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Relay-based information broadcast in complex networks

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HIGHLIGHTS

- A relay-based mechanism referred as RB is proposed for information broadcast.
- Influence of relay assignment on RB is investigated.
- Impacts of network features on RB are studied.
- The effectiveness of RB in real-world networks is confirmed.

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ABSTRACT

Information broadcast (IB) is a critical process in complex network, usually accomplished by flooding mechanism. Although flooding is simple and no prior topological information is required, it consumes a lot of transmission overhead. Another extreme is the tree-based broadcast (TB), for which information is disseminated via a spanning tree. It achieves the minimal transmission overhead but the maintenance of spanning tree for every node is an obvious obstacle for implementation. Motivated by the success of scale-free network models for real-world networks, in this paper, we investigate the issues in IB by considering an alternative solution in-between these two extremes. A novel relay-based broadcast (RB) mechanism is proposed by employing a subset of nodes as relays. Information is firstly forwarded to one of these relays and then re-disseminated to others through the spanning tree whose root is the relay. This mechanism provides a trade-off solution between flooding and TB. On one hand, it saves up a lot of transmission overhead as compared to flooding; on the other hand, it costs much less resource for maintenance than TB as only a few spanning trees are needed. Based on two major criteria, namely the transmission overhead and the convergence time, the effectiveness of RB is confirmed. The impacts of relay assignment and network structures on performance are also studied in this work.

1. Introduction

Broadcast is a common and critical process in complex networks, aiming to disseminate information from one node to all the others. It has raised a lot of attention, not only because of its theoretical importance, but also its broad applications. Examples include the study of rumor and disease spreading over a community [1,2], the link-state advertisement in routing protocol for router networks [3], message dissemination mechanism in early warning system [4], just to name a few.

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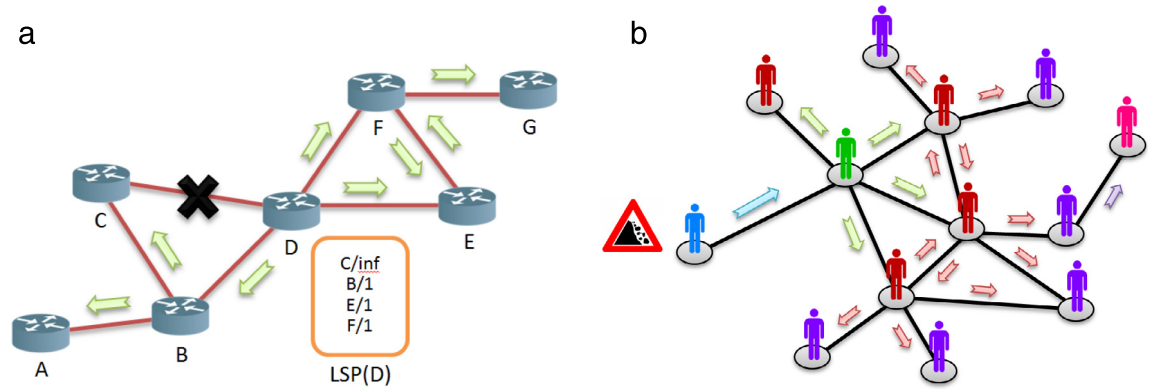

Fig. 1. Information broadcast over complex networks. (a) Flooding of LSP in link state routing due to topology change. (b) Flooding of information in people-centered early warning system.

The most fundamental mechanism for information broadcast is flooding, which simply forwards information to all the neighbors except the sender. Flooding is straightforward but it costs a lot of transmission resources. In [5], another possible way for information broadcast, called tree-based broadcast (TB), has been proposed. In TB, information is disseminated over a tree, accordingly eliminates all redundancy transmissions. However, it requires many computational and memory resources to maintain the trees, making it less popular than flooding.

On the other hand, due to the recent findings in complex network sciences, many real-world networks are reported to possess some common characteristics, where the most remarkable ones are the scale-free and the small-world properties. Well-known examples include the World Wide Web (WWW) [6], the Internet [7,8], social networks [9], and so on. In these networks, some nodes have relatively high centrality and therefore play a more important role. It is interesting to point out that, by utilizing the high centrality of these nodes, many interesting research works have been reported, such as the pinning control of most centric nodes in scale-free dynamic networks to achieve synchronization [10], the centrality-based caching algorithm in information-centric networks [11], the bow-tie model to characterize relations between webpages based on some central core webpages [12,13] and the impacts of centric nodes on cascading failures of power grid systems and other supply networks [14].

In this paper, we are interested in utilizing some hub nodes to facilitate information broadcast and investigating their impacts. A novel broadcast mechanism called relay-based broadcast (RB) is proposed. A subset of nodes is selected as relays, and information is now firstly forwarded to one of them, then from the relay to all the destinations over a tree. In addition, due to the scale-free nature, our study shows that the delivery time can be close to that of flooding/TB which is the global minimum.

The contributions of this paper are multi-fold. Firstly, a new information broadcast method based on relay is designed and its effectiveness is demonstrated. Secondly, different relay assignment methods and the influence of the number of relays are studied. What is more, the impacts of network characteristics on the performance of the proposed RB mechanism are investigated. As a result, it can be understood under what condition this kind of mechanisms becomes practically preferable.

The rest of the paper is organized as follows. Information broadcast together with the two conventional methods, flooding and tree-based broadcast, are revisited in Section 2. In Section 3, the novel RB is proposed and its mechanisms are explained in details. In Section 4, the effectiveness of RB is investigated. Analyses onto the influence of relays and topological characteristics are also presented. Finally, conclusion remarks are given in Section 5.

2. Information broadcast over network

It is common to disseminate information from one node to all the others over a complex network. This process, referred as information broadcast (IB), plays a critical role in many real-world systems. For example, in link-state routing protocol [3], which is generally performed by routers in the Internet, a node will update all the others with a link state packet (LSP) that contains names of its neighbors and the delivery costs in respect to the change of topology or periodic update (see Fig. 1 (a)). Consequently, each node can reconstruct the updated topology of the whole network and achieve shortest path routing. Another example is the people-centered early warning system for disaster risk management [4], in which message dissemination is one of the four elements of the system. It is to assure a clear and understandable message to be reached to everyone in the area at risk (see Fig. 1 (b)).

2.1. Conventional approaches

To broadcast a piece of information, flooding is a typical approach. Consider a general mechanism, known as Sequence Number Controlled Flooding (SNCF), it only consists of two simple rules: (1) Every node forwards the received information