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Combing CCN with network coding: An architectural perspective

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ABSTRACT

Content-centric networking and network coding both revolve around content distribution, trading storage and computation for bandwidth respectively. Although it was believed network coding benefits CCN, the real advantages, architectural implications and design choices are not fully explored. In this paper, we first investigated the possible advantages of combing network coding with CCN. We argue doing so can eliminate the fine-grained naming in CCN, effectively utilize multi-path parallel forwarding, reduce the complexity of cache coordination and simplify the transport design. We then analyzed the architectural implications and design choices for incorporating network coding with CCN, especially the architectural changes arising from the semantic difference of naming. Finally, following the architectural implications, we proposed a prototype implementation called NC-CCN and evaluated its performance by substantial simulations. We compared two matching mechanisms for linear dependency checking, and found that the rank-based matching mechanism(*RB-Matching*) can achieve slightly lower performance compared with precise matching mechanism(*Precise-Matching*) with much lower computation and communication overhead.

1. Introduction

In recent years, the Internet usage has shifted from sender-driven one-to-one communication to receiver-driven many-to-one content retrieval, e.g., Internet Video and App software downloading. Present TCP/IP centers around unicast, which cannot adapt to this shift easily. Recently, information-centric networking(ICN), such as CCN/NDN [14], DONA [15], NetInf [1] and PSIRP [10], has emerged as a promising alternative to TCP/IP. The decoupling of sender and receiver, native support of transparent and pervasive in-network caching, name-oriented content retrieval and content-based security together give ICN native support for content-based and receiver-driven communication paradigm.

Presently, CCN/NDN receives the most attention among the research community, and research work on CCN to date primarily focus on routing scalability, request forwarding and cache coordination. However, some issues still remain:

- Although the requirement of unique naming for each data chunk enables in-network content caching, it poses complexity for pipelined request issuing because the specific naming rules should be known in prior for the requestor to send multiple consecutive Interests.
- It is hard to fully utilize the advantage of multiple paths even with an intelligent strategy layer. If the interests are sent in parallel along multiple paths, duplicated data blocks will be transmitted in different paths, which could potentially reduce cache diversity. On the other hand, if round-robin is used, the response time can be potentially increased.

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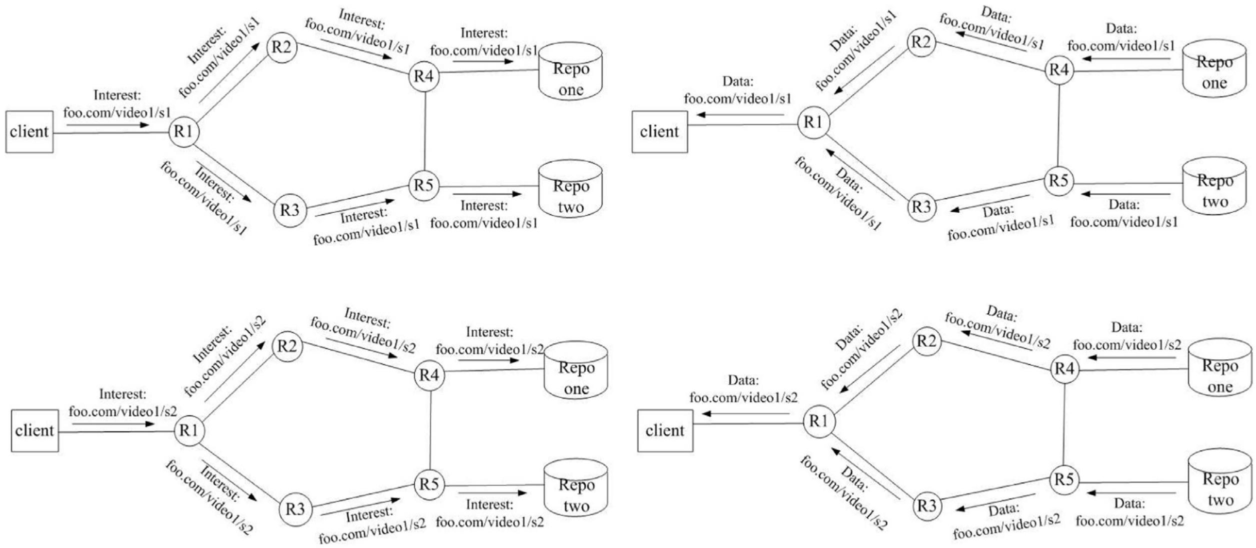

Fig. 1. Traditional CCN.

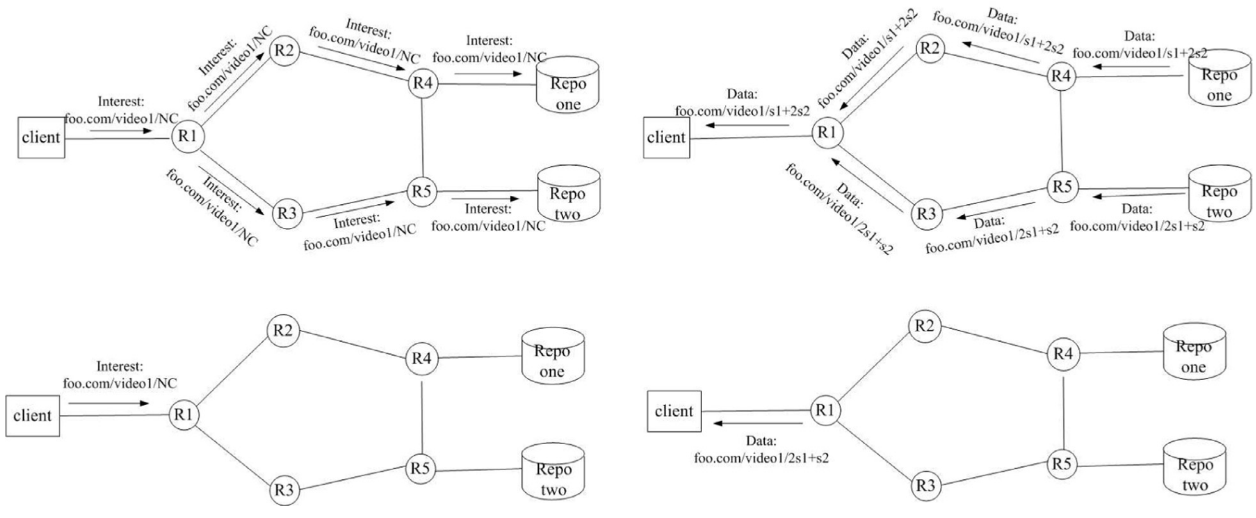

Fig. 2. NC CCN.

- Although receiver-driven transmission simplifies the transport by allowing a sender to be stateless, the receiver still remains complex.
- Sophisticated cache coordination is required to improve the network-wide cache utility, especially when the limitation of individual cache capacity imposed by the requirement of line-speed operation is to be considered.

Network coding is a new paradigm of information transmission and processing [3]. In addition to buffering, replication and forwarding, network coding allows intermediate nodes to perform arbitrary coding operations on data, thus realizing the upper bound of multicast capacity given by max-flow min-cut theorem. Network coding is proved to be helpful in P2P content distribution systems, due to its ability to simplify data scheduling algorithms, avoid the last block problem and improve transmission parallelism [6].

Recently, it is argued that network coding also benefits Information Centric Networking [24–26]. Indeed, both network coding and ICN focus on the improvement of content distribution efficiency. The former trades computation for bandwidth, whereas the latter trades storage for bandwidth. Adopting network coding in ICN allows internal network nodes to simultaneously perform computation, storage and forwarding on data, which can effectively utilize multiple paths in the network, simplify receiver-side pipelined Interest sending and transport design, and reduce the complexity of cache coordination.

An illustrative comparative example is given in Figs. 1 and 2. Assuming a file consists of two chunks *s*1 and *s*2, with traditional CCN, as shown in Fig. 1, each Interest should specify the unique name of each data chunk, and moreover, multipath parallel forwarding of Interest for */foo.com/video/s1* at *R*1 will result in two duplicated */foo.com/video/s1* data chunks