

Loadsharing – A key to the reliability for SS7-networks

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Abstract

This paper analyzes loadsharing principles and their relationship to reliability requirements for SS7-networks. After an introduction to loadsharing in SS7-networks and general problems associated with it, a specific problem resulting from the deregulation in Germany will be discussed in detail. New loadsharing algorithms that fulfill the reliability requirements of SS7-networks but which also overcome the limitations and shortcomings of the standardized loadsharing algorithm for ISUP-messages will be presented. Last but not least, measurements of SS7-traffic in the network of a new carrier are presented showing the applicability of the algorithms discussed in this paper.

1 Reliability requirements in SS7-networks

The reliability of the signaling network No. 7 (SS7) is crucial for the reliability of the PSTN/ISDN. This has already been discussed at the first DRCN. The importance of robust signaling network planning is pointed out in [2] where several practical approaches to the planning process are presented. SS7 protocol inherent reliability aspects were discussed in [3]. In SS7-networks the link and network layer provide an almost 100% guaranteed in-sequence and loss-free message transmission service for the upper layer. The SS7-network layer guarantees with a probability of 0.9999999999 that messages are delivered in sequence despite the fact that the transport network is a connectionless network. This fact, together with an almost as high probability of 0.9999999 of successful message delivery, allows the applications of the MTP to rely on the MTP as if it provided a reliable connection oriented service. Normally in connectionless networks – like IP-based networks – the link and network layer provide only a best effort service and leave it to the upper layer to provide reliable transmission.¹ In an SS7-network, however, the reliability described above is achieved by the combined efforts of the link and network layer. Therefore the loadsharing algorithm used in the network layer must be in tune with these requirements and dynamic, load dependent loadsharing and routing, for example, is not possible.

2 Loadsharing in SS7-networks

The nodes in SS7-networks are called signaling points (SP) and are identified by a unique 14-bit integer called the signaling point code (SPC). SPs are connected by signaling links.

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¹It should be noted that recent studies, see for example [1], show that out-of-sequence delivery of IP-packets is not a pathological behavior resulting from broken equipment.

The bandwidth of a signaling link is normally 64 kbit/sec. If a larger bandwidth is necessary up to 16 links between two signaling points can be used. These links between two SPs are called a linkset.

The loadsharing in SS7-networks is based on the signaling link selection field (SLS), a 4-bit integer provided by the userpart in the MTP-TRANSFER primitive. Therefore all userparts should select the SLS values for each destination with a uniform probability of $\frac{1}{16}$. The point codes of the destination (DPC) and of the origin (OPC) are also provided by the userpart and the triple consisting of the SLS, OPC and DPC is called routing label and is part of each MTP-3 protocol data unit, called message signal unit (MSU).

The MTP-3 provides a reliable in sequence delivery for all MSUs with the same routing label by ensuring that such MSUs take the same physical path through the network.

There are two kinds of loadsharing: loadsharing within a linkset and loadsharing between linksets. For a better understanding of these two loadsharing concepts consider

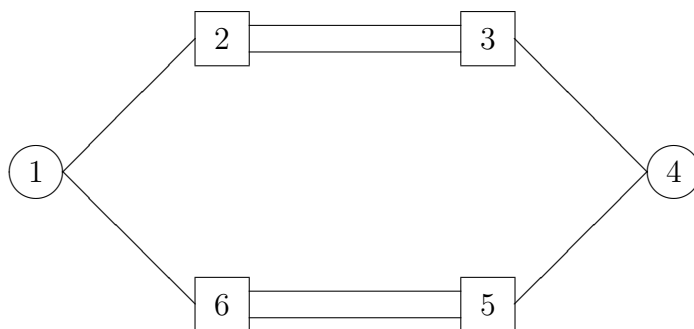


Figure 1: A simple (and not realistic) SS7-network

the network of figure 1.

For linksets consisting of more than one link the SLS-value is used to select the link in the linkset. To distribute the load equally on the links a linkset therefore thus normally consists of 1, 2, 4, 8 or 16 links. For example, in figure 1 the linkset between the SP with SPC 2, denoted by SP(2), and SP(3) consists of 2 links.

For loadsharing between linksets consider traffic from SP(1) to SP(4). There is one linkset each consisting of one link between SP(1) and SP(2) and between SP(1) and SP(6), respectively. SP(1) uses the two linksets (also called a combined linkset) for traffic to SP(4) with equal priority. The choice between the linksets is made using one bit of the SLS-field. This in turn implies that the linksets between SP(1) and, respectively, SP(2) or SP(6) cannot consist of more than 8 links each, as only at most 3 bits of the SLS vary anymore and are thus available for loadsharing. The same holds true for the linksets between SP(2) and SP(3) and between SP(6) and SP(5). Furthermore, SP(2) and SP(6) must know which bit of the SLS has been used by SP(1) for linkset selection. Therefore a network wide coordination regarding which of the SLS bits is used for linkset selection is necessary and cooperation between SS7-network planing departments is important.²

3 Additional problems of loadsharing in the German SS7-network

In the deregulated environment in Germany with the interconnection of dozens of SS7-networks since 1998 we saw that the assumption of uniformly distributed SLS-values is

²In SS7-networks based on ANSI standards using a 5 or 8 bit long SLS field and technique called SLS-rotation these problems do not arise.

not always valid (SS7 interconnection in Germany is described in [4]). ISUP is currently the only user part deployed in the German PSTN SS7-interconnection-networks. For this bearer related traffic the four least significant bits of the 12 bit circuit identification code (CIC) are taken as SLS.

Several facts contribute to the observed uneven SLS distribution.

1. To prevent dual seizure situations for bi-directional trunk groups it was agreed that the gateway with the higher SPC controls and seizes first the even CICs and the one with the lower SPC controls and seizes first the odd ones. Additionally, the SPC allocation for the national gateway switches by the German regulatory authority resulted in the new carriers' gateways always having higher SPCs than Deutsche Telekom's gateway switches. As a consequence Telekom seizes first the odd CICs and new carriers first seize the even CICs.
2. A typical ISUP call uses seven messages in forward direction, three messages in backward direction.
3. For charging purposes it was bilaterally agreed to use two different trunk groups between each gateway pair: one for incoming call-by-call and preselected traffic to the new carrier and the termination traffic to the Telekom and the other for the termination traffic to the new carrier. The second group was assigned to the slots 29, 30, 31 in each PCM-system. Especially in the beginning the second group runs nearly empty and therefore the corresponding SLS values are underrepresented.
4. Timeslot zero in a PCM-system is reserved for synchronization.

Bearing these facts in mind it is possible to interpret a linkload measurement from the STP of a new carrier to an STP of Deutsche Telekom in early 1998. Four different load

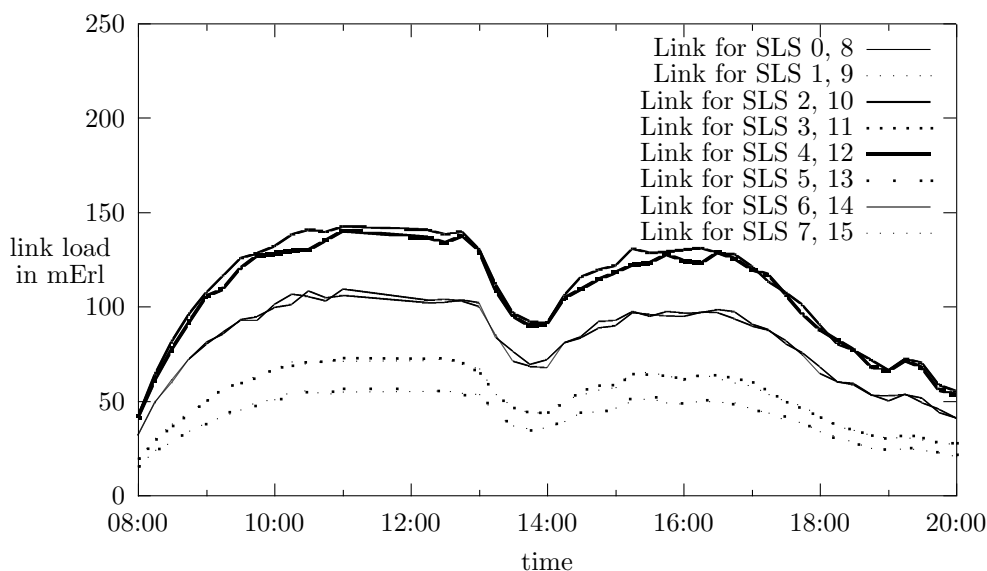


Figure 2: Traffic measurement in a linkset with 8 links.

groups can be distinguished with the lowest value nearly a third of the highest group value. In the lowest group messages containing the CICs 5, 13, 21, 7, 15, 23 are transmitted; in highest group messages with CICs 2, 10, 18, 26, 4, 12, 20, 28 are transmitted.

4 Loadsharing based on the routing label

Loadsharing defined by ITU and described in section 2 makes use only of the 4-bit SLS-field provided by the userparts. However, to fulfill the requirements for in-sequence delivery of MSUs loadsharing can be based on any function of the whole routing label – not just the SLS field – resulting in appropriately distributed 4-bit values. It is important, though, to use a function depending only on the routing label and not, for instance, on the length of the transmission queues of the links. Basing linkset and link selection on such a function will guarantee that all MSUs with a specific routing label take the same way in the SS7-network and are thus delivered in sequence.

In the following, for a non-negative integer n , the n -dimensional vectorspace over the field with two elements \mathbb{F}_2 is denoted by \mathbb{F}_2^n . We consider this vectorspace to be always equipped with the standard bases. Keeping in mind that the addition in \mathbb{F}_2^n is given by componentwise XOR-operation we look at functions F

$$F : \mathbb{F}_2^4 \times \mathbb{F}_2^{14} \times \mathbb{F}_2^{14} \rightarrow \mathbb{F}_2^4 \quad (1)$$

depending on the SLS, OPC and DPC. Thus loadsharing according to ITU recommendations would use for F the projection P_{SLS} onto the first factor.

Consider now two random variables X' and X'' with values in \mathbb{F}_2^4 . In this paper the distribution of X' is called not worse than the distribution of X'' if

$$\min_{v \in \mathbb{F}_2^4} \{P(X' = v)\} \geq \min_{v \in \mathbb{F}_2^4} \{P(X'' = v)\} \quad \text{and} \quad \max_{v \in \mathbb{F}_2^4} \{P(X' = v)\} \leq \max_{v \in \mathbb{F}_2^4} \{P(X'' = v)\}$$

holds with P denoting the probability. Obviously, the uniform distribution is not worse than any other distribution and it is the only distribution with this property. It is easy to show that for independent random variables X' and X'' with values in \mathbb{F}_2^4 the distribution of the sum $X' + X''$ is not worse than the distribution of X' and X'' (see for example [5]).

Looking for ways to overcome the limitations described in section 3 it was realized that the lower 4 bits of the OPC and DPC were independent of the SLS-value and were not constant. Thus if $P_{\text{OPC}}^{(4)}$ denotes the projector which maps the routing label to the 4 lowest order bits of the OPC and $P_{\text{DPC}}^{(4)}$ denotes the corresponding projector for the DPC one can consider

$$F = P_{\text{OPC}}^{(4)} + P_{\text{DPC}}^{(4)} + P_{\text{SLS}}. \quad (2)$$

Deploying this solution in the new carrier's network showed a significant improvement on inter-STP linksets (for example between SP(2) and SP(3) and between SP(6) and SP(5) in figure 1). Linksets from the STPs to an exchange (for example from SP(3) to SP(4) in figure 1), however, did not show an improvement in general. Analyzing the network topology explained this observation: only a very small number of OPC and DPC values were used on such linksets whereas the inter-STP linksets carried MSUs with a sufficient variety of pointcode values.

5 A new procedure for ISUP-messages

As described in section 2 the network layer of SS7-networks guarantees the in sequence delivery of messages with the same routing label, and userparts therefore choose the same SLS value for messages which have to be delivered in sequence. For ISUP, which sets the SLS-value as described in section 3, the MTP could relax this quality of service: It is only important that all ISUP-messages containing the same 12-bit CIC-field and the same OPC and DPC are delivered in sequence. Thus, for ISUP-messages, it is possible by generalizing the mapping given in (1) to consider

$$F : \mathbb{F}_2^{12} \times \mathbb{F}_2^{14} \times \mathbb{F}_2^{14} \rightarrow \mathbb{F}_2^4. \quad (3)$$

More precisely, in this section

$$F = P_{\text{OPC}}^{(4)} + P_{\text{DPC}}^{(4)} + F_{\text{CIC}} \quad (4)$$

is considered, where F_{CIC} maps a 12-bit CIC to a 4-bit value. To overcome the problems described in sections 2 and 3 one is interested in linear mappings $F_{\text{CIC}} : \mathbb{F}_2^{12} \rightarrow \mathbb{F}_2^4$ with the following properties:

1. F_{CIC} depends only on the first N , $4 \leq N \leq 12$, components. The restriction of F_{CIC} to this N -dimensional subspace is denoted by $F_{\text{CIC}}^{(N)}$.
2. For a random variable X with values in \mathbb{F}_2^N with the property that k , $0 \leq k \leq N - 4$, components are constant and the random variable induced by the other $N - k$ components is uniformly distributed, the random variable $F_{\text{CIC}}^{(N)} \circ X$ is uniformly distributed.

This condition can easily be formulated in the language of linear algebra.³ Using such a mapping F_{CIC} one can now handle k constant bits in the lower significant part of the CIC-field. Furthermore, the position of the k constant bits does not have to be known. This lack of knowledge has to be paid for and $k < N - 4$ holds in the general case. For example if $N = 7$ then k cannot be bigger than 2. For this case $N = 7, k = 2$, which is of interest if, for example, a full 8448 kbit/s digital path is used between two exchanges, linear maps $F_{\text{CIC}}^{(7)}$ given by

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 1 & 1 \\ 0 & 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 \end{pmatrix} \quad \text{or} \quad \begin{pmatrix} 1 & 0 & 0 & 0 & 1 & 1 & 1 \\ 0 & 1 & 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 1 & 1 & 0 \end{pmatrix} \quad (5)$$

can be used. But in the special case of $N = 5$, which is of interest if for example one or more 2048 kbit/s digital paths are used between two exchanges, a solution for $k = 1$ exists and is of practical interest. $F_{\text{CIC}}^{(5)}$ can, for example, be given by

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 1 \end{pmatrix} \quad \text{or} \quad \begin{pmatrix} 1 & 1 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 \end{pmatrix}. \quad (6)$$

The second map is very easy to implement and was used in the test run described in the following section 6.

6 Results of a test run

A loadsharing algorithm based on formula 4 with F_{CIC} based on the second matrix of (6) was implemented and tested in the new carrier's network. The number of MSUs transmitted on the 4 links of the linkset between an STP and an exchange was measured. The curves in figure 3 show the portion of the traffic carried by each link. One can see that the loadsharing is substantially better during the time the new algorithm is used.

³One has to study the $(4 \times N)$ -matrices M over \mathbb{F}_2 , such that all $(4 \times N - k)$ -submatrices of M have rank 4.

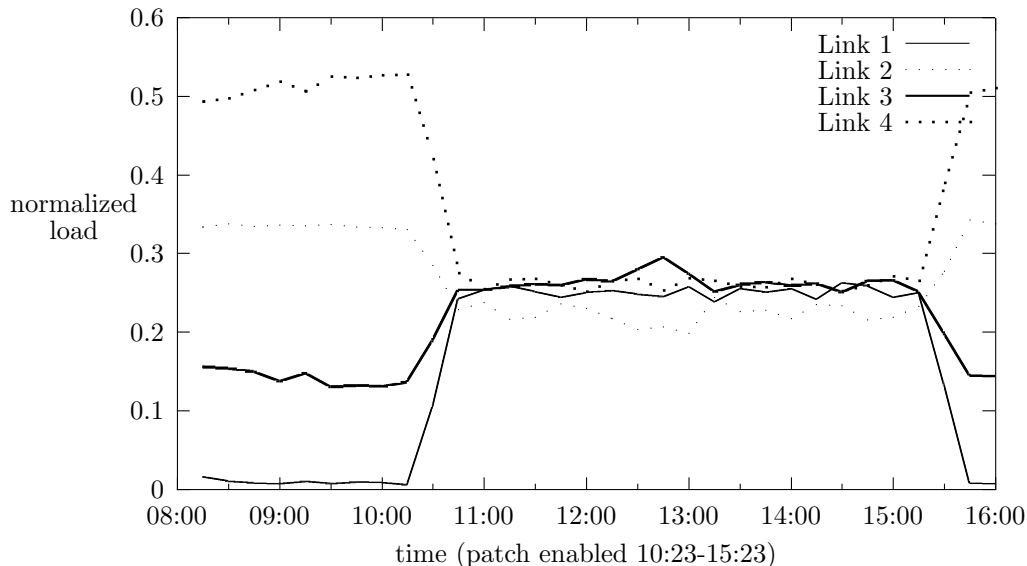


Figure 3: Traffic measurements in a linkset with 4 links using the new algorithm.

7 Concluding remarks

This paper looked at two solutions to overcome general limitations of ITU-T conformant loadsharing based on 4-bit SLS values and additional limitations introduced in the German SS7 network. For inter-STP linksets a general solution using additional information from the routing label of an MSU was presented. For linksets between STPs and exchanges a special solution for ISUP-messages using additional information from the CIC field could be identified. Compared to possible administrative methods not described in this paper, our solutions, successfully deployed in STPs of a new carrier, have two advantages. First of all, no information on how the SLS values are used by other SS7 planning departments is required anymore. Second, by effectively extending the 4-bit SLS field individual linksets consisting of up to 16 links each can be fully utilized in a combined linkset. Future work will focus on the implications of a network-wide deployment of these methods and the application of the method described in section 5 to the routing label itself.

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