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An adaptive epidemic information dissemination model for wireless sensor networks

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ABSTRACT

We propose an adaptive bio-inspired information dissemination model that exploits the specific characteristics of the sampled/generated data stream (DS) in a wireless sensor network. Our model extends the basic epidemic algorithm by adapting key operational parameters (i.e., the forwarding probability and validity period) of the data dissemination process. The main idea is that the forwarding probability is tuned according to the variability of the involved DS. Our findings from the introduction of this adaptive epidemic are quite promising. Our scheme supersedes conventional probabilistic information dissemination algorithms in terms of efficiency and reliability.

1. Introduction

A major issue in Wireless Sensor Networks (WSN) is the efficient dissemination of data from sources to the entire network. A WSN node adopts some data dissemination algorithm for diffusing information in the network, e.g., flooding, bio-inspired spreading and gossipping [1]. The main objective of such algorithms is to reliably spread information across a WSN where no direct path from source to (any) destination can be secured. We focus on a specific bio-inspired dissemination algorithm: the epidemic algorithm [2]. Such algorithm (along with its variants and extensions) has been widely used for data dissemination in WSNs because of its reliability and spreading efficiency [3–5]. Most epidemic-based algorithms take into account the characteristics of the nodes and the network for diffusing information. However, the characteristics of the disseminated data can be also taken into consideration for increasing the dissemination efficiency. In this paper, we introduce a data-centric, adaptive epidemic algorithm which takes into account statistical features of the disseminated data. The proposed algorithm extends the basic epidemic algorithm by adapting key operational parameters like the forwarding probability and validity period. Such adaptation results to a more efficient scheme than the conventional (probabilistic) epidemic algorithms [2].

1.1. Epidemic algorithm

There is an analogy between the dissemination of certain information (e.g., an environmental parameter, like wind speed and temperature) among nodes and the spreading of infectious diseases between individuals. Both processes contribute to the spreading of something upon some form of contact. The widespread occurrence of a disease, which infects individuals, is referred to as an *epidemic* [6]. According to the Kermack and McKendrick epidemic model, an individual i can be in three

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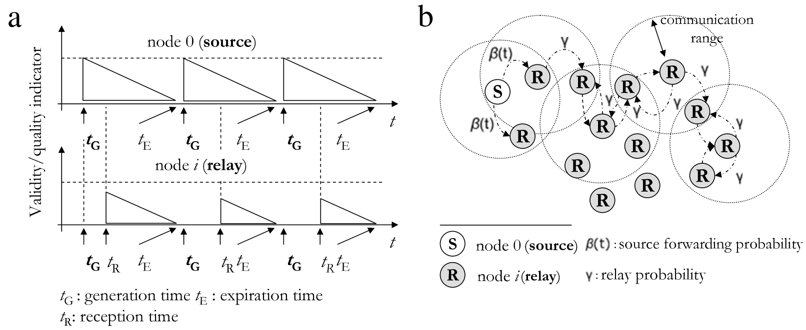

Fig. 1. (a) The validity/quality indicator for sensed/captured information data from the source to a relay node in a WSN, (b) the (probabilistic) epidemic information spreading in a WSN with one source (node 0) and relay nodes.

states: Infected (i is infected with epidemic), Susceptible (i is infection-prone) and Removed (i is immune, as it recovered from the disease). This model is also referred to as SIR. A simplified version of SIR is the SIS model in which the individual i can be either in the susceptible or in the infected state. This means that i never gets immune after its contact with an epidemic. Evidently, in the simplest SI model, i never turns susceptible if infected once. In SIS, an individual transits between states with certain probabilities. Specifically, an infected individual i may recover from the epidemic and, then, transit to the susceptible state, with recovery probability $0 \leq \delta \leq 1$. In that state, i can get infected again with an infection probability $\gamma \in (0, 1]$.

In the context of information dissemination, a node i, which carries a piece of data (epidemic) is an infected individual, otherwise it is a susceptible one. An infected node can relay (infect with) a piece of data to neighbouring nodes with forwarding (infection) probability γ and recover with probability δ. In our case, the rate δ indicates the failure of node i to (randomly) transit between the operational state and the non-operational state: the former state denotes that the node is in operation while it remains inactive in the latter state. Moreover, we can assume some ageing (or quality) function for the disseminated information, for instance, a temporal validity indicator. Such a function indicates that the disseminated information remains valid only for a certain time horizon (similar to the TTL property). Consider that a piece of information x is generated (sensed/captured) by a source node at time instance t_G (generation time) and its validity ends at a certain time instance (expiration time) $t_E > t_G$. Hence, the piece of information is considered valid for the time interval $[t_G, t_E]$. A node i receives information x, which is considered valid at any reception time $t_R \in [t_G, t_E]$, relays and/or consumes x in the time interval $[t_R, t_E]$, as shown in Fig. 1(a). Hence, based on this setting, we adopt the SIS epidemic model for valid information dissemination. Specifically, our objective is twofold. We extend the SIS epidemic model for: (a) efficiently and reliably disseminating valid information across the WSN, and, (b) decreasing the delivery time of valid information to a certain node. The structure of the paper has as follows: Section 2 reports related work on probabilistic dissemination models. Section 3 introduces the proposed adaptive epidemic model. Section 4 reports a performance evaluation of the discussed model and a comparative assessment with other models. Finally, Section 5 concludes the paper with further research on that area.

2. Related work

The simplest technique for a node to spread information is flooding regularly to random subsets of the node's neighbours with a certain probability [6,7]. The basic parameters of such epidemic models [2] are the number of times a message is forwarded, the memory for each node and the total number of nodes. Such models suffer from certain drawbacks: (a) do not scale well, and, (b) impose considerable overhead (traffic) due to deliveries to uninterested nodes [2].

Work performed so far addresses some of the aforementioned issues. In all cases, the objectives of every epidemic algorithm are reliability and efficiency in data dissemination [5]. The authors in [8] proposed an enhancement to the basic epidemic algorithm. They exploit the connectivity and position history of the nodes for forwarding decisions. Nevertheless, the knowledge on the exact network topology is required for the model in [8] (contrary to our model). The work in [9] proposes an adaptation of the forwarding probability of a node based on the characteristics of the neighbourhood of the node. In addition, the authors in [10] use acknowledgement messages to passively cure an epidemic with the intention of reducing network traffic. Nevertheless, the approaches in [9,10] assume knowledge on the network topology and require additional information (acknowledgements) in order to achieve efficient data dissemination as considered in [11]. Moreover, the adaptive Gossip protocol in [12] requires that each nodes has knowledge on the local density of nodes. Hence, a node forwards data based on a pre-set wait period. The node forwards data during the selected period, which also requires a retransmission threshold. The probabilistic adaptive information dissemination model in [13] is based on the network density, which is inferred by the number of neighbours, and the mobility behaviour of nodes. However, such model preforms well in terms of network coverage once applied on very dense networks with high mobility. Moreover, in [14] the authors propose a mechanism that automatically adapts transmission probabilities subject to the underlying network topology. Nodes use relatively smaller forwarding probabilities in regions where node density is higher, and vice versa. The authors