

Chapter XVII

In-Stream Data Processing for Tactical Environments

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ABSTRACT

Data dissemination and information management technologies for tactical environments are quickly becoming major areas of research for both military and civilian applications. Critical to the problem is the need for fully distributed information management technologies that are efficient, adaptive and resilient. In this paper, we introduce and discuss a new strategy for tactical data dissemination and processing based on distributed online learning. Starting from a formal description of the problem we introduce our proposed solution and its theoretical properties. We also present and discuss a number of simulation experiments for different data dissemination scenarios, and conclude the work with a discussion on how such techniques may be applied to critical e-government environments under different assumptions of service availability and information release policies.

INTRODUCTION

Tactical networks are generally characterized as mobile ad hoc networks under policy and resource constraints. These types of network environments are commonly found in military and disaster recovery operations and represent a percentage of the types of environments where government agencies are required to effectively operate and collaborate.

Generally, the primary objective of tactical networks is to support fast formation of ad hoc groups and systems to share data, processing capabilities, and communication resources. One of the most critical and challenging problem in these types of environments is the distributed coordination of resource allocation for data distribution and processing. The decentralized and dynamic natures of tactical environments require resource coordination strategies that are distributed, efficient, and adaptive. Furthermore,

coordination mechanisms are expected to be resilient to environmental changes and failures, with minimum requirements for maintenance and configuration.

Conceptually, the problem of dynamic resource allocation in tactical networks consists of finding and maintaining the best data distribution trees that together minimize the global utilization of resources for data processing and data transmission, while complying with policy constraints both at the levels of the nodes and network.

In this work we revisit a reinforcement learning-based strategy proposed by Carvalho (2006) for the resource allocation problem in tactical networks. The goal is to formulate the problem in a way that supports the application of a resource coordination protocol that will leverage from previously established localized learning techniques.

BACKGROUND AND PREVIOUS WORK

The resource allocation problem for data processing in mobile ad hoc networks can be generally classified into three main groups: (1) local data processing, (2) remote data processing, and (3) distributed (or in-stream) data processing. In each case, the goal is to allocate resources for data processing and distribution from a source node to multiple sink nodes requiring (possibly) different variations of the data.

In the first type of problems (i.e., local data processing), the source of the data is responsible for providing the necessary transformations required by each client. Similar to conventional client-server models, local data processing essentially allocates all processing to the data source (i.e., the server). The research focus on these types of problems is basically in the allocation of resources for data distribution (i.e., data routing).

Curran (2003) proposed a reinforcement learning-based algorithm for routing in ad hoc

networks. The SWARM protocol is data agnostic, focused only on packet routing. When receiving a data packet, each node chooses the appropriate action (next hop) based on current policies. The work was later extended by Dowling, Curran, Cunningham, and Cahill (2004) who proposed the collaborative reinforcement learning-based routing protocol called SAMPLE, for mobile ad hoc networks. Chang, Ho, and Kaelbling (2004) have also proposed the use of reinforcement learning techniques for data routing in mobile ad hoc networks. Although the approach did not address tactical issues such as service decomposition and distribution, it did allow for interaction between data routing and node mobility. Peng and Deyun (2006) also leverage from reinforcement learning algorithms to improve quality of service (QoS) routing strategies. In his work, Peng proposes a heuristic-based algorithm that utilizes reinforcement learning to estimate best QoS routing paths from previous experience, reducing the number of QoS flood and probing packets for path maintenance in mobile networks.

Remote data processing problems try to identify a node in the network that is the best candidate for the data processing task. Like in the previous types of problems, the task of allocating resources for data processing is separate from the allocation of resources for data transmission in the network. For example, if a number of clients require data to be retrieved and processed from a server in the field, a remote data processing strategy will essentially identify a proxy node in the network (based on CPU, memory, and storage capabilities) to act as the point for data processing and re-distribution. Costs related with data transmission from the source to the proxy and from the proxy to each client are independently calculated.

In 2004, Baehni, Eugster, and Guerraoui proposed a data aware variation of conventional multicast protocols that took into account the nature of the data being transmitted when building

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