Chapter 10
Knowledge-Based Networking

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ABSTRACT
Knowledge-Based Networking, which is built on-top of Content-based Networking (CBN), involves the forwarding of events across a network of brokers based on subscription filters applied to some semantics of the data and associated metadata of the events contents. Knowledge-based Networks (KBN) therefore support the efficient filtered dissemination of semantically enriched knowledge over a large, loosely coupled network of distributed heterogeneous agents. This is achieved by incorporating ontological semantics into event messages, allowing subscribers to define semantic filters, and providing a subscription brokering and routing mechanism. The KBN used for this work provides ontological concepts as an additional message attribute type, onto which subsumption relationships, equivalence, type queries and arbitrary ontological relationships can be applied. It also provides a bag type to be used that supports bags equivalence, sub-bag and super-bag relationships to be used in subscription filters, composed with traditional CBN subscription operators or the ontological operators. When combined with the benefits of Content-based Networking, this allows subscribers to easily express meaningful subscription interests and receive results in a more expressive and flexible distributed event system than heretofore. Within this chapter the detailed analysis of ontological operators and their application to a publish/subscribe (pub/sub) domain will be fully explored and evaluated.

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INTRODUCTION

Content-based networks (CBN), such as (Carzaniga et. al., 2001; Peitzuch et. al., 2002; Segal et. al., 2000), formed around the necessity to match a varying subscriber base to that of a network’s publication creators. However, open standards for CBNs have been slow to emerge due to the difficulty in reaching a general compromise between the expressiveness of event attribute types and subscription filters, exacerbated by the need to both match these efficiently at CBN nodes and to efficiently maintain routing tables. The need for efficient network utilisation requires that notifications are routed towards nodes and subscribers that are interested in a particular message, using a routing table composed of subscription filters, rather than flooding the network in the search for all interested possible parties. This is usually combined with a mechanism to exploit multicast efficiencies made possible by aggregating/covering subscriptions with ones that match the same or wider range of messages. For example, in the Siena CBN (Carzaniga et. al., 2001) subscription covering is achieved by restricting attribute types and subscription filters to simple number, string and boolean types using a set of transitive operators to filter across them (i.e. greater/less than, super/sub string etc.). The underlying routing structure on which messages pass allows for a message inserted on one side of the network to propagate across the network based on positive matches to the filters (subscriptions) until every client, and only those interested in the message, have been delivered the message.

CBN Subscriptions are specified as a set of filtering constraints constructed using a filter operator and some values used to compare against the contents of any incoming notification. The range of these operators determines the type of pub/sub network in which the message is being sent. Mühl et. al. (Mühl et. al., 2006) describe this content-based matching as a set of “Filters which are evaluated against the whole contents of notifications”. Within this work, notifications can be thought of as publications. Publications are only forwarded to a user when the contents of their subscriptions’ filtering constraints matches a subset of the message’s contents. This allows for a more flexible message format and, in comparison to topic-based networks, allows an even looser coupling between publishers and subscribers.

As an example, in the Siena CBN system (Carzaniga et. al., 2001) a notification is seen a set of typed attributes. Each attribute is comprised of a name, a type and a value. The existing version of Siena supports the following types: String, Long, Integer, Double and Boolean. A Siena subscription is a conjunction of filtering constraints, where constraints are comprised of the attribute name, an operator, and a value. A subscription matches a notification if the notification matches all the filtering constraints of the subscription’s filter. The notification is then delivered to all of the clients that submitted those subscriptions that match against that publication. Carzaniga (Carzaniga et. al., 2008) defined three basic types of Siena topology: hierarchical client/server, acyclic peer-to-peer, and general peer-to-peer. All topologies provide the same functionality, however they differ in non-functional features, like time complexity, scalability and fault tolerance.

The work within this chapter focuses on Knowledge-Based Networks (KBNs) (Lewis et. al., 2006; Keeney et. al., 2008a; Keeney et. al., 2008b) rather than CBNs. It is important to note that Knowledge-based networks are defined, within this chapter, as publish/subscribe networks in which the semantics of the message play an important part in the matching of publications to subscriptions. The particular flavour of KBN investigated in this work is an extension of the Java Siena CBN middleware (Carzaniga et. al., 2001). The specific Siena-based KBN implementation introduces two extensions to the existing type set and the set of filter operators already provided by the