Ad Hoc Networks 36 (2016) 81–99

Contents lists available at ScienceDirect

Ad Hoc Networks

journal homepage: www.elsevier.com/locate/adhoc

Efficient content delivery in mobile ad-hoc networks using CCN

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ARTICLE INFO

Article history:
Received 28 October 2014
Revised 11 June 2015
Accepted 16 June 2015
Available online 20 June 2015

Keywords:
Information-centric networking
Content-centric networking
Ad-hoc networks
Energy-efficient routing

ABSTRACT

Information-centric networking (ICN) is emerging as a future network technology. It has introduced the great advantage of information dissemination with low bandwidth consumption in wired testbed networks. Recently, ICN is also studied for mobile ad-hoc networks environments for efficient content distribution. In the existing works in the literature, broadcast delivery is actively utilized for designing new routing schemes since it seems well fitted to the nature of ICN conceptually. In this paper, we raise questions about this research direction by analysing the performance of reliability and energy efficiency of both broadcast and unicast delivery schemes. Our analysis shows that unicast delivery outperforms broadcast delivery, unless topological changes incur too much packet flooding overhead. Based on this observation, we present a novel energy efficient content distribution scheme that delivers the content in a unicast manner while minimizing flooding overhead by taking advantage of ICN features. Via ns-3 simulation, we compare the performance of the proposed scheme with that of other comparative schemes, and show that the proposed scheme achieves much higher reliability and energy efficiency in content distribution under mobile ad-hoc network environments.

1. Introduction

The information centric networking (ICN) is an emerging proposal for efficient information/content distribution [1–4]. Among several proposed architectures for ICN, content centric networking (CCN) architecture has attracted a great deal of attention, with the following properties: (a) In CCN, content is addressed by its name itself, and an end-to-end connection is no longer required to retrieve content; and (b) by content naming, content can be cached in intermediate routers, and it can reduce bandwidth usage by multiple delivery of the same content [4].

CCN is naturally effective in saving energy to retrieve content, by content naming and caching. A request for content does not necessarily reach the original content provider. Instead, if the requested content is cached in an intermediate router, then the content can be retrieved with reduced hop distance, and consequently, reduced energy consumption. Once content is cached in an intermediate router, it can be served for multiple requesters without additional delivery from the original source to the intermediate router, and it can also save energy consumption. The energy saving effect of CCN can be expanded, when we apply CCN to mobile wireless networks. In a mobile wireless network using CCN, content can be retrieved from any node having the content without requiring end-to-end connection to the original

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http://dx.doi.org/10.1016/j.adhoc.2015.06.007
1570-8705/

source, and it makes the network less sensitive to the mobility of nodes [5].

In [6], a topology-agnostic routing scheme, namely LFBL (listen first broadcast later), has been presented as a new ad-hoc routing protocol for CCN environments. In LFBL, packets are relayed by broadcast in order to take advantage of multi-path delivery in CCN. It has been shown that, with an adequate pruning technique, LFBL outperforms the traditional unicast ad-hoc routing schemes in terms of delivery ratio and delay. Similar approaches using broadcast relay have also been proposed in [7,8]. These proposals in the literature based on broadcast relay seem to operate quite well for highly mobile networks with a low density of nodes. In a dense environment, however, relaying packets through broadcasting has several disadvantages. For example, first, since broadcast packet failure is not recovered by the link layer, link layer packet collision needs to be recovered through invocation of a re-querying process at the end user's side. Obviously, this results in network resource and energy wastage, and can lead to network congestion. Second, RTS/CTS does not go along with broadcast delivery at the MAC layer. This is very critical, because RTS/CTS addresses and resolves the hidden node problem, which otherwise deteriorates network performance especially in a dense environment. Third, broadcasting requires that every neighbour node decodes the transmitted packet. This, in turn, causes a critical problem in hand held devices: the waste of battery consumption. Fourth, contention and collision become much more frequent since multiple redundant delivery can act as interference to other network flows. This severely impacts the performance of high density mobile ad-hoc networks.

Authors in [9] developed a CCN publish-subscribe system on top of TCP/IP protocol for ad-hoc networks. In that scheme, locations of the content name prefix are combined with the IP routing table provided by OLSR [10], and the unicast path is set up and maintained in accordance with the IP-based routing engine. Since that scheme is optimized for publish-subscribe data dissemination, where the content will be published after the subscription time, the publisher-to-subscriber path is pre-established by the subscriber and probed periodically to deal with the change of network topology. When the existing path is broken, the subscriber floods a message to find an alternative path to the content as traditional ad-hoc routing schemes do. Although that scheme successfully achieves shorter delay, large overhead for path maintenance is inevitable.

Throughout this paper, we propose a novel packet delivery scheme based on the unicast manner. Unlike traditional unicast ad-hoc routing schemes, the proposed scheme uses inband-signalling to set up a path to the content source (or to a nearer intermediate node having the content), and requires each intermediate node to keep minimal information for maintaining the path, as in LFBL. This aspect remarkably mitigates contention by eliminating the transmission of additional control messages in the network. After the path is established, packets are delivered in a unicast manner. The novelty of the proposed scheme lies in the fact that it effectively handles breaking off the path by taking advantage of CCN features. In CCN, copies of the packet are stored in each relay node, and they are used for serving the future query. In the proposed scheme, these copies are exploited to make a bridge of the broken unicast path as well. When in-flight packets cannot find the next hop node to be forwarded, it spreads out in the vicinity of the broken path. In terms of symmetric routing of query and response in CCN, another packet spreading must occur from the other edge of the broken path. Then, nodes that receive both packets can work as a bridge to restore the broken partial path. With this technique, users can effectively keep track of the moving content provider while enjoying the benefit of unicast packet transmission. Here we note that the proposed scheme mainly focuses on CCN environments, but it can be applied to general information centric networking architectures that share the features of (1) query/response communication, and (2) in-network caching.

In particular, the proposed scheme has the following advantages for saving energy consumption: (a) it directly inherits all the aspects of CCN for energy saving, such as a shorter deliver path by caching, and avoiding multiple delivery of the same content; (b) it can remove the resource and energy wastage caused by broadcast in LFBL and other broadcast based schemes, such as the high link layer failure rate due to the absence of RTS/CTS and the recovery overhead for the failure, unnecessary energy consumption for neighbour nodes to decode broadcast packets, and redundant packet delivery and consequential high level of interference; and (c) it can minimize the damage of broken paths by effective localized path recovery.

The rest of this paper is organized as follows. In Section 2, we briefly describe CCN. We also summarize recent studies utilizing CCN for mobile wireless networks. In Section 3, we analyze and compare broadcast and unicast fashions for delivering packets in CCN based mobile wireless networks, which motivates the rest of this paper. In Section 4, we propose an efficient packet delivery scheme using unicast for CCN based mobile wireless networks. In Section 5, we evaluate the proposed scheme through simulation. Finally, in Section 6, we conclude this paper.

2. Related works

2.1. Energy efficient strategies in mobile ad-hoc networks

Energy efficient strategies have been researched for decades in IP based mobile ad-hoc networks, and various protocols have been proposed as a result. In [11,12], several types of link costs have been proposed based on the expected power consumption. They are used for the calculation of classical shortest path algorithms in order to find the optimal end-to-end path. In [13–15], the authors present the algorithm to find the minimum transmission power that preserves network connectivity. Since lower transmission power introduces a smaller transmission range, this approach effectively minimizes the effect of interference as well as the energy consumption for transmission itself. In [16,17], the energy consumption is minimized by making nodes sleep, provided that network connectivity is preserved. Since low power is dissipated in sleep mode, they spare energy by turning off the unnecessary nodes for a certain scheduled period. The schemes in [18–20] minimize the number of message transmissions by information aggregation, optimized flooding and controlling the frequency of control messages.