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Input Set Decomposition and Open-Loop Control in Telecommunications Networks

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Abstract

This article analyzes problems of development of open-loop control systems for telecommunications networks and discusses one of several possible algorithms for decomposition of the input set into closed convex subsets (if such decomposition is possible). This decomposition allows for creation of a control rules: "Control should be the same as long as an input vector belongs to the subset that corresponds to a control rule. If the input vector leaves this subset then a new subset, to which the input vector belongs, must be defined and control should be changed to the control assassinated with a new subset. This article presents examples of input subsets. The proposed decomposition approach is an illustration of the methodology the scrapping in [1].

Introduction

In this article we consider open-loop control as control that is based only on information about the status of the controlled system input. As an input we consider a combination of values off traffic entering a network from different service subscribers. Each combination is a vector in the input set. As a controlled parameter (output) we consider an average delay *T* that traffic undergoes in the network. Control can be executed via changes in the routing of traffic flow in the network. The task of the control system is to contain the controlled parameter below a tolerated limit d_{max} upon fluctuation of the input vector (input traffic) into the input set. A major problem in the development of open-loop control systems is the creation of "input is…, then control is…" rules that provide solutions to every input vector. If we try to define a separate control for each possible input vector, then the size of the control rule table becomes too large. However we can reduce this table if we decompose at whole input set into subsets and, for each subset, find a corresponding control rule [1]. Moreover, we can avoid analysis of all possible control vectors via a properly organized routing optimization procedure. The development of control roles requires the availability of a network input - output transformation model.

Network Model

The proposed approach is currently under investigation far possible use in the development of an on-line performances oriented open-loop control system for highly heterogeneous frame relay and ATM networks. The open-loop approach was chosen to decrease the reaction time of the control system to a minimum. A network model is created and traffic routing is optimized in correspondence with [2]. The models of frame relay [3] and ATM [4] switches are the results of Ph.D. studies. However, for demonstration we use a very simple example of the network from [5] (Figure 1). To save space we don’t provide network and traffic parameters used in the example. These parameters can be found in either [1] or [5]. Although the decomposition and open-loop control studies [1] were made on a network with 30 source-destination couples, that is, into a 30-dimensional input set, illustrate our analysis with a three dimensional input set. This allows us to better visualize the results of the decomposition and provide valuable information about the shape properties of the subsets. The three dimensional input set is created by varying traffic values between nodes C and A, B. and E and D and E. Traffic for the rest of the network is fixed. Network control is executed via routing tables created for each network node.

If during routing optimization we find control for which network provides $T \leq d_{max}$, then it means the volume of input traffic can be steadily increased until *T* reaches its limit i.e., it is possible to define for this control an input subset in which an input vector can fluctuate, and condition $T \leq d_{max}$ will be satisfied. If we can find another control that provides $T \leq d_{max}$ for an input vector that does not belong to the already-defined input subset, then the input set can be decomposed on a set of input subsets.

Input Set Decomposition

We are proposing a decomposition procedure in which we assume that the inputs subsets are convex and the subsets are defined when their boundary sets are defined. This procedure is as follows: The center of the first (initial) subset is determined via a randomly selected input vector. We denote that input vector as Z_{10}. The routing (control) that provides the best possible value of the controlled parameter *T* for Z_{10} is defined via optimization [2]. If the control that provides $T \leq d_{max}$ for this input vector is found, then we can define the input boundary points that correspond to $T = d_{max}$. To do so we generate a test vector that originates at the point representing the input vector and expends from it to the boundary set in a random direction. The boundary input point is defined via one – dimensional optimization executed along this direction to minimize $|T - d_{max}|$. Then another test vector and direction are selected another boundary point is defined.

After a number of boundary points are found, we can try to represent a created boundary set via some polynomial. (It is desirable for open-loop control to describe a boundary set analytically). This can be down by using either the “Fit” function of [6] or some other fitting algorithm. We use the optimization algorithm proposed in [2]. The result of a fitting provides us with information about the polynomial and the value of the least squares error corresponding to that polynomial. Using this polynomial allows us to speed up our process, since now we can continue selection of testing points that are very close to the boundary set. These points are randomly selected one-by-one and inch point is considered as the origin of the test vector. Additional boundary pints are defined via procedure similar to that describe it above. Each additional boundary point is used to correct the polynomial and recalculate the value of a least squares error define iper point. When this error is stabilized, we terminate the procedure and consider the polynomial found.

Figure 2 presents a boundary set in which no constraints are applied to network performance. Figure 3 represents a set which is defined so that the load of no network circuit can exceed 66%. For illustration we note that that boundary set in Figure 3 is represented by $a - b/(c-x) - dx + kx^2 - m/(n-y) - ry + py^2 - z = 0$. Received data show that subsets are convex. Figure 4 presents an example of input sets decomposition into two three-dimensional sets.

In our studies we were able to define surfaces analytically for input sets with up two 30 dimensions. The describe algorithm can be modified to also allow decomposition of an output set. Moreover, input set and output set decomposition can be combined, thus increasing control system capabilities

Open-Loop control

After decomposition we can employ a variety of procedures for on-line open-loop control. One is to monitor the input vector and perform verification for conditions similar to: $a - b/(c-x) - dx + kx^2 - m/(n-y) - ry + py^2 - z \geq 0$.

If the condition associated with the subset is satisfied and the control role associated with this subset is currently active, than we consider that the input vector belongs to the subset and continued current control. If at some moment monitoring detects a violation of this condition, then the subsets closest to the input vector are tested. This process continues until a suitable subset is found and its corresponding rule is fired.

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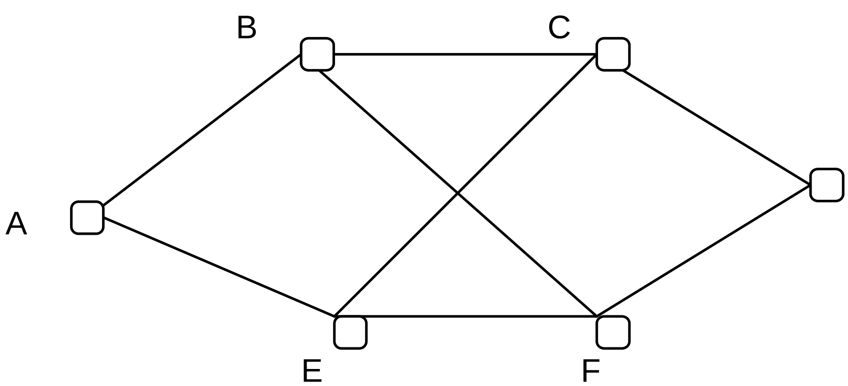

Fig 1

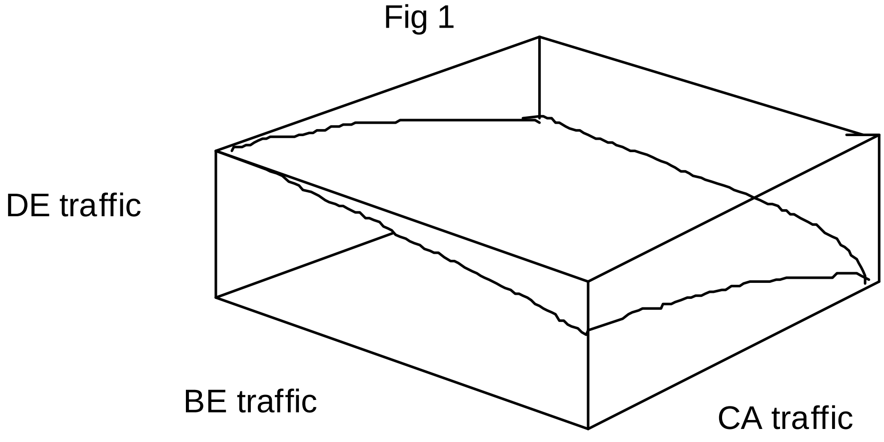

Fig.2

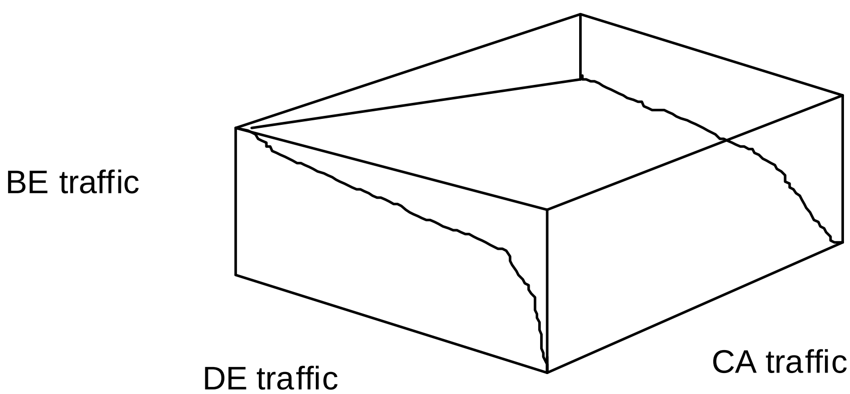

Figure 3