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Review

Information centric network: Research challenges and opportunities

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ABSTRACT

For more than a decade, the inherent drawbacks of current Internet have been calling for its revolutionary designs. The end-to-end model, which was designed for special data transmission in the early age of Internet, is causing troubles everywhere in nowadays content based web services. Consequently, Information Centric Network (ICN) is proposed to solve these problems. As the most permanent clean-slate approach for next generation Internet, ICN has attracted much attention from network researchers in the passed few years. This survey focuses on the current progress of the research work in ICN. It investigates various key aspects such as naming and routing schemes, in-network caching policies, *etc.*, and highlights the benefit of implementing ICN, open research issues and new interests in this domain.

Contents

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1. Introduction

Since the Internet was designed in 60s–70s, it has played a more and more important role in people's life. From the beginning, the Internet runs on top of the protocol stack of TCP/IP with the intention of connection a few of machines. The Internet paradigm, which is deployed till now, is a host-host based model. All the Internet information exchanges are realized by establishing the communication channels. This host-centric Internet has perfectly matched the early Internet usage, which is not that complicated. Basically the Internet applications or protocols are all end-to-end communications like the web surfing, instance massage chat, sending e-mail or FTP file download, *etc*.

The science and technology never stop from evolving. For example, the networking link layer is no longer limited at the xDSL technologies. The Internet uses various technologies from WiFi, FTTH, Satellite, to mobile 3G and 4G for information exchanges. End-user terminals which support the Internet experience cover from the PC, laptop, to the smartphone, tablette, set-top box, *etc*. More importantly, the Internet usage is changing as well. It is switching from the host-centric to a content-oriented model. Peer-to-peer applications (P2P) (http://en.wikipedia.org/wiki/Peer-to-peer), Content-Delivery Networking (CDN) (Vakali and Pallis, 2003) are developed for improving the content delivery. HTTP video is already the major contribution of the networking traffic. Flickr, Instagram are more and more popular because people prefer more and more share their daily life on-line. And E-commerce, social-networks, Video-on-Demand, *etc*., all the things that people care about is no longer "where" it can get the information which they are interested in, but "what" the information actually are. In order to follow these evolutions, Internet becomes more and more complex. Security, NAT, DNS, multicast, multi-homing, mobility, CDN, security for multi-homing (Migault et al., 2012), security for mobility, *etc*., more and more patches or overlay are added on the current Internet protocol stack. From that the host-based TCP/IP Internet is becoming too heavy to offer the best performance to the end-users.

Facing these shortcomings, many research communities are motivated to develop an Information-Centric Networking paradigm (ICN). The ICN aims to shift the current complex Internet model to a simple and generic one. The basic networking unit is no longer the identified node (*servers, routers, terminals*). The ICN networking activities are all based on the named content objectives. ICN is receiver-driven networking model, where end-users only express their interests for a given content, the entire network is in charge of routing the requests based only on the content names towards the best content containers and delivering the contents through the reverse paths to the end-users. The ICN aims to build the features directly into the networking design. It natively includes the features as location-independent naming, name-based routing, in-networking caching, native multicast, self-secured content, *etc*.

Although ICN enters now into the main stream of networking research, it is still in its early stage. In the past few years many projects have been carried on in order to propose a concrete ICN solution to deploy it in reality. In this survey we intend to give a general presentation of different ICN features with the goal of raising an in-depth discussion of this novel Internet paradigm. Our study is arranged according to the common components in various ICN designs such as naming and routing schemes, in-network caching technique and security issues. These components are presented in Sections 2, 3 and 4 respectively. In the discussion for each component, we briefly introduce the design principles raised by various research projects, and address prospective opening issues. Then, we investigate in Section 5 other potential benefits brought by ICN in several aspects such as cloud computing environment and green IT. Finally, we summarize the study and research challenges in Section 6.

Different projects use distinct notations to indicate their design choices and features. For example, DONA uses *Data-Oriented* instead of information-centric, CCN is the abbreviation of *Content-Centric Network*. Therefore, in our presentation, the terms as information, content and data are used interchangeably.

- In CCN, the unit of transmitted content in the network is called *Data*, while in NetInf it is denoted as *Named Data Object*.
- Names for request routing devices are also diverse. PSIRP routing scheme consists of four key components: *RendzVous Nodes, Topology Nodes, Branching Nodes* and *Forwarding Nodes*. DONA leverages the *Resolution Handles* to discovery requested content. *Content Router* is implemented by CCN to realize their longest prefix matching routing scheme, and NetInf routing is achieved by a *multi-level DHT* mechanism.
- While the ubiquitous in-network caching is integrated as a function of Content Router in CCN, other projects usually depends on dedicated modules as *Storage Engine* in NetInf and RendezVous Nodes in PSIRP.

These distinct design patterns will be detailed in the following sections.

2. Naming and routing

The fundamental concept of the ICN is to switch the address based Internet architecture to a named-content based one. The naming and the named-based routing scheme is the core of all the concrete ICN projects. We will present firstly in this section the naming and routing issues of the ICN networking.

2.1. Overview

The content retrieving in ICN can be mainly divided into two parts: the content discovery and the content delivery. The content discovery is related to how a content is named, how it is published and how an ICN node addresses it. The content delivery defines the ICN routing protocol which is about how a content provider propagate its contents into the network, how an ICN router routes the end-users' interests to the best content sources and how an ICN router deliver the contents to the end-users. In this section we will globally present the ICN naming and routing aspect.

The content name is the only identifier of each content object, which permits either the end-user or the intermediate networking unit locates the best content holder. The content name usually is a globally unique identifier, but the unique named content can sojourn in different containers, for example the origin content servers, the CDN repositories or the on-path caches. In the following we will try to summarize the different naming issues of the ICN domain.

(a) *The properties of the ICN naming*: Of course the fundamental role of the unique name is to identify the different content, but it also include other properties:

- *Globally unique*: In ICN, each networking unit is identified by a content name. Thus the content name should be globally unique in order to arrive at a global level routing.
- *Location independent*: The IP address is highly related to the geography location. When the location is changed, the IP address is changed. The ICN name is independent from the physical location. A content is named when it is created, no matter where or from who. A named content can be re-published, replicated everywhere, but the name does not changed.
- *Security intergraded*: The security was not designed in the first version of IP network. As long as the Internet evolution, the security service is added into the IP prototype, *e.g. IPsec*. In ICN,