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Modelling Blocking on Admission of Tasks to Computer Systems

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Abstract
The need for modelling techniques to allow blocking of tasks prior to admission to the computer system in queueing network models is described. A detailed algorithm which presents a technique to enforce blocking by priority of class for an arbitrary number of blocking constraints is presented. The resultant solution is exact and produces an analysis by class of admission queueing delays.

1. Introduction

Queueing network models [1] have been used extensively for modelling computer systems. Most of the modelling performed to date has been confined to construction of models to describe existing computer systems and extrapolate the growth of the component workloads so as to predict the effect of upgrading hardware components. In a few cases, attempts have been made to predict the effects of systems not yet implemented [2], [3] and [4]. The basic statistics required from queueing network models are response times per class together with the associated utilisations, waiting times and queue lengths at each component device of the system.

These statistics are consequent upon the accurate modelling of all system environmental components which contribute towards the overall response times. They include the data communications network, the user terminal characteristics and the behaviour of the computer system itself. In particular, the computer system component incorporates certain multiprogramming constraints by type of workload which affect overall response time. For example, a particular online system may only be capable of processing six tasks concurrently whereas the network volumes dictate the concurrent presence of ten tasks at the computer system. This means that a large proportion of the total number of tasks at the system must queue for admission into the system.

Unless the queueing network model used for analysing the system takes these constraints and resultant admission queueing into account, the resultant model output will not be realistic.

2. Approaches used to date

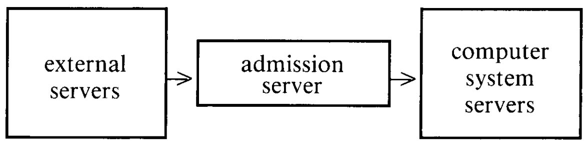
Decomposition [5] consists of analysing a submodel in isolation, (ie the computer system submodel component) and then replacing this subsystem in the original model by a single, composite load-dependent server which appears to the rest of the system to behave the same as the original subsystem. Such an approximation is accurate if the rate of interaction within the submodel is substantially higher than the rate of interactions between the submodel and the rest of the model. In the case under discussion, the submodel consists of computer system components with service times of the order of 10^{-2} seconds whereas the terminal network has service times of the order of 10 seconds. Consequently, decomposition has been widely used as a technique to model large terminal-based systems.

Although effective results can be derived using this approach, the multi-step nature of arriving at a model solution impedes the ease of formulation and solution of the model. Consequently, an alternative approach is needed to model blocking of tasks on admission from part of the queueing network (the external system) to the remaining part (the central computer system itself).

The approach to blocking presented here is based on a technique suggested in [6] and that presented in [4]. The latter reference contains a validation of the technique. We assume that the queueing network consists of a number of servers such that some are located external to the computer system and others are located within the computer system where the blocking constraints hold. We define an additional dummy server which serves as the system admission adjudicator. It initially has zero service time. The model is then solved. If the resultant solution is feasible in terms of the blocking constraints then the algorithm terminates. Otherwise, class-dependent service times are calculated so as to produce a feasible solution by delaying additional tasks at this admission adjudicator. The solution obtained at the end of this procedure is not only feasible — the extent of the delay prior to admission of tasks of each class can be measured.

3. Notation used in the Algorithm

We assume the the model topology is as follows:



where "external servers" refers to servers outside the computer system, "computer system servers" to those inside the computer system and "admission server" to the dummy server with initial class-dependent service times all set to zero.

Let K denote the number of classes and M be the number of queues (servers) in the network. We then define the notation used in the algorithm as follows:

N_k No. of class k jobs in the network for $k = 1, \ldots, K$
S_{mk} Mean service time of class k job at queue m.
v_{mk} Visit ratio of class k jobs at queue m.
Q_{mk} Mean no. of jobs of class k at queue m.
W_{mk} Mean waiting time of class k jobs at queue m.
T_{mk} Throughput of class k jobs at queue m.

We define further the following set of multiprogramming blocking constraints:

$$\sum_{r \epsilon C_c} \quad \sum_{\substack{m = \text{computer} \\ \text{system queues}}} Q_{mk} \leq P_c \qquad (1)$$

where P_c is a constant and C_c is a set of classes such that $k \epsilon C_c$ implies $k \epsilon \{1, \ldots, K\}$

Define the admission server to be device f so that external devices are such that $m = 1, \ldots, f-1$ and internal devices such that $m = f+1 \ldots, M$

Each blocking constraint (1) is defined for a given set of classes C_c. Each class C_c has a given priority G_k.

The following algorithm calculates values S_{fk} $(k = 1, \ldots, K)$ in such a way that if priority $G_r < G_s$ for $r,s \epsilon C_c$ then S_{fr} is increased before S_{fs}. (ie. lower priority classes are blocked on admission into the computer system before higher priority classes in order to satisfy given multiprogramming constraints).

4. The Blocking Algorithm

We assume the queue f is an infinite server device so that following [6]:

$$W_{fk} = S_{fk} \; v_{fk} \text{ for all } k = 1, \ldots, K \tag{2}$$

Initially $S_{fk} = 0$ for all $k = 1, \ldots, K$. Then by global application of Little's Theorem [7] :

$$T_{mk} = N_k \, v_{mk} / (\sum_{i \neq f} W_{ik} \, v_{ik} + S_{2k} \, v_{2k}) \tag{3}$$

By local application of Little's Theorem and (1) and (3) above:

$$\sum_{k \epsilon C_c} \sum_{m > f} Q_{mr} = \sum_{k \epsilon C_c} \sum_{m > f} (N_k v_{mk} W_{mk} / (\sum_{i \neq f} W_{ik} v_{ik} + S_{2k} v_{2k})) \tag{4}$$

The following algorithm is then applied to evaluate the S_{fk}:

1 $S_{fk} = 0$ for all $k = 1, \ldots, K$
2 Compute W_{mk} for all $m = 1, \ldots, M$ and $k = 1, \ldots K$
3 Sort constraints so that if C_{c_1} is a subset of C_{c_2} then constraint c_1 is processed before constraint c_2
4 For all constraints c

```
        For all priorities Gq of classes q∈C_c
        until H*_c ≤ P_c

          S¹ = 0
          H*¹_c = 0
          Do until H*_c ≤ P_c or H*_c = H*¹_c
H^c_r = Σ N_k v_mk W_mk /( Σ W_ik v_ik + S_2k v_2k)
                           m>f
                            i≠f
            for all k∈C_c
            H*_c = ΣH^c_k
                   k∈C_c
            If S¹ = 0
              S¹ = Σ H^c_k ( Σ W_mk W_mk v_mk)
                  r∈C_c  m>f
                  G_k = G_q
            else
              S¹ = S¹ (H*_c/P_c)
            Do for all k∈C_c such that G_k = G_q
              If S_2k < S¹
                S_2k = S¹
            Doend
          Doend
      Doend
  Doend
```

5. Conclusions

Execution of the above algorithm during solution of the model is iterative. Initially, no admission delays by class are assumed. If a feasible solution does not result then delay service times of an infinite server device are calculated so as to keep tasks outside the system. This continues until a feasible result is obtained. The result is not only intuitively understandable — a delay queue prior to admission but also exact in queueing network solution terms. The technique has been widely used [4] and can be extended to model blocking and adaptive routing in data communications networks.

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1. ASHCROFT, E. and MANNA, Z. (1972). The Translation of 'GOTO' Programs to 'WHILE' Programs, in *Proceedings of IFIP Congress 71*, North-Holland, Amsterdam, 250-255.
2. BÖHM, C. and JACOPINI, G. (1966). Flow Diagrams, Turing Machines and Languages with only Two Formation Rules, *Comm. ACM*, **9**, 366-371.
3. GINSBURG, S. (1966). *Mathematical Theory of context-free Languages*, McGraw Hill, New York.

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