PERFORMANCE ANALYSIS OF A LARGE-SCALE COMMON CHANNEL SIGNALLING NETWORK

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Besides switching and transmission, signalling is one of the basic functions of telecommunications networks. Common channel signalling (CCS) is a signalling system in which a single channel conveys signalling information relating to several trunks and other interexchange information, such as network management, operation & maintenance etc.

In this paper the planned CCS network (CCSN) of DBP-Telekom is regarded as a data communication network with given routing plan and network topology. The signalling traffic is measured in terms of message signal units per second (MSU/s). It consists of link-by-link signalling traffic, end-to-end signalling traffic (ISDN services), and signalling network management traffic.

We present a procedure that evaluates the signalling traffic load of all signalling points (SP) and signalling link sets for any given network availability status and signalling traffic demand.

For the ISDN user part, the signalling traffic demand is evaluated by means of the traffic carried in the corresponding digital trunk network. The impact of the congestion control strategy on the CCSN is studied for several cases.

1. INTRODUCTION

The telephone network of Deutsche Bundespost Telekom is currently being enhanced with digitally switched SPC exchanges and digital transmission systems. For interexchange signalling, the internationally standardized CCITT SS No. 7 was adopted in order to dispose of a general purpose common channel signalling system serving new services (e.g. ISDN) and service features.

Many studies have dealt with aspects of function, network and implementation concerning CCITT SS No. 7 which is now available in Version No. 3 [1]. An excellent treatment of the main features of CCITT SS No. 7 is given in [2]. The author describes the development of SS No. 7 and asks whether it will be able to meet tomorrow's telecommunications needs.

In [9] the two error correction procedures proposed by CCITT for the functional level 2 (link level) of SS No. 7 are examined with the aim of establishing engineering criteria for link delay performance, whereas in [8] approximate formulas for message delay, queuing size and system capacity in functional level 3 are presented.

In [11] a complete generic framework for the analytical performance evaluation of CCSNs based on SS No. 7 is developed and illustrated by means of a small network. Problems related to practical aspects of CCSN planning (meeting redundancy, transfer time, delay, economy and security requirements) are discussed in [10].

In [7] a basic concept and a configuration of a CCS operation system is proposed. In [4] routing plan design and validation procedures for large-scale CCSNs based on SS No. 7 are presented. The main aspect covered is how to avoid the cycling of signalling messages (SM) irrespective of the network status. Finally, in [5] these procedures are extended to cover signalling relation availability aspects, too.

This paper describes a procedure that evaluates the total signalling network load (MSU/s). It is intended to be used as a flexible tool for performing case studies and analysing network management actions. At first, we resume some features of CCITT SS No. 7 as far as they affect the model presented in this paper.

2. SOME BASIC FEATURES OF CCITT SS No. 7

CCITT SS No. 7 provides a framework for the fast and reliable exchange of signalling information between the corresponding User Parts (UP) of adjacent or non adjacent SPs via signalling links (link sets).

Two UPs, having the ability to communicate with each other, form a signalling relation. Figure 1 gives two examples of signalling relations (SR). SRa is handled over the direct link (SP1,SP2), whereas SRb makes use of the route (SP3,SP5,SP4). SP5 serves as signalling transfer point. UPs belonging to a particular SR exchange signalling information by means of data packets called message signal units.
In the following, some details of signalling route management and congestion control are given.

### 2.1 Signalling route management

Figure 3 shows an example of routing for different routing conditions. In the case of normal routing conditions, MSUs with DPC = 6 arriving (generated) at SP 1 take the route (1, 3, 4, 6). Accordingly, (2, 3, 4, 6) is the normal route for MSUs with DPC = 6 arriving (generated) at SP 2. Let us assume that links (link sets) (3, 4) and (3, 5) fail. Then, SP 3 is no longer able to transfer MSUs destined for SP 6. It sends TFP(DPC = 6) to its adjacent SPs, SP 1 and SP 2, urging them to reroute MSUs destined for SP 6. After rerouting, the actual routes are (1, 4, 6) and (2, 5, 6), respectively.

According to a fixed time schedule (e.g. 30 secs), SP 1 and SP 2 send RST(6) to SP 3 asking for permission to reroute MSUs with DPC = 6 back to their normal route. Once SP 6 is accessible for SP 3, SP 1 and SP 2 are acknowledged by means of TFA(6).

### 2.2 Congestion control in the message transfer part

In each SP the (re-) transmission buffer (level 2) of each outgoing signalling link is monitored. If a buffer is filled up to a certain limit, congestion in that direction is indicated. MSUs waiting in the buffer are randomly chosen to generate transfer controlled messages (TFC). Each of the TFC is sent to the OPC of the selected MSU to inform it about the congestion to the destination defined by the DPC of the MSU. If the OPC is its own SP-code, the MTP sends congestion indication primitives (CIP) to its own user parts instead.

A message transfer part (MTP) receiving a TFC destined for it sends CIPs to all its user parts. The CIPs request the UPs to reduce the signalling traffic to the given destination.

In the ISDN-UP (level 4) each trunk group is related to a SP to which the link-by-link signalling traffic is sent. If a CIP received by an ISDN-UP indicates a SP-code which does not correspond to a trunk group, no action will be taken.
On the other hand, for each of the related trunk groups a control mechanism is switched on which reduces the number of new seizures by a certain degree (reduction level) without affecting already established connections.

In Figure 4, the congestion control is illustrated assuming that congestion on link B-C is indicated.

The main set of input parameters is the traffic demand (MSU/s) generated by the user parts of the signalling network. This traffic demand has to be known for each user part on an OPC-DPC basis.

### 3.1 Evaluation of the CCSN traffic demand

The signalling traffic demand of the ISDN-UP consists of link-by-link and user-to-user signalling traffic. This traffic is generated by the traffic offered to the corresponding digital trunk network given by busy hour call attempts (BHCA).

As already described, congestion control in the CCSN may affect the traffic handling in the trunk network, which may cause extensive changes in the signalling traffic demand.

For analyzing the correlations between both networks, the traffic carried in the digital trunk network is calculated by TETRUN (traffic evaluation in the trunk network) taking into account:

- the topology, the trunk group sizes, and routing in the digital trunk network
- node and trunk group failures
- network management actions (caused by CCSN congestion control)
- the traffic offered to the trunk network.

The load of each trunk group is evaluated using approximative methods described in [6] and the Erlang fixed-point approach ([3]). It is distinguished between successful connections (answer message received) and unsuccessful connections (no answer message received) as different numbers of link-by-link MSUs are sent. In addition, for each traffic relation the mean rate of successful connections (user-to-user traffic) is calculated.

The link-by-link and end-to-end signalling traffic demands (MSU/s) of each ISDN-UP signalling relation are finally calculated by means of the trunk group loads, the user-to-user traffic, the mean holding times, and given mean numbers of
Figure 5: Flowchart of the procedure
link-by-link and end-to-end MSUs per connection.

For the other user parts, the calculation of the CCSN traffic demand is effected in a simple way because the user demand is considered to be directly offered to the CCSN.

3.2 Evaluation of the signalling load

PROSILE (procedure for signalling load evaluation) is based on the following input data:

- the topology and routing in the CCSN
- the availability of each signalling link set
- the route set test emission rate (RST-MSU/s)
- the signalling traffic demand of each signalling relation.

Assuming that all input data is fixed during the time period considered, PROSILE evaluates the signalling traffic load (MSU/s) of all SPs and link sets generated by the CCSS. This signalling traffic is partitioned into four traffic types:

(a) link-by-link traffic caused by successful user traffic
(b) link-by-link traffic caused by unsuccessful user traffic
(c) end-to-end traffic
(d) signalling route management traffic (RST-MSU/s)

Types (a) and (b) correspond to call set-up and release, whereas type (c) allows for new services and service features. A flow chart of the procedure is given in Figure 5.

4. CASE STUDIES

By means of PROSILE the CCSN can be studied under several conditions. For example, any link set failure or processor outage can be modelled by choosing the link set availability matrix appropriately.

In this way, routing plans can be analysed with regard to the load distribution in the CCSN. As the load of each SP and each link set is computed, PROSILE is able to indicate shortages of node and link capacities and may therefore support CCS network planning and dimensioning.

PROSILE is also suited for studying the effects of protocol changes on the signalling network load.

The following examples are to illustrate the correlations between the CCSN and the trunk network.

4.1 Description of the network and basic assumptions

The case studies were undertaken for a network consisting of

138 nodes (each node being both an exchange and a signalling point)
4844 edges (trunk groups with 414990 circuits and signalling link sets with 6842 links).

The network structure is as follows:

- average node degree = 35
- maximum node degree = 107
- average number of signalling links/node = 100
- maximum number of signalling links/node = 256
- average number of trunks/node = 6000
- maximum number of trunks/node = 10770

In addition, 18770 ISDN-user traffic relations were taken into account. The signalling traffic demand was generated by the ISDN-UP and network management actions.

The loads of the SPs and the link sets are described by the number of MSU/s. For link-by-link signalling 9 MSU/s (IAM, 3 SAM, 2 ACKN, REL, RLSD, RLC) are assumed to be sent for successful connections and 7 MSU/s (IAM, 3 SAM, UBM, RLSD, RLC) in case a connection is blocked on a successive link (unsuccessful connection). Two user-to-user MSUs are sent during successful connections.

In scenario 1 (normal load) the trunk network carries 98.3% of the offered traffic with average trunk group occupancy of 81.9%. In this case the load of the SPs varies between 150 MSU/s and 2000 MSU/s depending on the node degree, with an average value of about 600 MSU/s. The load of nearly all link sets is very low with an average of 17 MSU/s and a maximum of 310 MSU/s (see Table 1).

4.2 General overload

For each traffic relation 100% overload was assumed. The total traffic carried in the trunk network increased by 9.7%.

<table>
<thead>
<tr>
<th>scenario</th>
<th>SPs/ links</th>
<th>successful connections</th>
<th>unsuccessful connections</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>link-by-link</td>
<td>end-to-end</td>
<td>link-by-link</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MSU/s</td>
<td>MSU/s</td>
<td>MSU/s</td>
</tr>
<tr>
<td>1</td>
<td>all SPs</td>
<td>64328.4</td>
<td>15227.0</td>
<td>74.9</td>
</tr>
<tr>
<td></td>
<td>all links</td>
<td>31581.7</td>
<td>7973.0</td>
<td>24.7</td>
</tr>
<tr>
<td>2</td>
<td>all SPs</td>
<td>73844.9</td>
<td>16702.9</td>
<td>6842.6</td>
</tr>
<tr>
<td></td>
<td>all links</td>
<td>36296.5</td>
<td>8813.5</td>
<td>3305.2</td>
</tr>
<tr>
<td>3</td>
<td>all SPs</td>
<td>73155.8</td>
<td>16582.0</td>
<td>6634.0</td>
</tr>
<tr>
<td></td>
<td>all links</td>
<td>36031.4</td>
<td>8775.8</td>
<td>3263.6</td>
</tr>
</tbody>
</table>

Table 1: MSU/s for all SPs and all links

In Table 1 the load of the CCSN is given by the sum of all SPs and all link sets for normal load (scenario 1) and overload (scenario 2). The load of the CCSN increases by about 22% due to the huge amount of link-by-link traffic for unsuccessful connections.

In scenario 3 congestion towards SP A is assumed. According to the congestion control mechanism described in chapter 2.2, the numbers of new seizures on the trunk groups to A are reduced. The effect of the control mechanism depends on the node degree of A, the reduction level, and on whether or not rejected call attempts are offered to alternative routes. Here it is assumed that in each of the trunk groups connected with A every second call is rejected and is
either offered to alternative routes, if there are any, or else is blocked.

A closer look on the impact of the congestion control mechanism on the CCSN is provided in Table 2. The indicated SPs (B1-B4) correspond to the exchanges which are used as transit nodes in the final choice routes to A. It can be seen that the congestion control mechanism is able to reduce the load of SP A. But the loads of SPs B1-B4 and the loads of the associated links are increased due to unsuccessful connections.

<table>
<thead>
<tr>
<th>scenario</th>
<th>SPs/links</th>
<th>successful connections</th>
<th>unsuccessful connections</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2 SP A</td>
<td>1848.8</td>
<td>349.0</td>
<td>2260.8</td>
</tr>
<tr>
<td>3</td>
<td>SPs B1-B4</td>
<td>4666.8</td>
<td>952.8</td>
<td>5619.6</td>
</tr>
<tr>
<td>2</td>
<td>links to</td>
<td>4572.2</td>
<td>1102.6</td>
<td>5674.8</td>
</tr>
<tr>
<td>3</td>
<td>SPs B1-B4</td>
<td>4546.2</td>
<td>1102.4</td>
<td>5648.6</td>
</tr>
</tbody>
</table>

Table 2: Effects of the control mechanism

4.3 Overload to one destination

In addition to the normal load, a 500% overload to an exchange C is assumed (scenario 4). Besides SP C, the load of those SPs increased which are related to the exchanges of the transit nodes in alternative and final choice routes to C. In Table 3 we focus on an exchange D which is used as transit node in almost all non-direct routes.

<table>
<thead>
<tr>
<th>scenario</th>
<th>SP</th>
<th>successful connections</th>
<th>unsuccessful connections</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SP C</td>
<td>221.0</td>
<td>48.2</td>
<td>269.3</td>
</tr>
<tr>
<td></td>
<td>SP D</td>
<td>326.5</td>
<td>72.0</td>
<td>399.5</td>
</tr>
<tr>
<td>4</td>
<td>SP C</td>
<td>239.9</td>
<td>52.4</td>
<td>292.4</td>
</tr>
<tr>
<td></td>
<td>SP D</td>
<td>335.3</td>
<td>66.1</td>
<td>401.4</td>
</tr>
</tbody>
</table>

Table 3: Loads of SP C and SP D

These results clearly reflect the routing scheme in the digital trunk network. Most of the overload traffic cannot be handled by the direct routes to C and is therefore offered to alternative and final choice routes. The increased load of SP D in scenario 4 shows that many call attempts find idle circuits up to exchange D but are finally blocked by trunk group D-C.

If SP D indicates congestion to SP C, according to the control mechanism, only the trunk groups connected with C, i.e., the direct routes, will be affected. With the reduction mechanism defined as in scenario 3, the load of SP D would be further increased because of the higher number of unsuccessful connections (cf. Table 2). As the node degree of the chosen exchange C is low this also applies in case where any call attempt rejected by the reduction mechanism is blocked.

5. CONCLUSIONS

We have presented a procedure for load evaluation of a CCSN. The storage complexity of our procedure is O(n x nc) where n is the number of SPs of the CCSN and nc is the maximum number of routing choices. The computing time is difficult to be stated theoretically. A typical load evaluation of our CCSN takes about 4 CPU seconds on a mainframe IBM 3090-18E computer.

The method presented in this paper is based on mean value flows of MSUs. Short term fluctuations of MSU-flows are assumed to be averaged out by means of adequately dimensioned buffers. The MSUs are considered to have equal lengths, however, MSU-flows can easily be weighted according to their types.

The correlations between the CCSN and the trunk network are studied in several scenarios. According to the results obtained, it seems to be necessary to coordinate the congestion control mechanisms operating in either network. This will be for further study.

REFERENCES