Context Awareness based Bandwidth Management Scheme for Ad hoc Network

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Abstract

In order to guarantee key businesses when bandwidth resource is in shortage, an adaptive and flexible Context-Aware Bandwidth Management Scheme (CABMS) is proposed to improve network survivability. Nodes firstly query the local context information, and use Bayesian Network (BN) to determine the importance of current business, further to determine the utility function of bandwidth allocation. Through establishing the dual problem of original one, the "shadow price" of bandwidth is introduced, so that the nodes are able to adjust bandwidth requests on their own according to the price, with the convergence of allocation result. In the CABMS business is classified into different levels. When bandwidth resources is in shortage, the high-class business will be biased in bandwidth allocation; when in severe shortage, some regular business bandwidth requests will be rejected, in order to guarantee the bandwidth requests of key business. Simulation results indicate that CABMS can assign more bandwidth to relatively important business under given conditions, compared with proportional fairness. Specifically, urgent business bandwidth allocation increases by about 42%, important business bandwidth allocation remains essentially unchanged and the regular allocate bandwidth falls by about 37%.

Keywords: Ad hoc Network; Context Awareness; Bandwidth Management; Bayes Network; Proportional Fairness

1. Introduction

Because of the flexibility and rapidness of constructing network on various occasions, Ad hoc networks are widely used in emergency situations and in the battlefield environments. Bandwidth resource in Ad hoc network is scarce, when many data flows in the network contend for bandwidth; reasonable bandwidth allocation methods are needed. Currently, many research works have been done on bandwidth management for Ad hoc networks. Fang Z Y proposes two bandwidth allocation schemes based on gaming theory and they can change the utility function to balance the fairness and efficiency of bandwidth allocation [1]. Xue Y introduced the concept of shadow price of the maximum clique and a price based bandwidth allocation algorithm is proposed to achieve the utilization sum maximization of data flows with certain fairness [2]. In references [3][4], an Ad hoc bandwidth allocation algorithm
based on auction mechanism is proposed, data flows determine current bandwidth price according to the budget and compete for resources, reducing the complexity and accelerating the convergence time. In reference [5], a distributed admission control algorithm for Ad hoc networks is put forward which does not need knowing the exact amount of remaining bandwidth.

However, these studies don’t consider the rational allocation of bandwidth aiming to specific battle scenarios. In fact, the importance of different service follows in practical network environment varies greatly. From the perspective of network survivability, when bandwidth is scarce, more bandwidth should be allocated to the more important data flow, thus ensuring the completion of key services. In addition, the existing Ad hoc network bandwidth management solutions pay little attention to network context of applications, including network heterogeneity and special user needs. Anind Dey gave a more generic definition of context: it is any information that can be used to characterize an entity in its current state, the entity can be a person, thing or any other objects interacting with the user and application, including the user and the application itself [6]. In real network environment relevant context data can be collected by various sensors and detectors [7], and then tools such as Bayesian Networks are used to model and reason about context. Finally, context data will be stored in the repository for later query and usage. Bayesian Networks belongs to the probabilistic graphical model which is suitable for model and analysis of uncertainty problems and it has unique advantages in dealing with uncertainty and provides efficient inference algorithms [8]. At present, as an context inference toll Bayesian Network has been widely recognized by people [9-10]. Based on context-aware applications can timely learn environmental information to make reasonable actions and provide relevant information or services to users, allowing users getting satisfactory services efficiently at a lower cost.

2. Descriptions of CABMS

2.1. Context Awareness and Decision-making

To achieve adaptive allocation of bandwidth based on service importance, context-aware based Ad hoc network bandwidth management mechanisms (CABMS) requires context reasoning technologies to reason about the importance of various services. Specifically, CABMS uses Bayesian network as inference tool, which can express uncertainty in a visual way beneficial to understanding context model. Factors influencing service importance are various and complex. To simplify analysis, taking battlefield environment for an example, using seven kinds of common context information to evaluate the importance of services, including service type (Business), user identity (Identity), fighting state (Fight), environment noise (Noise), user acceleration (Acceleration), mechanical vibration frequency (Vibration) and service significance (Significance). Additionally, assuming these factors are discrete variables. Depending on whether the variable can be observed, those seven factors can be divided into observable variables $V_{observed} = \{I, N, A, V, B\}$ and hidden variables $V_{hidden} = \{F, S\}$. According to the causality of the impact of context on service importance, Bayesian Network is constructed.

In practical applications parameters of Bayesian Network can be trained based on a large number of samples. When no data is missing the maximum likelihood method is used to estimate the parameters. When data is missing, EM algorithm is utilized for parameter learning. After gaining context, using structured Bayesian Network to inference about relevant information. Specially, CABMS uses the clique tree method to calculate the probability distribution. Clique tree is an exact inference algorithm with high computing speed and its main step is to convert the Bayesian Network to clique tree and calculate the probability by belief propagation [13].

2.2. The Procedure of Bandwidth Allocation

To reflect impacts of different service importance on bandwidth allocation, Sigmoid function is used by CABMS to indicate the utility of data flows, depicted as follows.

$$
U_i(x) = \begin{cases} 
0, & \text{if } x_i < R_{mi} \\
1, & \text{if } x_i \geq R_{mi} \\
\frac{2}{1+e^{-\sigma x_i}} - 1, & \text{if } 0 > 0, \text{otherwise}
\end{cases}
$$

(1)
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