Comparison of Policies for Epidemic Broadcast in DTNs under Different Mobility Models

Francesco Giudici, Università degli Studi di Milano, Italy
Elena Pagani, Università degli Studi di Milano, Italy
Gian Paolo Rossi, Università degli Studi di Milano, Italy

ABSTRACT

The broadcast diffusion of messages in Delay Tolerant Networks (DTNs) is heavily dependent on nodes mobility, since protocols must rely on contact opportunities among devices to diffuse data. This work is a first effort to study how the dynamics of nodes affect both the effectiveness of the broadcast protocols in diffusing data, and their efficiency in using the network resources. The paper describes three control mechanisms. The mechanisms characterize a family of protocols able to achieve some awareness about the surrounding environment, and to use this knowledge in order to keep the broadcast overhead low, while ensuring high node coverage. Simulation results allow to identify the winning mechanisms to diffuse messages in DTNs under different conditions. [Article copies are available for purchase from InfoSci-on-Demand.com]

Keywords: Broadcast; Delay Tolerant Networks; Distributed Systems; Networking; Opportunistic Networks; Performance Evaluation; Wireless Technologies

INTRODUCTION

The mobile nodes of a delay tolerant network, or DTN (DTN Research Group, 2008), experiment intermittent connectivity and network partitions. So far, in such a critical scenario, the research mainly focused on the problem of providing unicast communications (e.g. (Burgess, Gallagher, Jensen, & Levine, 2006; Davis, Fagg, & Levine, 2001; Jones, Li, & Ward, 2005; Juang, Oki, Wang, Martonosi, Peh, & Rubenstein, 2002; Spyropoulos, Psounis, & Raghavendra, 2004)). By contrast, the one-to-all communication scheme has not received the same attention despite the fact that its service is strategic to support protocols at both application and routing levels. For instance, a broadcast service is required to diffuse scoped advertisements—e.g. about available services or events—and summaries (Lee, Magistretti,
Zhou, Gerla, Bellavista, & Corradi, 2006), to support podcasting (Lenders, Karlsson, & May, 2007), or to diffuse acknowledgments, or cure, packets (Harras, Almeroth, & Belding-Royer, 2005). In a DTN, broadcast can be designed by adopting one of the gossip-based mechanisms that have been proposed in the literature in a few slightly different alternatives by starting from the following PUSH-based scheme: when a node has a message $m$, it forwards $m$ to one or more (possibly all) neighbors it happens to encounter while moving. The forwarding, elsewhere called infection or epidemic, can be either performed periodically (Montresor, Jelasity, & Babaoglu, 2005) or whenever a contact occurs (Vahdat, & Becker, 2000). Infection can continue up to either the message lifetime or a given number of transmissions. The PUSH-based algorithm is effective in achieving a node coverage arbitrarily close to 1 with low latency, but fails in doing this efficiently. Indeed, nodes perform epidemic forwarding with no knowledge about the state of the encountered nodes and, as a consequence, they often happen to forward a message to already infected nodes.

The primary focus in the design of a—both efficient and effective—broadcast protocol is to increase the node likelihood of delivering a message only to uninfected nodes. There are several, growing levels of knowledge a node could achieve about the neighbors state and to approximate the global system state. Whatever is the followed approach to achieve efficiency, the performance of the algorithms is greatly influenced by the mobility patterns that nodes follow (Camp, Boleng, & Davies, 2002). The comparative analysis of the effects of mobility on protocols deserves more attention and, as far as we know, has never been applied to broadcast. This paper moves into this research track and provides some interesting contributions to understand broadcast delivery over DTNs under different mobility conditions. Firstly, the paper defines a family of broadcast protocols, obtained from the PUSH-based approach through the introduction of adaptive mechanisms whose purpose is the improvement of the node awareness about the level of infection in the neighborhood. Secondly, the performances of the different mechanisms are analyzed in three basic mobility models: the classical random waypoint, the swarm mobility, and the aggregation model where nodes move throughout aggregation points. The main contribution of the paper is twofold: (i) it identifies and characterizes the winning mechanisms to diffuse messages in DTNs under different conditions, and (ii) it is a first attempt to move toward the design of an autonomic and situational algorithm able of autonomously adapting its parameters according to the mobility context the node is moving through, in order to optimize performances.

**SYSTEM AND MOBILITY MODELS**

**System Model**

The scenario we consider in this paper includes people walking in a limited urban area, such as a campus area, and equipped with wireless portable devices. No base stations are assumed and the communication between a source $s$ and a destination $d$ may eventually occur through either direct contact, when, for instance, node $d$ moves into the range of $s$, or indirect contact, when one or more relaying nodes help to create the multi-hop path toward the destination and the last of them finally enters the range of $d$. The devices have a unique identifier, are not required to have positioning capabilities on board and, to meet resource saving requirements, are supposed to adopt a short radio range to communicate. This latter point, together with the fact that devices can be sparsely distributed over a large area, makes high the probability of network partitions and link disruption. Throughout the paper we only assume that each mobile device, or node, periodically broadcasts a beacon message in its radio cell. Beacons are used to discover other devices in the neighborhood and their content is limited to the device identifier. In such a scenario, people mobility might follow either
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