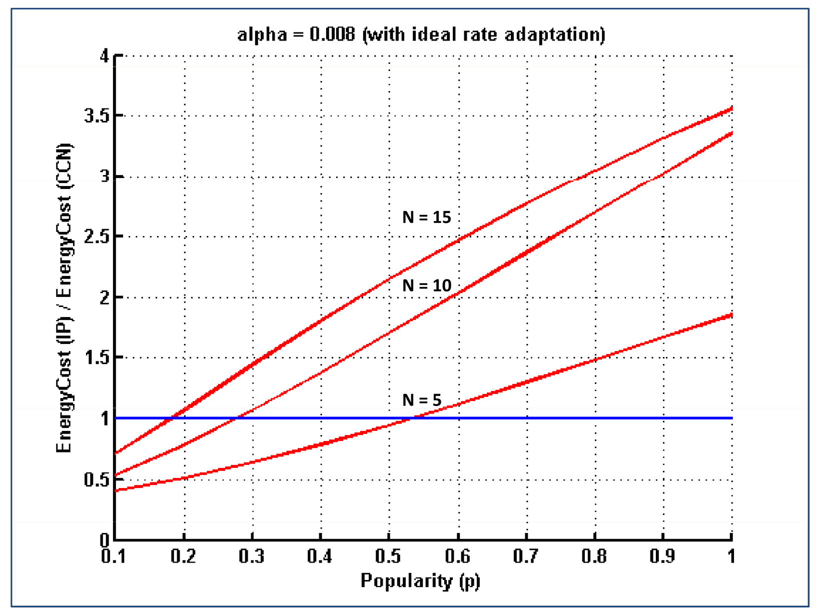
Results





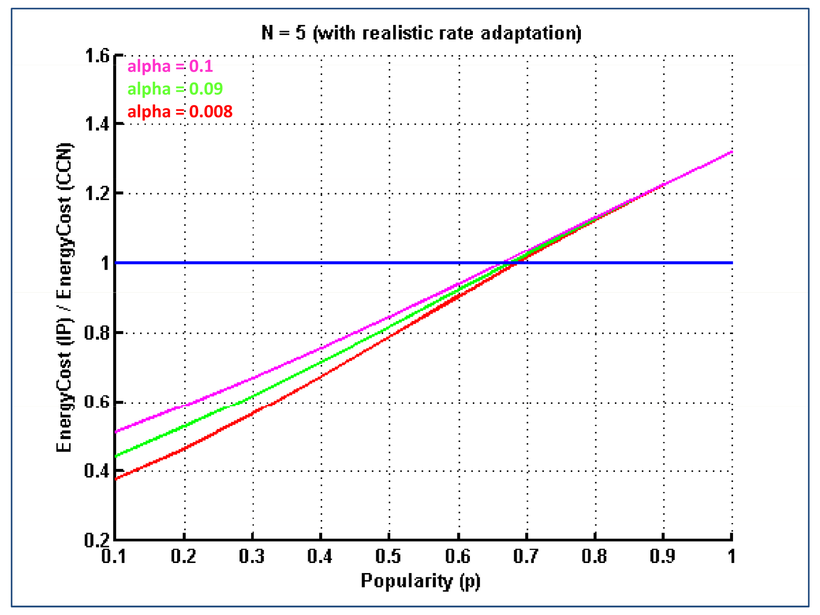
- These graphs depict the increasing trend of P_k with the increase in popularity of content and decreasing trend of Q_k with increase in P_k for our CCN model.

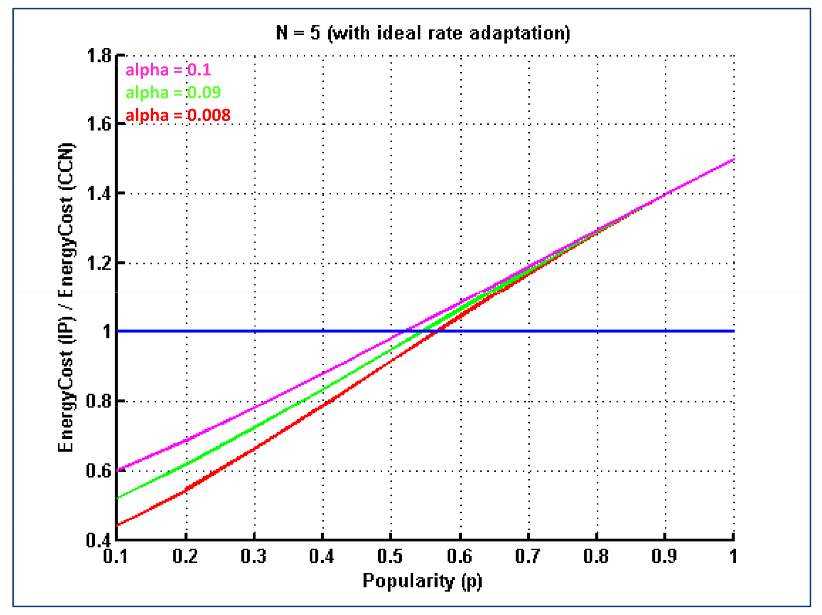




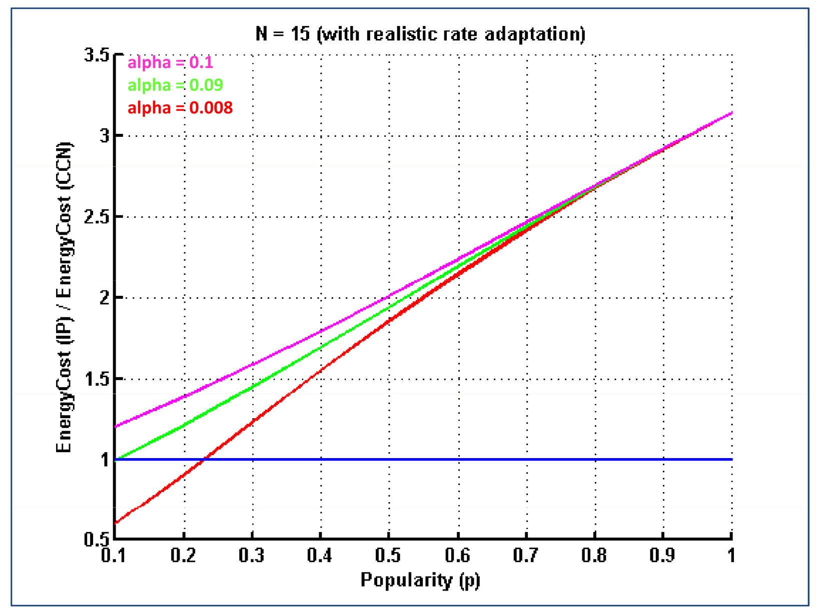
- CCN is more energy intensive for video streaming even with rate adaptation [2] if content popularity is low and network is small scale.
- As the number of hops to the video server increases, CCN starts to provide substantial energy benefits.

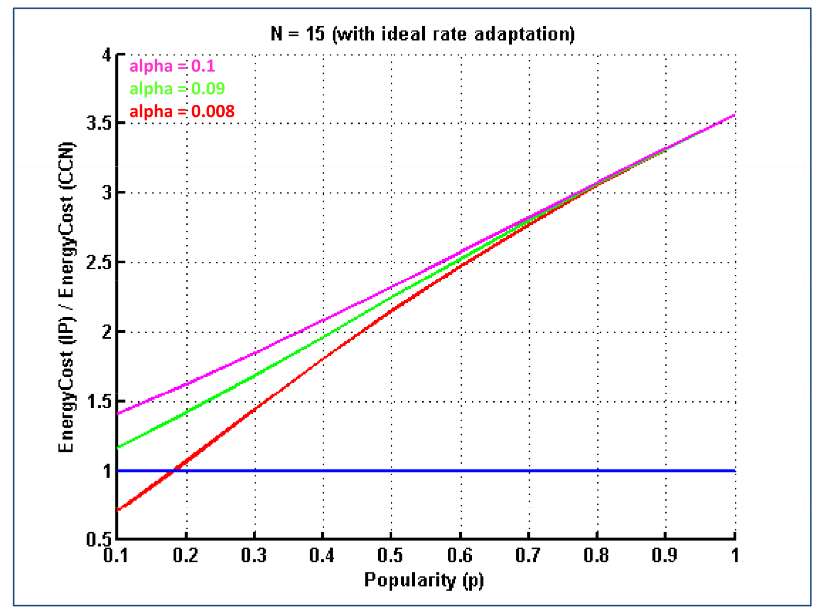
Results





- If there are only a few hops to the server, CCN requires more energy to deploy and operate even if the content is popular.





- CCN can provide significant energy savings in settings where the number of hops to the server is large even if content popularity is low.

Summary and Future Work

Summary

- CCN consumes less energy to stream content compared to IP if content is popular in the network.
- The caching capability of CCN routers leads to additional energy demands but at the same time reduces the distance content must traverse and enables the application of rate adaptation to reduce router operating costs.

Future Work

- We will develop a simulation environment to conduct a more accurate analysis, tracking the availability of content at individual routers.
- We will use the simulation results to refine our models for the probability of finding content.

References

[1] V. Jacobson, D.K. Smetters, J. D. Thornton, M.F. Plass, N.H. Briggs, and R.L. Braynard. "Networking named content," In *Proc. Int. Conf. on Emerging Networking Experiments and Technologies* (CoNEXT), Rome, Italy, Dec. 2009.

[2] S. Nedevschi, L. Popa, G. Iannaccone, S. Ratnasamy, and D. Wetherall, "Reducing network energy consumption via sleeping and rate-adaptation," In *Proc. USENIX Symp. on Networked Systems Design and Implementation*, Berkeley, CA, USA, Apr. 2008.