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A Scalable Load Balancing Strategy in an ATM Network Backbone

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☐ ABSTRACT ☐

In this paper, a generic load balancing strategy over a preplanned Asynchronous Transfer Mode (ATM) backbone is tested. Distributed systems are subject to an exponential increase in size due to widen use of distributed database banks. The ATM is moving promptly towards being a backbone for WANs. In this study, The ATM Virtual Path (VP) concept is used to plan the underlying distributed system network. ATM can support a guaranteed quality and a fast service. The of ATM characteristics give it the advantage of being a potential response to the transparent nature of remote accessing and load balancing which may require heavy traffic to perform the information policy in distributed systems. Preferred sets are chosen, VPs are established, the system is integrated and numerical results are presented.

Key words: ATM networks, Load balancing, Networks planning. Distributed systems.

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توزيع العبء المتدرج باستخدام نمط النقل اللاتزامني

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(قبل للنشر في 2003/1/5)

□ الملخّص □

يهدف هذا البحث إلى دراسة واختبار طرق توزيع العبء في المنظومات الموزعة (Distributed System) باستخدام نمط النقل اللاتزامني (Asynchronous Transfer Mode) كعمود فقري للنظام، من المعروف أن المنظومة الموزعة آخذة بالتوسع الهائل. وذلك بسبب استخدام بنوك قواعد البيانات الموزعة والمتباعدة ومن المعروف أيضا أن ATM هو في طريقه إلى أخذ موقع أساسي في شبكات WAN. في هذه الدراسة تم الأخذ بمفهوم Virtual Path VP لتخطيط البنية التحتية لمنظومة الشبكات الموزعة حيث أن ATM يضمن الخدمة من حيث السرعة والنوعية وهذا ما نحتاجه في عملية توزيع العبء حيث تحتاج هذه العملية إلى تبادل هائل للمعلومات لاتخاذ القرارات الماسبة بأقصى سرعة ممكنة من أجل اتمام هذا لاعمل على شكل منظومة متكاملة اقترحنا استخدام خوارزمية اختيار المجموعات المفضلة prefered sets وإنشاء المسارات التخيلية VPS اللازمة التي تمكن من الحصول على نتاج محاكاة موثوقة وأخيرا تم عرض النتائج العددية للبحث.

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INTRODUCTION:

Distributed systems can be defined as a set of sites connected by means of an underlying network. In heterogeneous systems, the processing power may vary from one site to another, and the jobs may arrive unevenly at different sites in the system, this entails that some sites might be temporarily overloaded while others are underloaded or even idle.

Load balancing plays a central role in system utilization by almost equalizing the loads on the system. As a result, the situation where some sites are heavily loaded and others might be idle is avoided. Decisions on how to balance loads among the nodes are either static [2, 5, 11] or dynamic [1, 3, 4, 6, 7, 8, 9, 12, 13, 14, 15, 16]. A static decision is independent of the current state of the system, where a dynamic decision depends on that state at the time of the decision. The dynamic policy is inherently more complex than any static one, because it requires that each node must know the states of the other nodes. Depending on the node initiating job transfer, the load balancing algorithms can be source-initiated or server-initiated. Typically a load balancing algorithm has three types of processes: a load information process, a transfer process, and a location process. There are basically two types of overhead costs involved in dynamic load balancing; i., e., communication and computation overheads. The latter issue originated from the preknowledge that should be available at decision time, such information includes, among others, local load conditions. Choosing the termination node is a site responsibility. On the other hand, the former issue, the communication problem, depends on the underlying network used in the system. Thus, typical networks as they are known, are a mixture of different technologies, which might have a great influence on the performance of any large, distributed system.

The underlying networks used in distributed systems are usually the LANs, but in general, due to very large distributed systems, certain sites could be situated even in different countries, making the LANs as underlying networks questionable. The networks are moving towards having the ATM network as a backbone. The characteristics of ATM networks might be used to enhance the overall performance of large distributed systems.

Large distributed systems,, do not usually take into consideration the availability of resources, such as links availability in terms of link capacity. For example, if one wants to use his/her Auto Taller Machine card on the eve of the Christmas remotely, then the possibility of getting connected is very low due to the excessive use of the network. Hence, network planning might be essential to reduce and/or to eliminate the possibility of not getting connected by designating paths with certain capacity to be used only by large distributed systems.

As mentioned above, one of the most famous trends in telecommunications is to have an ATM network as a backbone for WANs. An important characteristic of an ATM networks is the VP concept, in which a logical planning for a network could be applied off line; i.e., an adapted VP might be defined between any couple of nodes regardless the number of nodes that may be passed towards the destination. Therefore, neither delays are expected nor extra computation overheads are performed, except the normal propagation round time, which is very low due to the availability of high-speed networks. The VP is a logical connection that is to be established among different couples of nodes; where the physical link is subdivided into logical channels. The VP has its own identification number (ID), and width. The ID is used for routing while the width is used for the capacity of the identified channel.

NET WORK PLANNING:

As mentioned above, the networking system might get subject to a high saturation due to excessive use in a particular day or event. To avoid this dissatisfaction of end users and to enhance the overall system performance, networks planning using the VP concept in ATM systems might be a perfect solution for such a dilemma.
Upon thinking of networks planning, one might think of dividing the network itself into layers, the physical layer and the logical layer. This does not only facilitate the overall task, but it also gives more flexibility by having more than one procedure, each of which can be modified whenever any necessity arises [17].

A VP is an end-to-end logical path, although it might pass one or more servers. The physical link among different servers is subdivided into several VPs depending on some strategy. A certain amount of bandwidth is assigned to each VP. A number of VCs (the VC represents a service request) could be passed through any VP. This number depends on the bandwidth allocated to the VP, the bandwidth necessary to carry a single call, and on the number of calls in progress over the VP under consideration. This process is rather important because the control exerted in the intermediate nodes is shifted to the boundaries of the network [17].

Two main objects of network planning are obvious: The first is to create a new network with almost optimal cost and performance in terms of physical components and response time. The second is to enhance the already existing networks by selecting particular predefined logical paths. This concept when it is applied in a satisfaction manner yields a robust distributed system imminent to drastic change of load over the network.

In respect to the distributed systems, all the nodes in the system are well known and identified by the control regime. This facilitates the clustering process. The clustering procedure works as follows:

A VP is defined between any couple of nodes if and only if the difference of the processing powers (PP) is not high, depending on some strategy [16]. Hence the following constraint is to be satisfied:

$$\text{PP I} <= 3^{*}\ \text{PP J} \qquad (1)$$

Where PP I is the processing power of node I and PP J is the processing power of node J. To this aim the following pseudo-code is to be activated:

```
For I=1,n                       ; n is the number of nodes in the system.
     k=0;
    For j=1,n, (I¹ j)
         If (s(j) / s(i))<=3 then    ; S(i) is the power of node i.
        k=k+1;
       Set(I,k)=j;              ; set(I,k), k=1,...m, is the preferred set for node i.
   end
end .
```

Applying this simple procedure (Fig. 3) resulted in coupling any pair of nodes, bearing in mind that constraint (1) is to be applied. However, an eye should be kept on the location of such a pair of nodes to decide the importance of this particular connection. For example, let us have 5 nodes and their correspondence powers: (10, 40, 70, 15, 90), the table of preferred sets will be as follows

Table 1: Nodes number versus preferred set.

Node number	Preferred set
1	4
2	4
3	5
4	1, 2
5	2, 3

Having a network connected as mentioned above, the logical topology of the network is then devised. Therefore, the network planner should take such logical topology into account when the process of load balancing is to be activated. To make this point clear: let us first consider a network that consists of 3 nodes only as it is clear in fig.1. Fig.1.a shows the simple network before planning, while fig.1.b reflects the network after planning. To give a flavor of the planning process, fig.1.c is exactly as fig.1.b but nearer to the human understanding. Upon the configuration of such network, the virtual network is then obvious and therefore using the network becomes possible. To this aim, when it came to the load balancing, it was not important for us to apply a particular load balancing strategy, i.e., the most important thing for us was the application of any load balancing strategy over an ATM backbone. As a consequence we selected the central load balancing mechanism just for clarification: any other strategy might be used.

LOAD BALANCING STRATEGY

Any load balancing strategy could be implemented in terms of the above-mentioned model. In this work, we introduced a dynamic clustering method in which a special networks planning algorithm is implemented. The proposed algorithm determines for each node a set of nodes that can be considered as a preferred set. After determining the preferred sets for all nodes, we implement the **Central** algorithm [10] to balance the load in each set. In the **Central** algorithm, one of the nodes is chosen to be a central node (Fig. 4) for the process of load balancing. Each node on the set is connected on line with the central. All the information needed to the process of load balancing is passed to the central node. This information is collected in a table that helps the **Central** to balance the load in the following way. The **Central** searches the table for the heaviest loaded node, and the least loaded one, after that it informs both nodes to make the process of load balancing between them. The centralization system is not taken here in its absolute sense; instead, it is used within the cluster. For example, the couple of nodes that decides to make a load balancing between each other might divide the total number of jobs that they have at the moment of the decision.

SIMULATION RESULTS

The node under consideration in the load balancing process is usually responsible for making decisions about two things: first, the new job is to be executed locally or remotely, and, if remotely, where? In our model, the Central node makes these decisions. So all the information needed by the central node is passed through the online connection between the central and other nodes on the same preferred set. This process is achieved by using the Signaling System Number 7 (SS7) of the ATM networks (dark lines in Fig. 4). The SS7 is a dedicated channel among different sites in digital networks. One of the major roles of the SS7 is the communication between different connected nodes in the system. By using this facility of ATM, the overhead incurred from message passing is eliminated by diverting the exchanged messages through SS7.

The bandwidth used in our experiment ranges from 2 to 50 Mbps. Any selection of one of the previous bandwidths depends on the size of the network under consideration. One other metric is load 1. This means that the network is almost congested and it begins to reject the new arrival calls. This situation resulted when the traffic, in a certain occasion, exceeds some threshold due to heavy use of the facilities of the system. In our experiments we increased the boomed traffic to see the reaction of the network under a peak load.

Conducting different experiments leads to evaluate different metrics such as response time and number of accepted requests. The response time is reduced in a dramatic way since all the messages that are supposed to be exchanged are exempted, obviously due to the proposed usage of SS7. Therefore, the time needed to process the high number of messages is saved and might be used in processing the task. On the other hand, the number of accepted requests might be maximized due to the possibility of enlarging the bandwidth.

In figure 6, it is obvious that the number of failed jobs is inversely proportional to the bandwidth assigned. This enhancement is due to eliminating the overhead stems from job transfer and message passing.

Figure 7 show the bandwidth is fixed. Then the load is increased until rejection occurs, i., e., the jobs may be dropped due to exceeding a prefix threshold of delay. From the figure, one can see that jobs begin to fail at load 0.9

In this figure, we fixed the bandwidth, and we began to increase load until the system began to reject calls (jobs fails of their deadline). The jobs began to fall at load 0.9, so figure 7 includes the loading state of the system beginning from 0.9 and up. The effect of the load on the system performance is obvious.

Here, in figure 8 we show the benefits of load balancing on the system performance with defferent loading states. At initial phase, when the load is about 0.7, the response time of the system with and without load balancing is almost equal. When the load gets higher, the gain of the load balancing process is obvious, this is due to the possibility of utilizing the entire system resources in the process of load balancing.

CONCLUSIONS:

Load balancing alone might be a good solution to better utilization of resources in distributed systems. Shortcomings that may occur due to heavy use of the underlying network might be avoided or even eliminated by applying the ATM networks as a backbone. However, the concept and characteristics found in ATM network could be of special value to the distributed systems as our proposed model explains.

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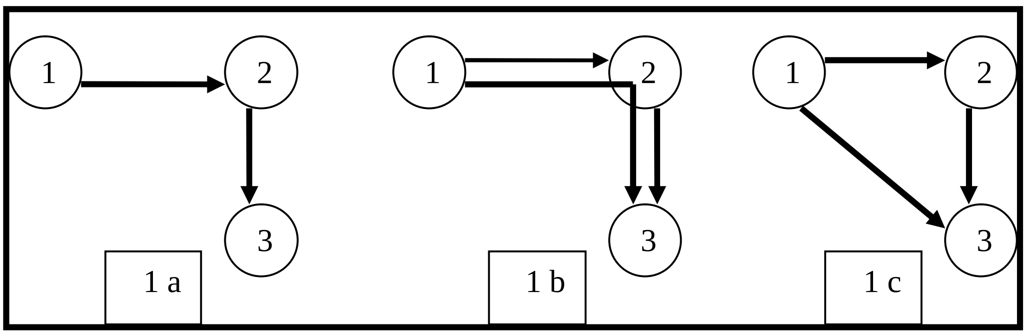

Figure 1: A three nodes network before and after planning.

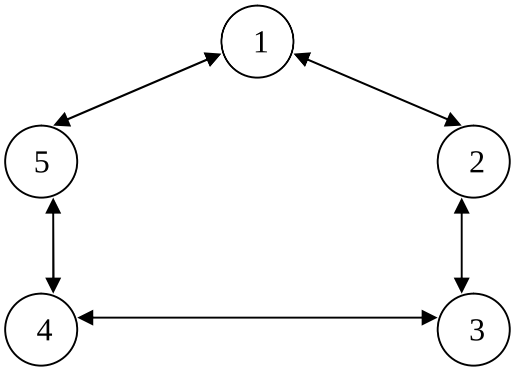

Figure 2: The topology of the system of 5 nodes.

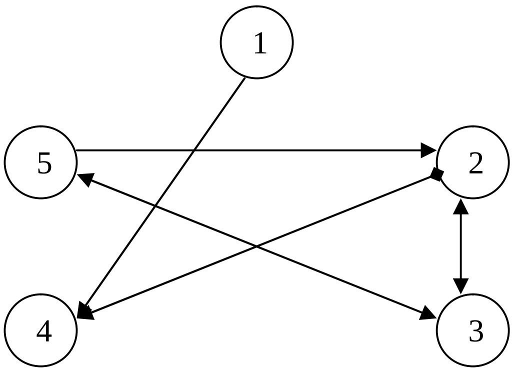

Figure 3: The topology of the system upon implementing the preplanned network algorithm.

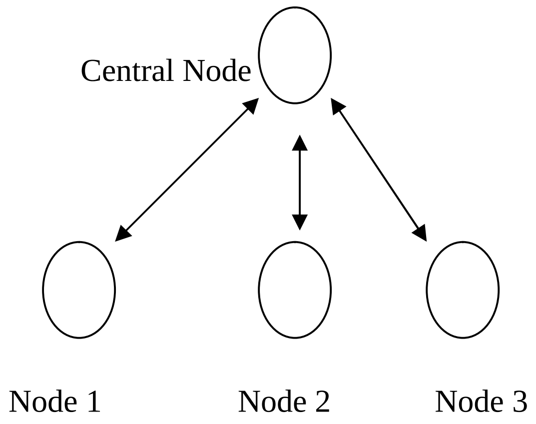

Figure 4: The Central node, which possesses the load balancing algorithm, connected with its preferred set.

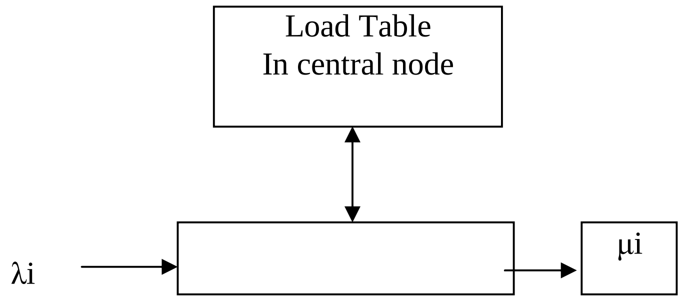

Figure 5: Node model

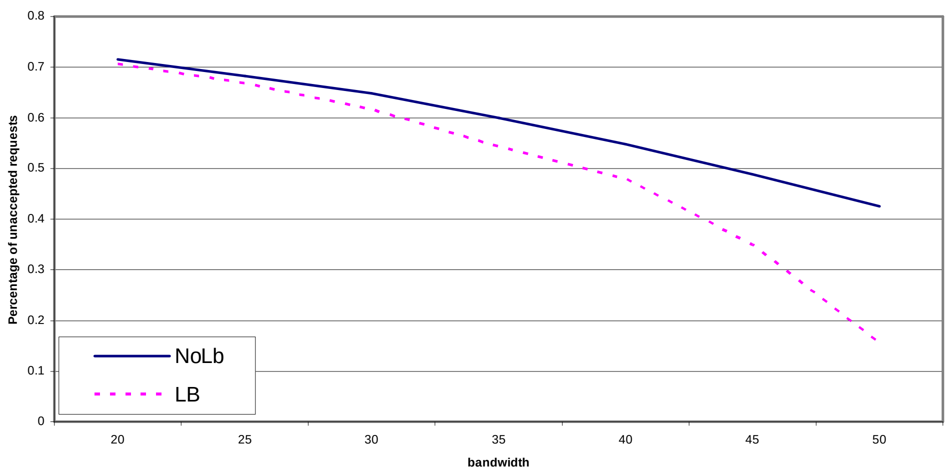

Figure 6: The effect of network bandwidth on the percentage of failed jobs with and without load balancing.

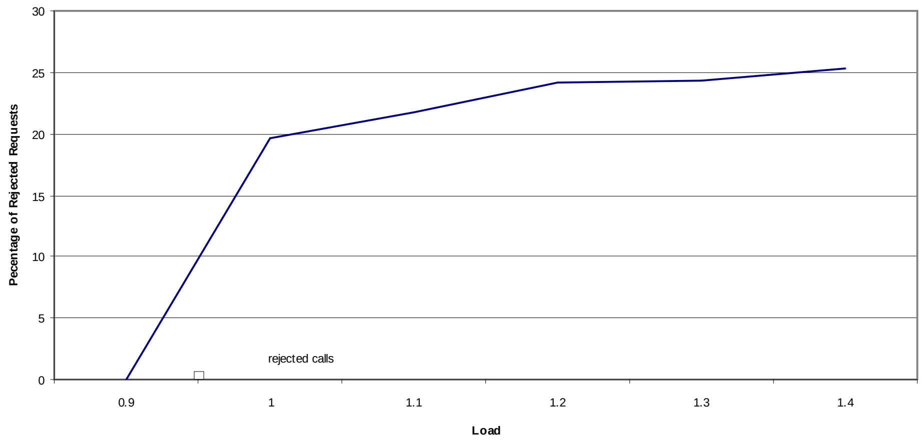

Figure 7: The effect of the load on job failure.

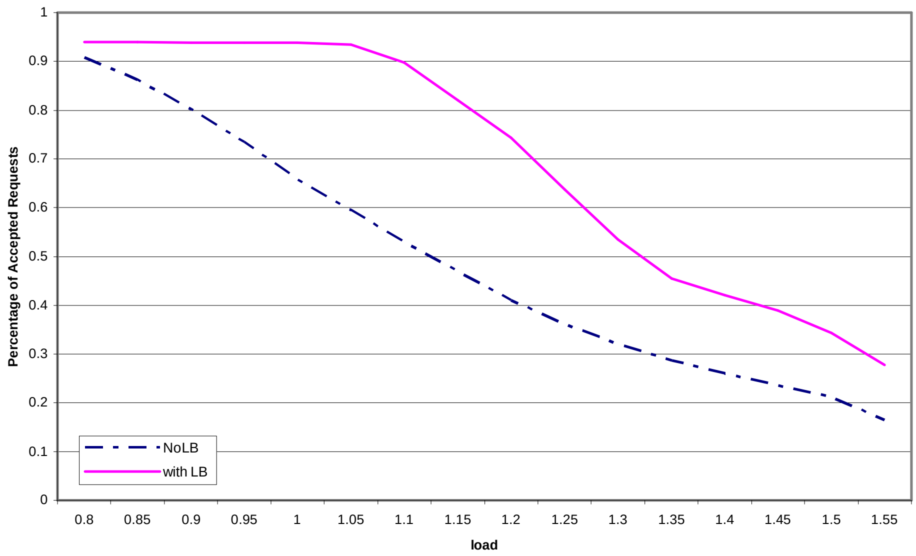

Figure 8: The effect of load balancing on the system performance with different loading states.