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Forwarding strategies in named data wireless ad hoc networks: Design and evaluation

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ABSTRACT

Named Data Networking (NDN) is a promising *information-centric* architecture for the future Internet that is also gaining momentum in wireless ad hoc networks as an alternative paradigm to traditional IP networking. NDN shares with other information-centric proposals the same innovative concepts, such as named content, name-based routing, and in-network content caching. These principles and the simple and robust communication model, based on *Interest* and *Data* packets exchange, make NDN especially appealing for deployment in wireless ad hoc environments, characterized by a broadcast error-prone channel and time-varying topologies.

Nevertheless, making NDN-based solutions really effective in ad hoc networks requires rethinking some of the basic NDN forwarding principles to cope with wireless links and node mobility. In this paper, we analyze two classes of forwarding approaches: (i) a minimalist, *provider-blind* forwarding strategy, only aimed at keeping packet redundancy on the broadcast wireless medium under control, without any knowledge about the neighborhood and the identity of the content sources; and (ii) a *provider-aware* strategy, which leverages soft state information about the content sources, piggybacked in Interest and Data packets and locally kept by nodes, to facilitate content retrieval.

Performance evaluation is carried by means of *ndnSIM*, the official NDN simulator, that is overhauled for use in realistic wireless ad hoc environments. Results collected under variable traffic loads and topologies provide insights into the behavior of both forwarding approaches and help to derive a set of recommendations that are crucial to the successful design of a forwarding strategy for named data ad hoc wireless networking.

1. Introduction

Information-Centric Networking (ICN) has emerged as a new paradigm for Future Internet architectures (Jppinen and Correia, 2013) that focuses on finding and delivering named contents, instead of maintaining *end-to-end* communications between hosts identified by IP addresses (Xylomenos et al., 2013). In this research arena, the Named Data Networking (NDN) architecture (Zhang et al., 2010) has rapidly gained consensus, thanks to the simple, robust and effective communication model, originally advocated in the Content Centric Networking (CCN) proposal (Jacobson et al., 2009).

Information retrieval in NDN is driven by the *consumer*, which uses Interest packets to request a content "by name". Intermediate receivers select their outgoing network interface(s) for Interest forwarding. Finally, upon receiving an Interest, a *provider*, which is the content source or any other network node that temporarily stores the requested content, replies with a named Data packet that piggybacks authentication and data-integrity information. The content packet is a self-identifying and self-authenticating unit, so in-network data caching is enabled. The Data packet follows the "bread crumbs" left by the Interest at intermediate nodes back to the consumer.

The salient NDN features, i.e., location-independent named data, in-network caching and lightweight forwarding, make NDN a particularly attractive solution for wireless ad hoc environments, like Mobile Ad hoc Networks (MANETs). In MANETs, nodes move at pedestrian speeds and create dynamic topologies that make traditional *host-based* routing protocols ineffective; indeed, they may suffer from temporary network partitioning and high overhead for end-to-end route set up and maintenance (Loo et al., 2012). On the contrary, NDN supports *asynchronous* communication that does not require the simultaneous presence of consumer and provider, and thus *it can work under intermittent connectivity conditions*.

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In this paper, we focus on the design and evaluation of the NDN *forwarding plane* in a MANET. Starting from a few works currently available in the related literature, we classify the forwarding policies and implement some exemplary cases whose performance is comparatively evaluated.

After scanning the related literature, we broadly divide the NDN forwarding strategies in a MANET into two classes:

- *blind forwarding:* a minimalistic topology-agnostic scheme, whose basic aim is to counteract the *broadcast storm* problem (Wang et al., 2012);
- *aware forwarding:* schemes that use additional information about the content source(s) and/or the neighborhood to help in the forwarding decision. The diffusion of this information requires the exchange of additional packets (Oh et al., 2010), and/or additional fields in Interest/Data packets (Amadeo et al., 2013a; Meisel et al., 2010b; Angius et al., 2012).

The better performance of provider-aware approaches in any condition cannot be taken for granted and requires to be explored. The objective of this study is to deeply analyze strengths and weaknesses of the two forwarding classes by taking features from some representative schemes and implementing them under realistic simulation scenarios.

The key contributions of this work can be summarized as follows:

1. We analyze the overhauling in the basic NDN forwarding fabric that is required to support NDN in a wireless ad hoc network, and we discuss in detail the design of the blind and aware forwarding strategies.
2. We implement the conceived overhauling in *ndnSIM* (Afanasyev et al., 2012), the official NDN simulation environment, and we compare the two forwarding strategies by means of an extensive simulation study under realistic settings. Guidelines are highlighted for the design of successful forwarding in named data wireless ad hoc networks.

The rest of the paper is organized as follows. Section 2 provides an overview of the NDN communication model. In Section 3 NDN blind and aware forwarding strategies are scanned in wireless ad hoc environments. Section 4 describes the instances of forwarding schemes chosen as benchmarking solutions for the two approaches. The ndnSIM simulation framework and its overhauling are described in Section 5. Performance is evaluated in Section 6, while the main findings are summarized in Section 7. Section 8 concludes the paper.

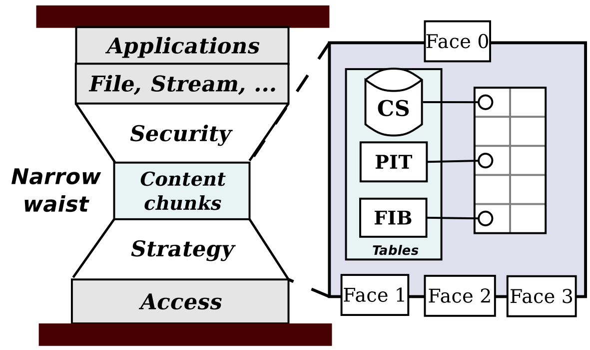

Fig. 1. NDN hourglass.

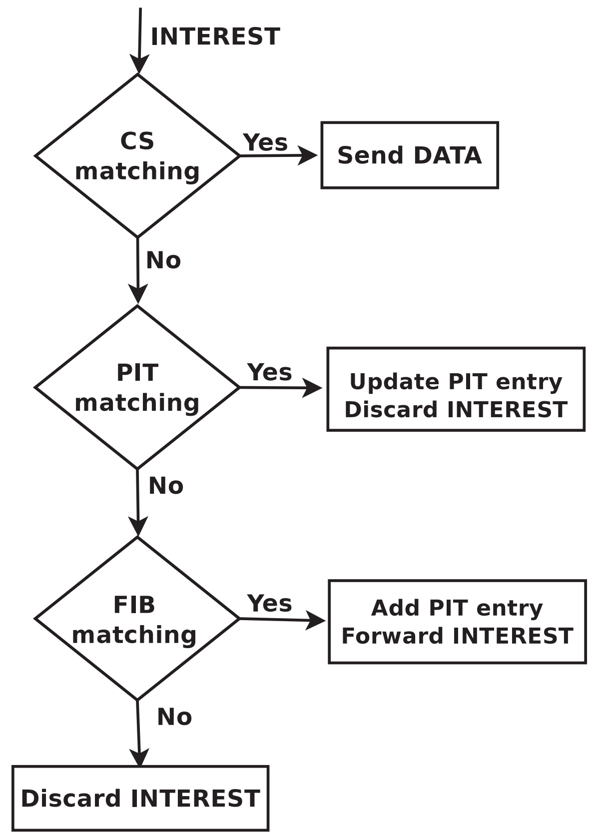

Fig. 2. NDN Interest processing.

2. NDN in a nutshell

NDN presents an hourglass model in which the narrow waist leverages data names instead of IP addresses for data delivery, Fig. 1. It proposes a simple communication model based on the exchange of two packet types: the *Interest* and the *Data* that carry Uniform Resource Identifier (URI)-like content names.

NDN deals with content integrity and authenticity by piggy-backing the data publisher's signature and other authentication information (e.g., the publisher's public key digest) in each Data packet. As a consequence, protection and trust are embedded in the Data packet rather than being developed in a end-to-end fashion. NDN security services do not mandate any particular certification infrastructure, relegating trust management to individual applications.

NDN refers to as *face* any *medium* for transmitting and receiving packets: both upper layers (application processes) and lower layers (hardware network interfaces) interact with the core of the NDN system using the face abstraction.

A consumer device requests a named content by broadcasting an Interest packet over its available network *faces*. The Interest is forwarded hop-by-hop in the network until a provider replies with Data.

The Interest processing leverages three data structures maintained in every NDN node: (i) the Content Store (CS) that caches incoming Data, (ii) the Pending Interest Table (PIT) that keeps track of the forwarded Interests, and (iii) the Forwarding Information Base (FIB), populated by a specific routing protocol, used to relay Interests towards content source(s).

As shown in Fig. 2, when an Interest arrives, an NDN node checks

- if it has the matching Data packet in the CS, then it transmits the packet on the same face the Interest arrived from;