Traffic Engineering for IP Telecommunications

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Abstract

This report describes how to traffic engineer a trunk connection to assure a Level of Service. IP telecommunications is a broadly defined set of services that include the standard set we know as the Internet service set as well as the expanding set including the standard telephony set, such as voice. In the telephony world, voice has a well established set of metrics for the determination of service quality. The measurement called the Mean Objective Score, MOS, is a standard process wherein the psychometric measurements are made as to speech quality and then the system parameters such as echo, signal distortion, loss, and other factors can be measured and if they are in a certain range then the QoS can be guaranteed to be within a certain window.

Contents

1. Summary

This report describes how to traffic engineer a trunk connection to assure a Level of Service. IP telecommunications is a broadly defined set of services that include the standard set we know as the Internet service set as well as the expanding set including the standard telephony set, such as voice. In the telephony world, voice has a well established set of metrics for the determination of service quality. The measurement called the Mean Objective Score, MOS, is a standard process wherein the psychometric measurements are made as to speech quality and then the system parameters such as echo, signal distortion, loss, and other factors can be measured and if they are in a certain range then the QoS can be guaranteed to be within a certain window.

This paper presents a set of tools and methodologies wherein the service quality for IP telecommunications can be developed. It should be pointed out that the IP world view is dramatically different than the telecommunications world view. This difference is a powerful barrier to effective communications between the two communities. This paper will attempt to address this issue and then with that fundamental philosophical difference allow for a reinterpretation of service quality in the IP world.

The issue of service quality is very complex. First, generally the service quality is generally reflected ultimately in the quality of the service offering provided the end user, not necessarily the metric as measured within the network. The metrics measured in the network, albeit well defined measurements that can be both measured and generally controlled are reflected as end user metrics through what is termed a subjective or psychometric tool. Namely, voice quality is in the “ear of the beholder”. Thus several naive users may be used as a test ensemble and they are asked what the level of service is as one modifies some of the well understood network metrics such as delay, echo level, channel isolation, and other similar metrics. Then the subjective metric, say the MOS, is determined and the MOS is then correlated to each of the metrics on a statistical basis. The network engineers are then told to keep the network at the measurable network levels wherein the subjective levels can be guaranteed. One never measures subjective values “on the fly” rather they are measured in benchmark levels and then projected to metrics that can be measured “on the fly”.

1.1 The IP Platform

As one evolves into a global IP platform, the issue then becomes one wherein the question asked is what metrics in an IP network are important and in turn what values are acceptable for those IP metrics to ensure that the subjective end user levels are met.

The challenge in an IP environment for service quality is several fold:

1. ***Services:*** What are the service descriptions that will be provided. One know voice, one know web browsing, one is familiar with web video and web audio. The latter two are poor quality now but they may have quality standards applied. There are metrics for broadcast audio and broadcast video. Can similar standards be applied for IP base video and audio, or is it too early. In the case of new services, what are the service metrics, how can they be determined, and who specifies them.

2. ***Metrics of Services:*** The service metrics are generally subjective and psychometric. We know voice, video, and broadcast audio. We know voice in the context of an ITU international environment. We have different video standards, PAL, CECAM and NTSC, for example. Will there be national standards or should they be international. When should these standards evolve and in what manner.

3. ***Correlates of System Metrics with Service Metrics:*** What are the system metrics. The IP and ATM world are generating what they call QoS system metrics which in many cases the engineers doing so believe that they are the end of the process. How do we correlate them with the service metrics and who specifies that. In many telecommunications interconnection agreements service quality is determined by system quality and remedies are available if the provider fails to meet the levels

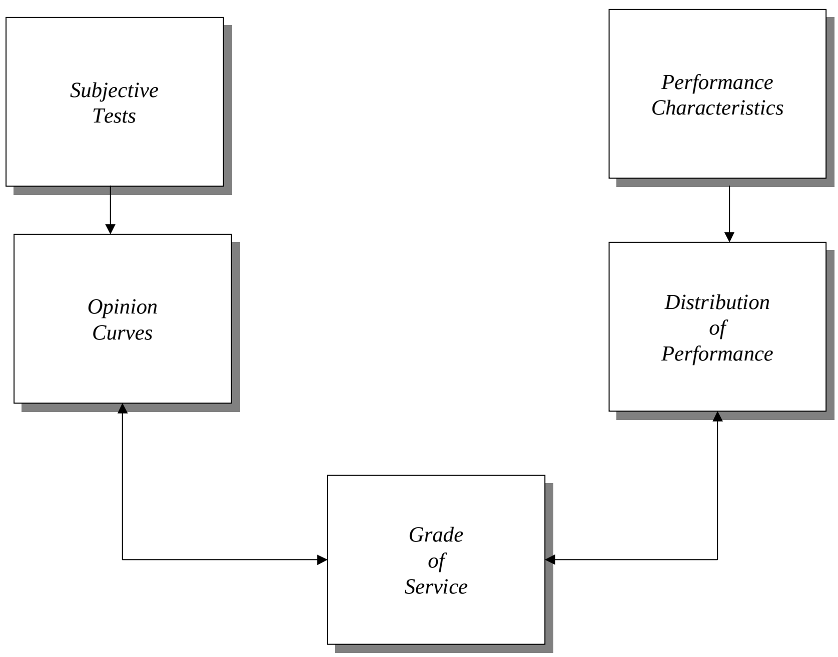
specified. How do we monitor, manage, and in turn incorporate these into the IP interconnection world.

4. ***Management of System Metrics:*** What process is created for the management of the standards and of the measurements. This is a process which is actually a dialectic, one of almost Hegelian dialectic of thesis, antithesis and synthesis. Where is the venue for this process, how do network providers provide overall end to end management, and what transparency is required.

We address these issues from both a top down and bottom up view in this paper.

1.2 Grade of Service

Grade of Service has been defined by AT&T as follows.[1] Let R be the rating of a call by a customer in category R by a customer and let M be the system performance measurement. Let M be measured from the system. For example, in a voice call, a customer may measure a call quality, MOS score, as “4.1”, given packet delay of 20 msec. The following is from the TT report and depicts the process of Grade of Service.



We can now expand on the above concept and define Grade of Service as a relationship between the system variable, such as packet delay or loss, and the service variable such as voice quality. Let x be a variable that is a system variable. For example x may be the packet delay or the noise on the circuit.

Let M be a performance measure parameter, namely a service variable, such as the MOS score.

Let us assume that one can determine via psychometric testing the probability density of:

$$p_{M/x}(M/x)$$

[1] Rey, p. 674-675.

where this is the conditional probability density of M given the system variable x.

Let us also assume that one can determine the density of x, namely:

$$p_X(x)$$

The we can determine:

$$p_M(M) = \int_{-\infty}^{\infty} p_{M/x}(M/x)\,p_x(x)\,dx$$

The on can create a Grade of Service metric, say the average M, or MOS score, given by:

$$\overline{M} = \int_{-\infty}^{\infty} M p_M(M)\,dM$$

The we can say what the average M is as a function of the psychometric filter of the conditional probability and of the performance of the system by the probability density of the system variable, say the packet delay.

We can now pose the following design problem:

If $p_{M/x}(M/x)$ is known, what is the acceptable set of $p_X(x)$ such that $\overline{M} \geq M^*$.

The Grade of Service, GoS, is thus defined as:

GoS = $\int P(R/M)\,p(M)\,dM$

Namely, GoS is the expected R averaged over the anticipated M.

1.3 Quality of Service

Quality of Service is a term now used for the actual system level elements. There is a growing issue regarding the Quality of Service on the Internet. For the most part, the Internet was an “as is” facility, namely the user took what they got and liked it. There were and are ways around this issue but for the most part they are patch works of improvement. The issue of Quality of Service, Level of Service and Grade of Service, will dominate the evolution of Internet II as well as the evolution of new IP based networks such as those proposed by Bell Atlantic and the AT&T and British Telecom joint venture. Will the Internet evolve into the network of last resort if QoS, LoS, GoS are better on private IP based networks. Is this threat to the Internet or will their be a natural tiering of such Service grades.

1.3.1 The Development of Hierarchical Entities

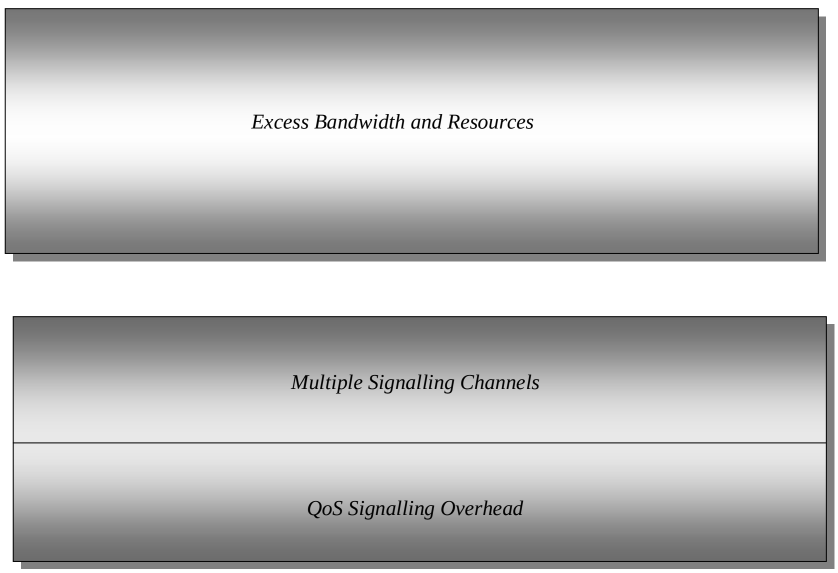
The development of extra-Internet entities, as may be envisioned by certain carriers, who desire to ensure a better quality of service at a higher price, may result in the ghettoization of the internet and may result in a segmentation and fragmentation of the Internet. This may result in the establishment of separate IP networks that have restricted connectivity, which may allow for “improved” service when one agrees to be controlled by larger entities.

1.3.2 No Quality-of-Service (QOS)

As noted above the Internet is more distributed and adaptive but more difficult to control if a QOS is to be achieved. In the PSTN traffic congestion is managed such that under overloads connections may not be made. In the Internet originating traffic will access the destination endpoint and receive some level of service even though that service level may not be useful – referred to as “best effort”. Thus, certain applications, e.g., voice or video, may be restricted in their use unless service management capabilities are introduced to ensure acceptable performance levels. And, although higher-priced high-speed links may be made available, there is no guarantee that the unmanaged core of the network will provide high-speed throughput.

1.4 Capacity versus Capability

There are several ways to guarantee quality of service. One is to have a highly interactive signaling channel and the other extreme is to have excess capacity. In this traffic Note we suggest the over design by capacity as shown below.



However, if we over-design, then this is the traffic engineering approach rather than say the approach used in ATM. The latter approach has been discussed in the Zephyr QoS note in detail.

1.5 **Service Quality**

Service quality is defined in terms of many factors. For the purpose of this design memo we have chosen the ASR, attempted service request, or completed call attempts as the metric.

We know that the ASR is a fully competent system is A_0 which is the response to calls where there may or may not be someone on the other side. If the system delivering the calls has queuing blockage, then the actual ASR, A_{eff} is less than the expected and is generally given by:

$$A_{Eff} = A_0[1 - P[Block]]$$

where P[Block] is the blocking probability of the system above the ASR response. We generally attempt to engineer the system so that the degradation in effective ASR is minimal. Thus is we have a DS1, 24 channels or servers, and we have the Level of Service desired, then we have to keep the total traffic offered to the DS1 during the peak busy hour below a certain level. This means that the system must be traffic engineered at the source or by the Provider and that no matter what the Carrier does if the Provider overloads the system the ASR effective will degrade.

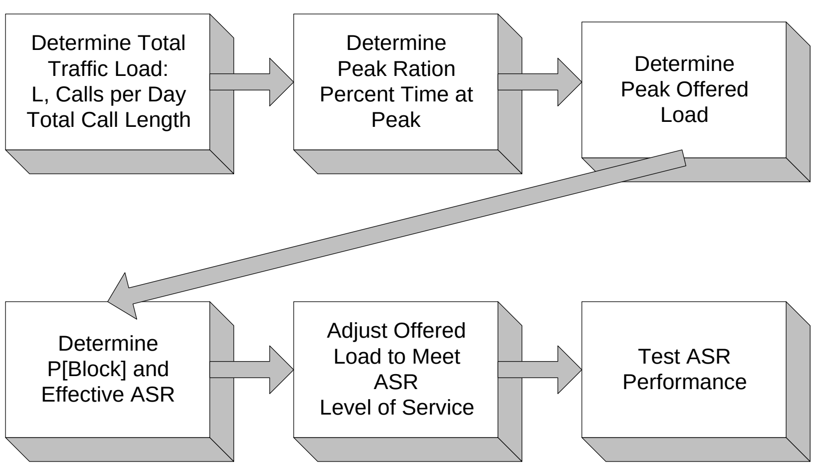
This Design Memo is specifically prepared to be shared with Providers of traffic to the Zephyr network and details the engineering requirement to assure service levels.

1.6 Traffic Loading

The delivery of service quality is dependent upon the level of traffic and the traffic handling capabilities. Traffic is measured in terms of to total number of calls, the holding time per call and the total call minutes, as well as the peak hours and the measure of peak traffic to average or peak to off peak traffic. Fundamentally, if there is a DS1 to service the traffic, then if there is then effectively 24 servers in a DS1, namely 24 DS0 channels, then if the effective load to the DS1 exceed 24 there will be no ability to handle the traffic. Moreover, if the load on average exceeds some fraction of the DS1, say 25%, then the probability that a call will be blocked will increase. If the average load is say 50% f the DS1 capacity then there is a very high chance that the blocking will occur. This is determined by the Erlang formulas. This report develops a set of metrics to properly engineer such a system.

1.7 Methodology Of Traffic Engineering

The Traffic Engineering Methodology is as shown in the following Flow Chart.



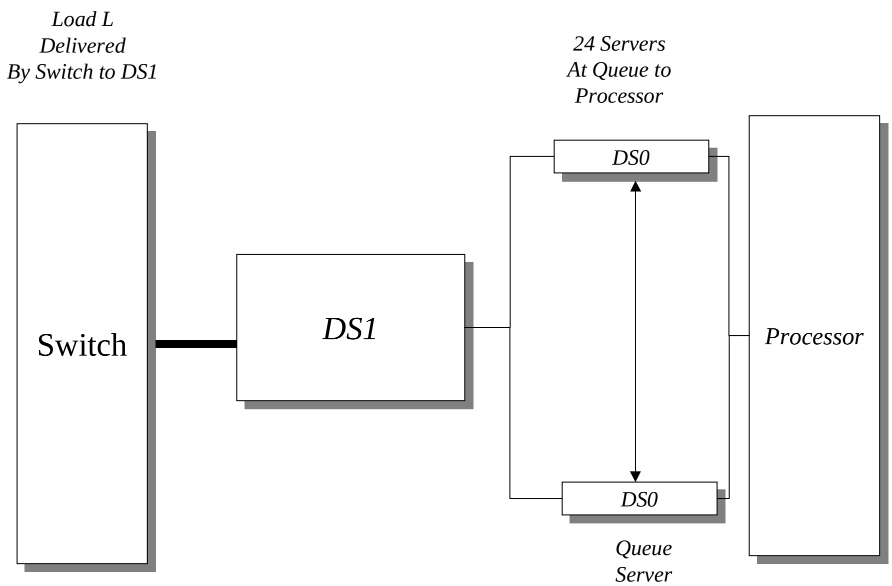
The details of this traffic engineering design is simple and is detailed in this note. The flow as depicted above will be presented in the latter sections of this Note.

2. System Design

This section presents the model for the customer and carrier relationships. There are two cases presented, a single carrier and multiple carriers. The multiple carrier case depicts the concept of having the other carriers with more peaked traffic. We discuss this factor latter in this Note.

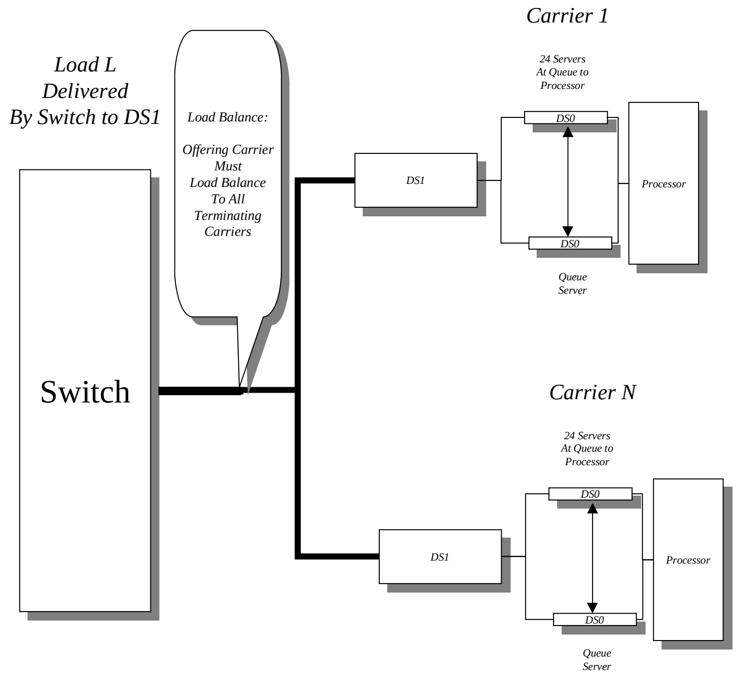
2.1 Single Carrier

The following is the overview of the system design for a single DS1 24 server queuing system.



2.2 Multiple Servers

The following depict multiple carriers with multiple servers. The load may then be shared over the multiple carriers. The key issue is that the offering carrier must carefully load balance the traffic so that the carriers each see the same traffic characteristics. This can be a major problem if the offering carrier fails to load balance then the last carrier in line will always be presented with the most peaked traffic and will have the highest P[Block] and then the lowest ASR. This means that the offering carrier is ultimately responsible for their own traffic Level of Service.


Carrier 1
Load L
Delivered
By Switch to DS1
Load Balance:
Offering Carrier
Must
Load Balance
To All
Terminating
Carriers
24 Servers
At Queue to
Processor
DS0
DS1
Processor
DS0
Queue
Server
Switch
Carrier N
24 Servers
At Queue to
Processor
DS0
DS1
Processor
DS0
Queue
Server

3. Peak and Average Traffic

The traffic presented to the network is measured in total calls and total minutes. Let L be the total calls and let M be the total minutes.

3.1 Peak Traffic Analysis

The traffic has a peak behavior. The characteristic is shown in the following Figure. The duration of a "day" has been normalized to 1 and the duration of the peak calling is T, a fraction of the total. The peak is P times above the base level. The base level has been normalized to B and the peak is (P+1)B.

Now the call arrival rate is the number of calls per unit time and the holding time is the average time per call.

Let:

λ = Call Arrival Rate

μ = Call Holding time

Then we can define the peak and non-peak arrival rates as follows:

$\lambda_{Peak} = \frac{L_{Peak}}{T_{Peak}}$, where this is the ratio of the load during the peak time and the duration of the peak time.

$\lambda_{Off-Peak} = \frac{L_{Off-Peak}}{T_{Off-Peak}}$, where the terms are as above but for the off peak periods.

We know the times but we now need to determine the peak and off peak loads as a function of the total load, the peak P ratio, and the time interval T.

Now we define:

$$L = L_{Peak} + L_{Off-Peak}$$

And then:

$$L_{Off-Peak} = B(1-T)$$

$$L_{Peak} = B(1+P)T$$

We know L, P, and T, and we can then solve for B. This can then be used to determine the peak and off peak numbers. Specifically:

$$L = B - BT + BT + BPT = B(1+PT)$$

then this yields:

$$B = \frac{L}{1+PT}$$

and in turn:

$$L_{Off-Peak} = \frac{L}{1+PT}(1-T)$$

$$L_{Peak} = \frac{L}{1+PT}(1+P)T$$

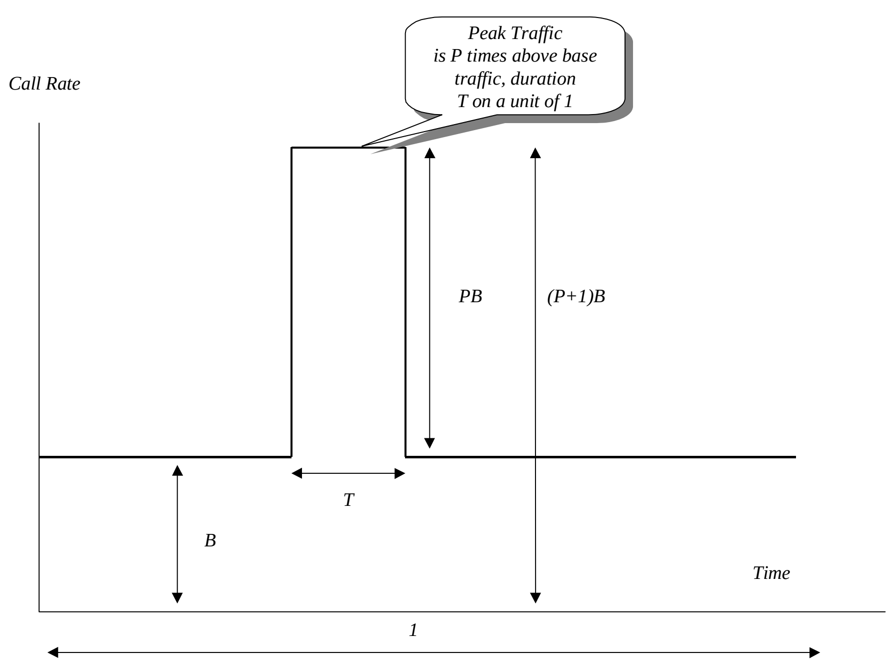
Then the arrival rates are as follows:

$$\lambda_{Peak} = \frac{L}{T_{Peak}}\frac{(1+P)T}{1+PT}$$

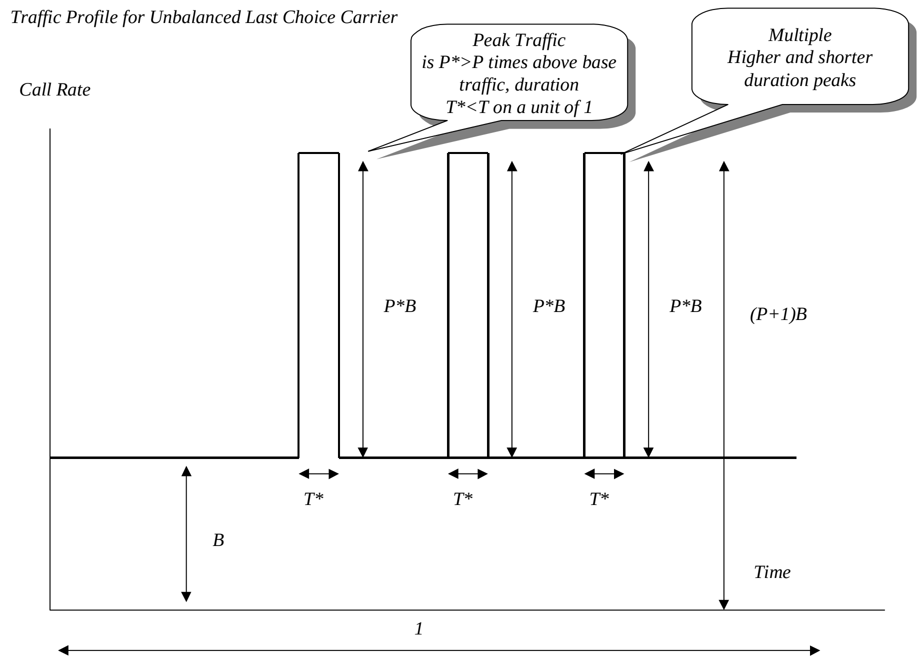
$$\lambda_{Off-Peak} = \frac{L}{T_{Off-Peak}}\frac{(1-T)}{1+PT}$$

3.2 Balanced Peak Traffic

The following Figure depicts this peak and average traffic relationship. This can be what every Carrier sees if the originating carrier provides adequate load balancing to all terminating carriers.



If the offering carrier does not load balance, then the first carrier receives a lower P and greater T and the last carrier of choice receives a very spiked traffic flow. This is shown below. Note that this means that no matter what the last carrier does, it is forced into a position of either over designing its network or in effecting a lower effective ASR.



The above situation can be corrected in one of several ways:

1. Originating carrier load balances traffic

2. Terminating Carrier provides significant additional capacity for carriage.

3.3 Effective Load

We now want to consider an example. The following is a summary of the effective load to the system. We define:

$$\rho_{Peak} = \frac{\lambda_{Peak}\mu}{24}$$

where 24 is the total maximum capacity of a DS1.

The following Table depicts a typical calculation.

Load	*Calling_Time*	*P*	*T*	*Tpeak*	*Toff*	*Lpeak*	*Loff*	*Arpeak*	*Aroff*	*HT*	*Rho_peak*	*Rho+off*
1,000	5,000	4	0.1	144	1,296	357	643	2.48	0.50	5.00	0.52	0.10

The following Table depicts the Rho at peak as a function of the T value and the P value as we have defined them. Notice that for the offered traffic, namely 5,000 min per day, we have the Rho's as described. We will show in the next section that certain of these Rhos will result in significant degradation of service. The solution is simple, limit traffic flow or increase capacity.

Peak/T	0.05	0.10	0.15	0.20	0.25
1	0.276	0.263	0.252	0.241	0.231
2	0.395	0.362	0.334	0.310	0.289
3	0.503	0.445	0.399	0.362	0.331

4	0.603	0.517	0.452	0.402	0.362
5	0.694	0.579	0.496	0.434	0.386
6	0.779	0.633	0.533	0.460	0.405
7	0.857	0.681	0.565	0.482	0.421
8	0.930	0.723	0.592	0.501	0.434

4. Traffic Loading

This section presents an overview of the blocking formula and the effect on Level of Service.

4.1 Erlang Blocking

This section overviews the Erlang B formula. The P[Block] is defined as follows:

$$P[Block] = \frac{1 - \left[\frac{\sum_{N=0}^{M-1} \frac{(M\rho)^N}{N!}}{\sum_{N=0}^{M} \frac{(M\rho)^N}{N!}} \right]}{1 - \rho \left[\frac{\sum_{N=0}^{M-1} \frac{(M\rho)^N}{N!}}{\sum_{N=0}^{M} \frac{(M\rho)^N}{N!}} \right]}$$

where we have defined:

$$\rho = Offered\_Traffic = \frac{\lambda\mu}{PeakCapacity(24\ forDS1)}$$

and M is the number of servers, 24 for DS1.

The analysis is as described in the previous section. We generally do this analysis for a fully loaded period, namely peak.

The ASR is:

$$ASR_{Eff} = ASR_0 P[Block] T_{Eff}$$

where T_{Eff} is the efficiency of the network above and beyond blocking. Generally we assume that to be 1.

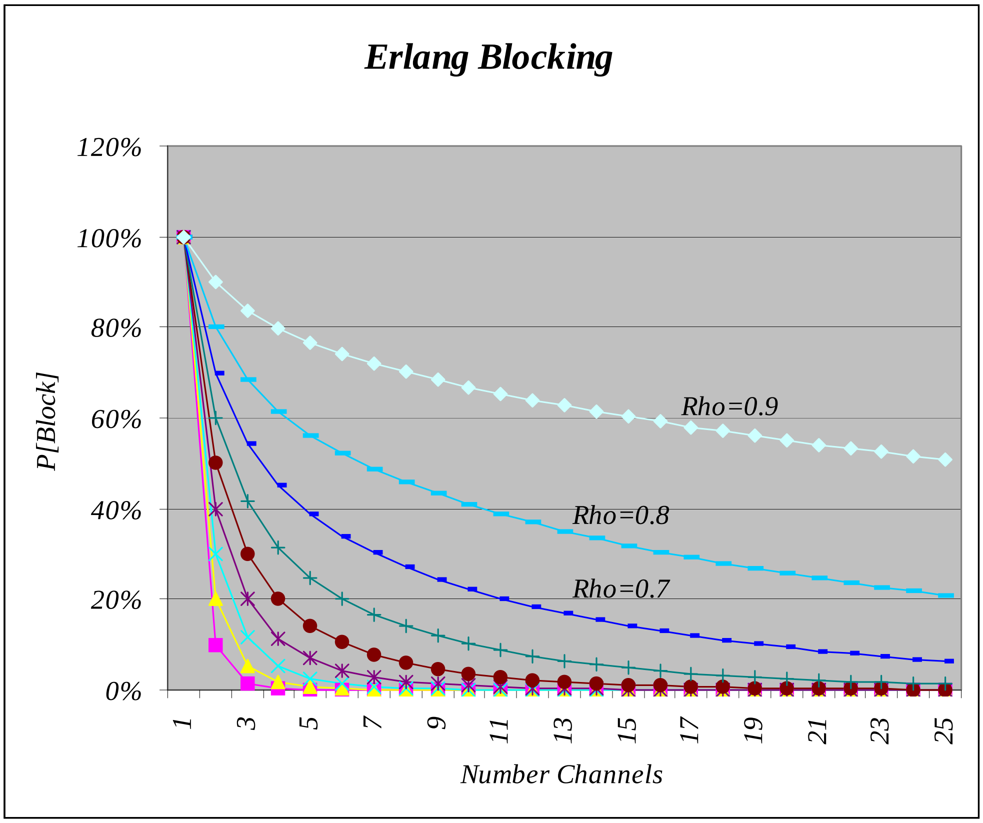
4.2 Detailed Loading Performance

The following Table depicts the P[Block] as a function of the Load in terms of Rho and the number of servers, namely DS0 channels.

Erlang Blocking Probability

Servers	*Load*								
	0.1	*0.2*	*0.3*	*0.4*	*0.5*	*0.6*	*0.7*	*0.8*	*0.9*
1	*1.00000*	*1.00000*	*1.00000*	*1.00000*	*1.00000*	*1.00000*	*1.00000*	*1.00000*	*1.00000*
2	0.10000	0.20000	0.30000	0.40000	0.50000	0.60000	0.70000	0.80000	0.90000
3	0.01429	0.05455	0.11739	0.20000	0.30000	0.41538	0.54444	0.68571	0.83793
4	0.00241	0.01739	0.05294	0.11327	0.20000	0.31304	0.45132	0.61317	0.79672
5	0.00045	0.00606	0.02591	0.06897	0.14172	0.24771	0.38788	0.56140	0.76629
6	0.00009	0.00223	0.01335	0.04392	0.10425	0.20181	0.34048	0.52095	0.74172
7	0.00002	0.00086	0.00712	0.02881	0.07854	0.16747	0.30277	0.48732	0.72062
8	0.00000	0.00034	0.00389	0.01928	0.06014	0.14067	0.27152	0.45825	0.70181
9	0.00000	0.00014	0.00216	0.01309	0.04656	0.11915	0.24494	0.43248	0.68465
10	0.00000	0.00006	0.00122	0.00898	0.03635	0.10155	0.22192	0.40929	0.66878
11	0.00000	0.00002	0.00069	0.00621	0.02855	0.08695	0.20175	0.38820	0.65397
12	0.00000	0.00001	0.00040	0.00432	0.02253	0.07473	0.18393	0.36886	0.64005
13	0.00000	0.00000	0.00023	0.00302	0.01785	0.06443	0.16807	0.35104	0.62692
14	0.00000	0.00000	0.00013	0.00212	0.01418	0.05569	0.15389	0.33453	0.61447
15	0.00000	0.00000	0.00008	0.00149	0.01130	0.04824	0.14116	0.31919	0.60263
16	0.00000	0.00000	0.00004	0.00105	0.00902	0.04187	0.12968	0.30488	0.59134
17	0.00000	0.00000	0.00003	0.00074	0.00722	0.03640	0.11930	0.29150	0.58056
18	0.00000	0.00000	0.00002	0.00053	0.00578	0.03170	0.10989	0.27896	0.57022
19	0.00000	0.00000	0.00001	0.00037	0.00464	0.02764	0.10135	0.26717	0.56030
20	0.00000	0.00000	0.00001	0.00027	0.00373	0.02413	0.09356	0.25608	0.55077
21	0.00000	0.00000	0.00000	0.00019	0.00300	0.02110	0.08646	0.24561	0.54159
22	0.00000	0.00000	0.00000	0.00013	0.00242	0.01846	0.07997	0.23573	0.53273
23	-	0.00000	0.00000	0.00010	0.00195	0.01617	0.07402	0.22637	0.52418
24	-	0.00000	0.00000	0.00007	0.00157	0.01417	0.06857	0.21751	0.51592
25	-	0.00000	0.00000	0.00005	0.00127	0.01243	0.06357	0.20910	0.50792

The following Figure depicts the blocking rates as described in the previous Table.


Erlang Blocking
120%
100%
80%
60%
40%
20%
0%
P[Block]
Rho=0.9
Rho=0.8
Rho=0.7
1
3
5
7
9
11
13
15
17
19
21
23
25
Number Channels

5. Traffic Examples

This section presents actual data and demonstrates the methods and procedures developed in this Technical Note. The data are taken from a Customer who is presenting traffic to Zephyr and to other Carriers.

5.1 Raw Data Examples

The following demonstrates the actual data from 8 Carriers, Zephyr being the last carrier to be given traffic, It should be recalled that as the last carrier, if the Traffic Engineering is not properly done by the offering carrier then the Zephyr link will have the highest P and smallest T thus having the lowest ASR effective. This is because the Zephyr link has trunk over flow traffic which has the characteristic of being the most “peaked”.

We show the detail statistics for three days.

4/20/99

Carrier	Total Calls	Total Min	Ans Calls	Ans Min	ASR %	Min/Call	Tot Min/Tot Calls	No T1s	Capacity/Day	Tot Cap Load	Carried Cap Load
4	2,791	12,893	1,176	11,818	42%	10.05	4.62	1	34,560	37%	34%
6	12,310	79,723	7,305	75,670	59%	10.36	6.48	5	172,800	46%	44%
7	1,869	12,811	998	12,104	53%	12.13	6.85	1	34,560	37%	35%
8	6,013	28,611	3,355	26,006	56%	7.75	4.76	1	34,560	83%	75%
9	3,095	17,684	1,381	16,012	45%	11.59	5.71	1	34,560	51%	46%
13	3,201	21,310	2,261	20,385	71%	9.02	6.66	1	34,560	62%	59%
17	3,916	18,785	2,347	16,552	60%	7.05	4.80	1	34,560	54%	48%
Zephyr	945	4,667	598	4,275	63%	7.15	4.94	1	34,560	14%	12%

4/21/99

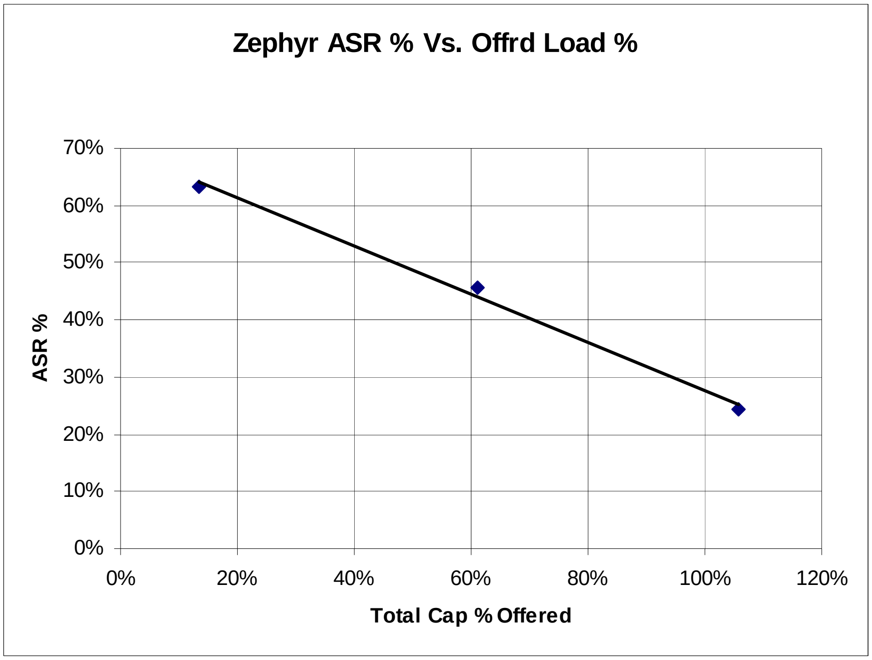
Carrier	Total Calls	Total Min	Ans Calls	Ans Min	ASR %	Min/Call	Tot Min/Tot Calls	No T1s	Capacity/Day	Tot Cap Load	Carried Cap Load
4	2,793	13,353	1,205	12,307	43%	10.21	4.78	1	34,560	39%	36%
6	10,790	73,680	6,641	70,155	62%	10.56	6.83	5	172,800	43%	41%
7	1,469	9,924	827	9,351	56%	11.31	6.76	1	34,560	29%	27%
8	3,937	18,912	2,086	17,180	53%	8.24	4.80	1	34,560	55%	50%
9	2,848	16,920	1,331	15,457	47%	11.61	5.94	1	34,560	49%	45%
13	3,112	20,707	2,253	19,832	72%	8.80	6.65	1	34,560	60%	57%
17	3,682	18,009	2,250	15,961	61%	7.09	4.89	1	34,560	52%	46%
Zephyr	4,701	12,071	1,149	10,438	24%	9.08	2.57	0	11,405	106%	92%

4/22/99

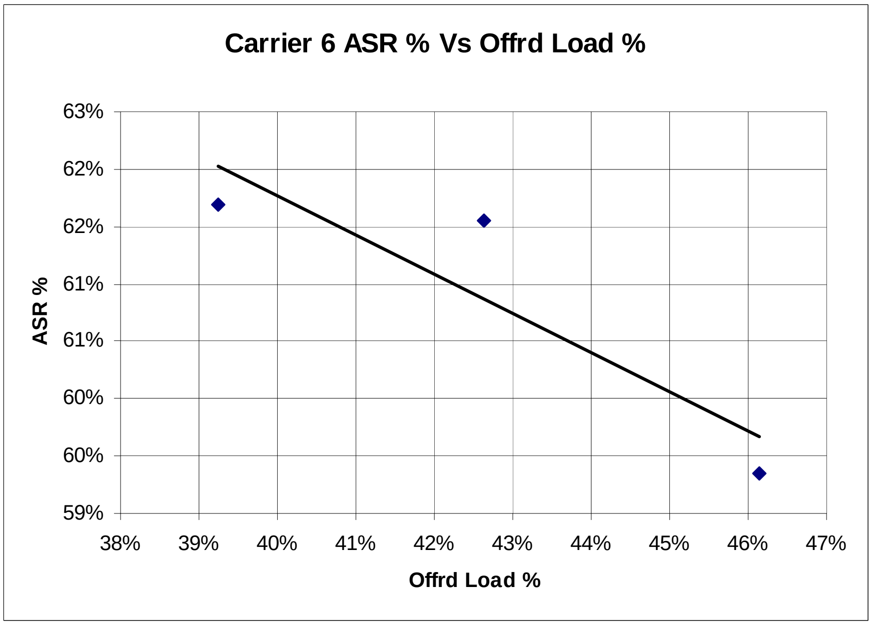
Carrier	Total Calls	Total Min	Ans Calls	Ans Min	ASR %	Min/Call	Tot Min/Tot Calls	No T1s	Capacity/Day	Tot Cap Load	Carried Cap Load
4	2,610	13,145	1,201	12,140	46%	10.11	5.04	1	34,560	38%	35%
6	10,566	67,800	6,518	64,404	62%	9.88	6.42	5	172,800	39%	37%
7	1,552	9,885	814	9,326	52%	11.46	6.37	1	34,560	29%	27%
8	1,948	9,236	878	8,282	45%	9.43	4.74	1	34,560	27%	24%
9	3,400	18,825	1,597	17,060	47%	10.68	5.54	1	34,560	54%	49%
13	3,372	20,118	2,391	19,159	71%	8.01	5.97	1	34,560	58%	55%
17	3,404	16,699	2,090	14,804	61%	7.08	4.91	1	34,560	48%	43%
Zephyr	5,871	21,153	2,677	18,892	46%	7.06	3.60	1	34,560	61%	55%

5.2 Analysis of Data

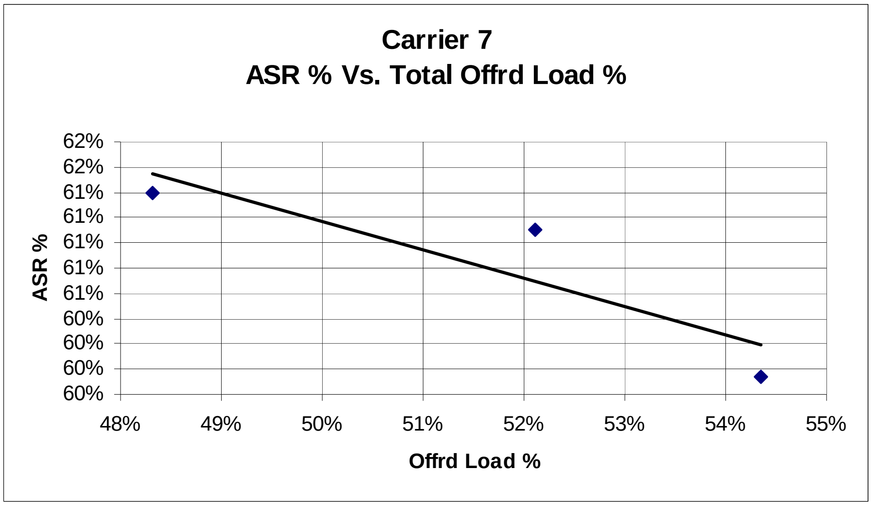
The following is a graphical analysis of the results of the analysis applied to the raw data. The first chart is the Zephyr traffic.



This second chart is for a second carrier. This is the carrier with the greatest offered load. It is also the carrier with the largest capacity. It is second in assignment.



The following is the response for the this carrier which has a load similar to Zephyr but which we expect actually has twice the capacity. The charts assumes that the capacity is the same as Zephyr's.



5.3 Sizing and Traffic Engineering

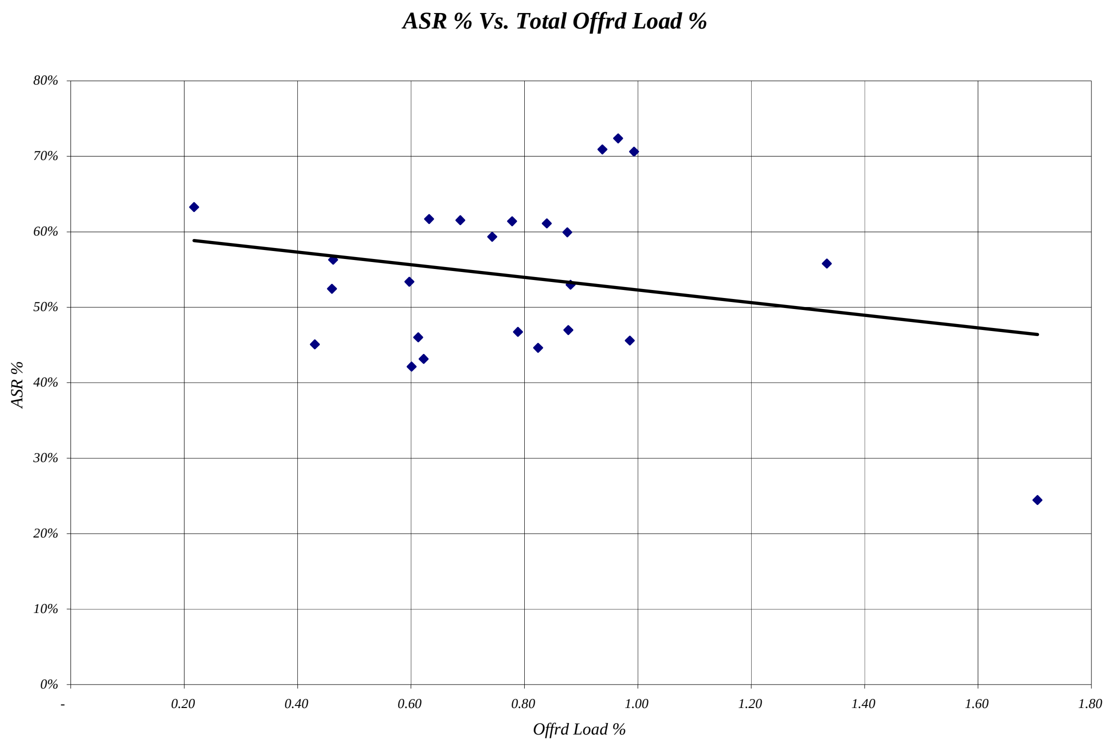
The following Table presents a summary of raw data from three days that details the Zephyr performance and that of several other carriers. We have calculated the peak Rho for the carriers and we have stated the ASR measured.

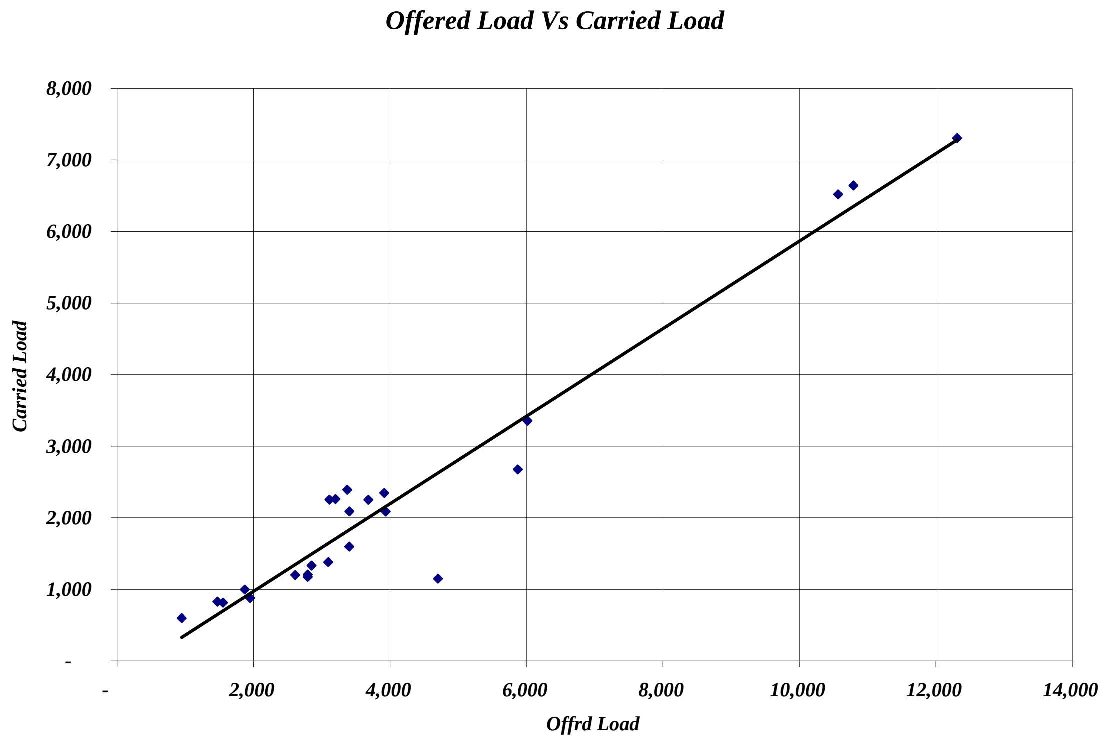
We will use this data as a baseline and this is what can be used in may other analyses.

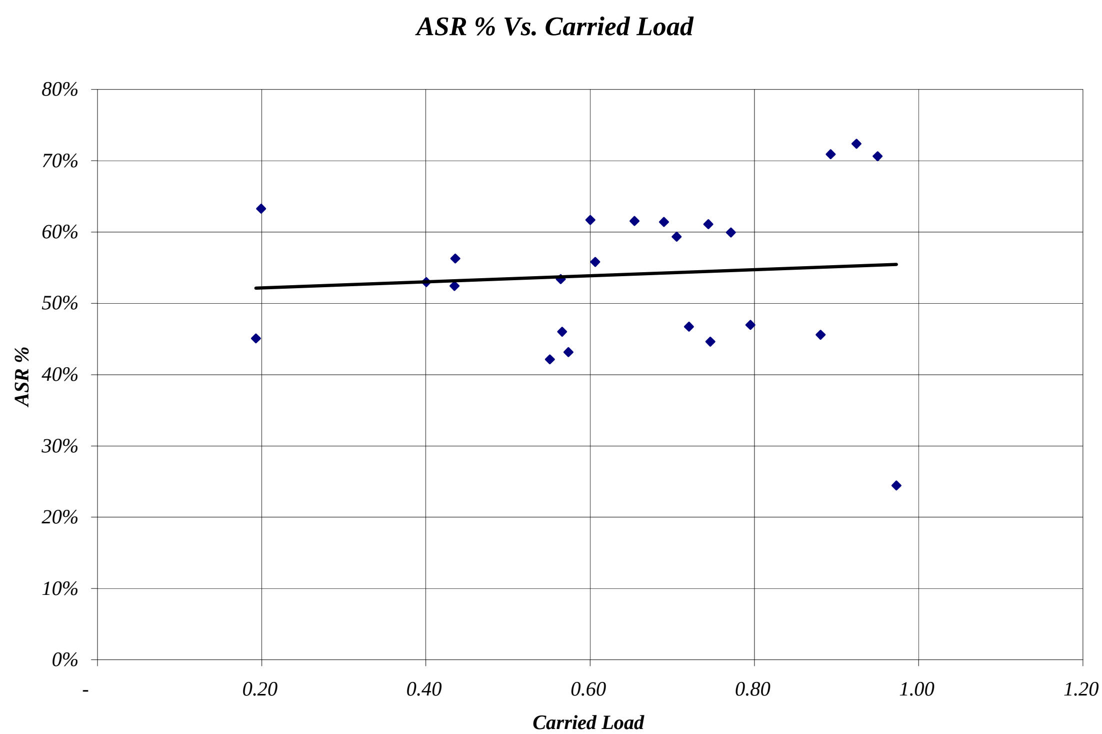
Carrier	*Load*	*Calling_Time*	*P*	*T*	*Tpeak*	*Toff*	*Lpeak*	*Loff*	*Arpeak*	*Aroff*	*DS1s*	*HT*	*ASR%*	*Rho_peak*	*Rho_off*
	1,000	5,000	1.4	0.35	504	936	564	436	1.12	0.47	1.00	5.00	*ASR%*	*Rho_peak*	0.10
4	2,791	12,893	1.4	0.35	504	936	1,573	1,218	3.12	1.30	1.00	4.62	42%	0.60	0.25
6	12,310	79,723	1.4	0.35	504	936	6,940	5,370	13.77	5.74	5.00	6.48	59%	0.74	0.31
7	1,869	12,811	1.4	0.35	504	936	1,054	815	2.09	0.87	1.00	6.85	53%	0.60	0.25
8	6,013	28,611	1.4	0.35	504	936	3,390	2,623	6.73	2.80	1.00	4.76	56%	1.33	0.56
9	3,095	17,684	1.4	0.35	504	936	1,745	1,350	3.46	1.44	1.00	5.71	45%	0.82	0.34
13	3,201	21,310	1.4	0.35	504	936	1,805	1,396	3.58	1.49	1.00	6.66	71%	0.99	0.41
17	3,916	18,785	1.4	0.35	504	936	2,208	1,708	4.38	1.83	1.00	4.80	60%	0.88	0.36
Zephyr	945	4,667	1.4	0.35	504	936	533	412	1.06	0.44	1.00	4.94	63%	0.22	0.09
4	2,793	13,353	1.4	0.35	504	936	1,575	1,218	3.12	1.30	1.00	4.78	43%	0.62	0.26
6	10,790	73,680	1.4	0.35	504	936	6,083	4,707	12.07	5.03	5.00	6.83	62%	0.69	0.29
7	1,469	9,924	1.4	0.35	504	936	828	641	1.64	0.68	1.00	6.76	56%	0.46	0.19
8	3,937	18,912	1.4	0.35	504	936	2,220	1,717	4.40	1.83	1.00	4.80	53%	0.88	0.37
9	2,848	16,920	1.4	0.35	504	936	1,606	1,242	3.19	1.33	1.00	5.94	47%	0.79	0.33
13	3,112	20,707	1.4	0.35	504	936	1,754	1,358	3.48	1.45	1.00	6.65	72%	0.97	0.40
17	3,682	18,009	1.4	0.35	504	936	2,076	1,606	4.12	1.72	1.00	4.89	61%	0.84	0.35
Zephyr	4,701	12,071	1.4	0.35	504	936	2,650	2,051	5.26	2.19	0.33	2.57	24%	1.70	0.71
4	2,610	13,145	1.4	0.35	504	936	1,471	1,139	2.92	1.22	1.00	5.04	46%	0.61	0.26
6	10,566	67,800	1.4	0.35	504	936	5,957	4,609	11.82	4.92	5.00	6.42	62%	0.63	0.26
7	1,552	9,885	1.4	0.35	504	936	875	677	1.74	0.72	1.00	6.37	52%	0.46	0.19
8	1,948	9,236	1.4	0.35	504	936	1,098	850	2.18	0.91	1.00	4.74	45%	0.43	0.18
9	3,400	18,825	1.4	0.35	504	936	1,917	1,483	3.80	1.58	1.00	5.54	47%	0.88	0.37
13	3,372	20,118	1.4	0.35	504	936	1,901	1,471	3.77	1.57	1.00	5.97	71%	0.94	0.39
17	3,404	16,699	1.4	0.35	504	936	1,919	1,485	3.81	1.59	1.00	4.91	61%	0.78	0.32
Zephyr	5,871	21,153	1.4	0.35	504	936	3,310	2,561	6.57	2.74	1.00	3.60	46%	0.99	0.41

Based upon the above data we have plotted the ASR versus the load in terms of the calculated peak Rho. It should be noted that we have assumed that there were a set of DS1s from each carrier. This may not be the actual capacity ad the data may have to me modified accordingly.

The most critical data point is the low ASR for Zephyr on one day. This is clearly due to the high Rho at peak. There is also the trend that matches the Erlang degradation that we have calculated before.




Offered Load Vs Carried Load
Carried Load
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
-
-
2,000
4,000
6,000
8,000
10,000
12,000
14,000
Offrd Load


ASR % Vs. Carried Load
ASR %
80%
70%
60%
50%
40%
30%
20%
10%
0%
-
0.20
0.40
0.60
0.80
1.00
1.20
Carried Load

6. Loading Analysis

The traffic capacity to Poland has been under stress and we have not been able to adequately handle what we had planned for. The issue is whether the Motorola VIPR capacity is an issue, whether the network capacity is an issue or whether the router problem is still an issue. The conclusion of this analysis is that the Motorola router is still an issue. The issue was simply stated as follows:

"Given the traffic to Poland, having a 2:1 ratio of weekends to weekdays, having a peak busy hour of 6-7 hours, and having a max to min ratio of traffic of 2:1, what was the effective carrying capacity per VIPR?"

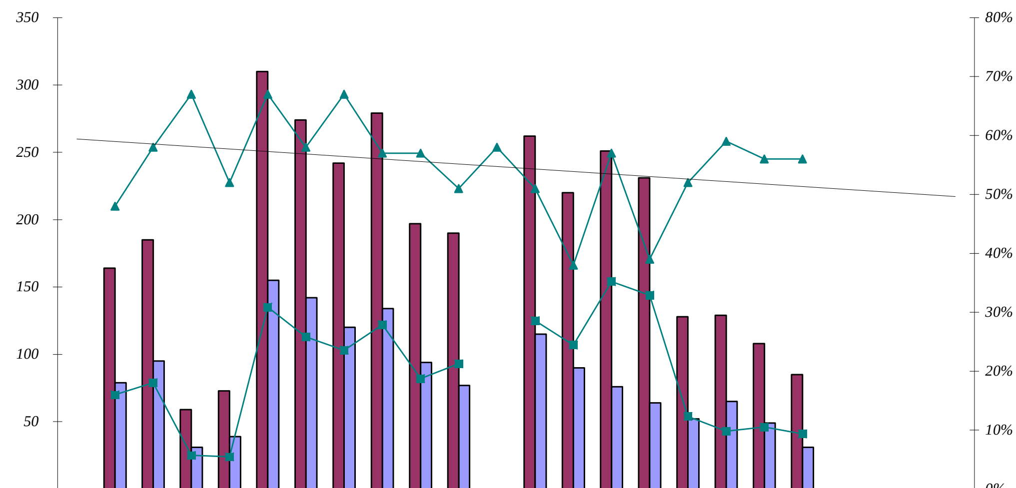
The contention was that the Motorola VIPR capacity it was in excess of 15,000 min per day, more likely 22,000 min per day, or in excess of 600,000 min per month. The planning number is 500,000.

Let us review the facts:

6.1 Network Data

6.1.1 Fact, Based on Pilipenko data, we agree that the traffic is 2:1 on max to min and the busy hours are 6-7 per day, or about 30% of the day.

The following is a typical Pilipenko chart showing Total Attempted Calls, Total Completed Calls, Total Failed Calls, and the ASR %. These are shown by hour on a busy day.



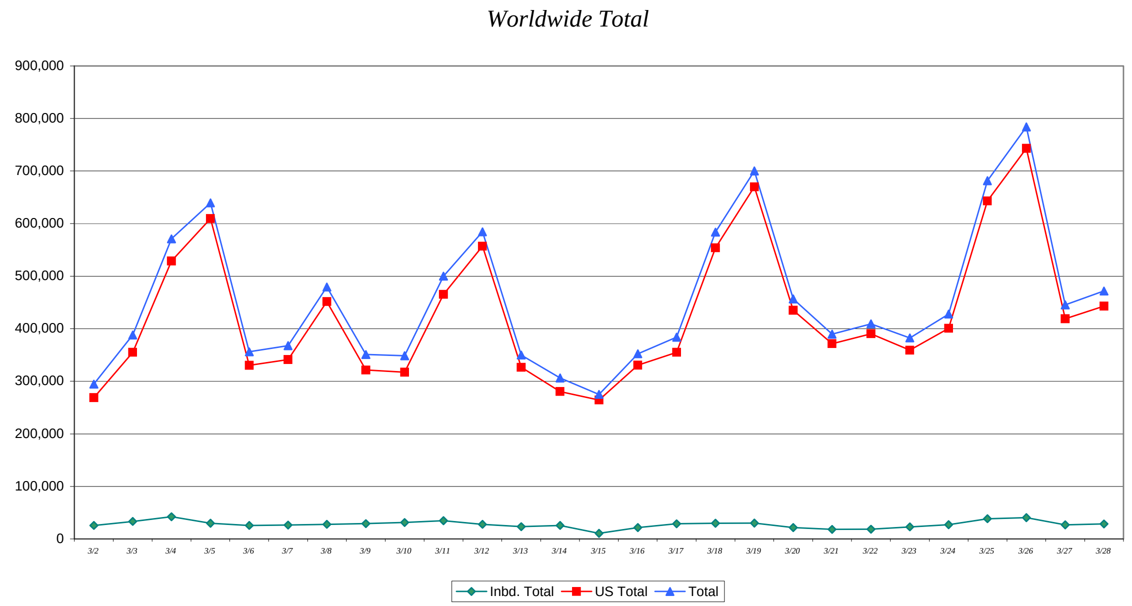
	1:00 AM	2:00 AM	3:00 AM	4:00 AM	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM	12:00 AM
Total Attempted Calls		164	185	59	73	310	274	242	279	197	190		262	220	251	231	128	129	108	85				
Total Completed Calls		79	95	31	39	155	142	120	134	94	77		115	90	76	64	52	65	49	31				
ASR		48%	58%	67%	52%	67%	58%	67%	57%	57%	51%	58%	51%	38%	57%	39%	52%	59%	56%	56%				
Total Failed Calls		70	79	25	24	135	113	103	122	82	93		125	107	154	144	54	43	46	41				

The chart shows that the typical traffic peaks during the daily hours and we have the peak hours of about 6 to 8 per day and we know that the peak and non peak loads are roughly 2:1.

The Internal M&P on Network Traffic Engineering details this model and the corresponding traffic analysis. The model assumes Poisson statistics and Erlang blocking levels.

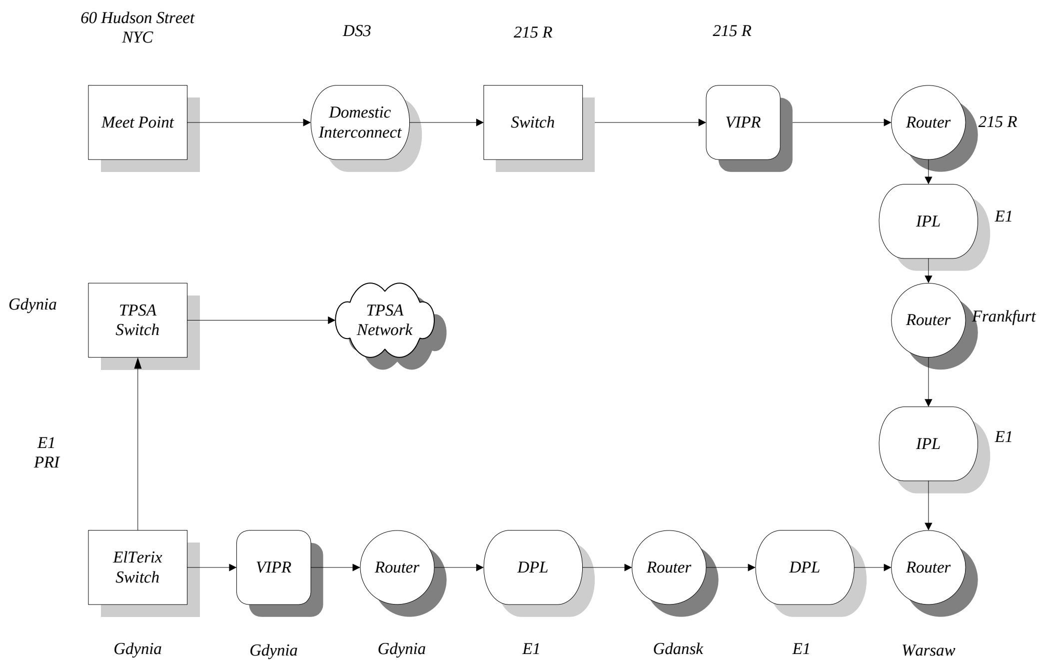
6.1.2 Fact, based on Kurnath's data, the weekend to weekday ratio is 2:1.

This generally is due to the fact that there are a load of non-business customers in the mix. This is changing however. See the March data below.



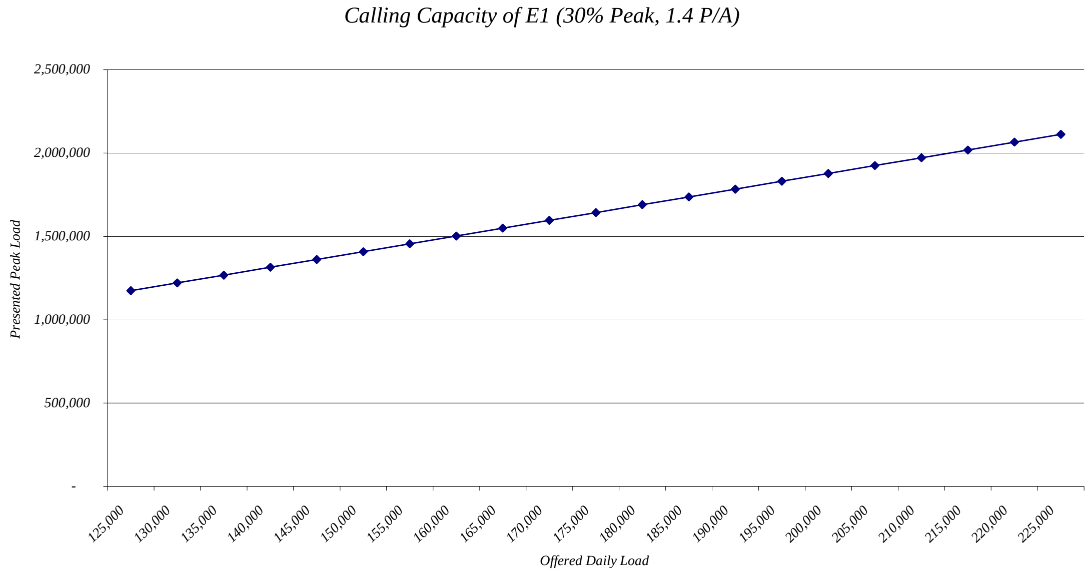
6.1.3 Fact, the network elements are all well known and each has a determinable carrying capacity.

The loading and capacity can be calculated for an end to end link by determining the capacity of each element in the link. A typical link is as follows.



The elements are as follows:

Links; Domestic and International (DPL and IPL): These are the E1 or higher links. Some may be sub rate depending on the particular network.

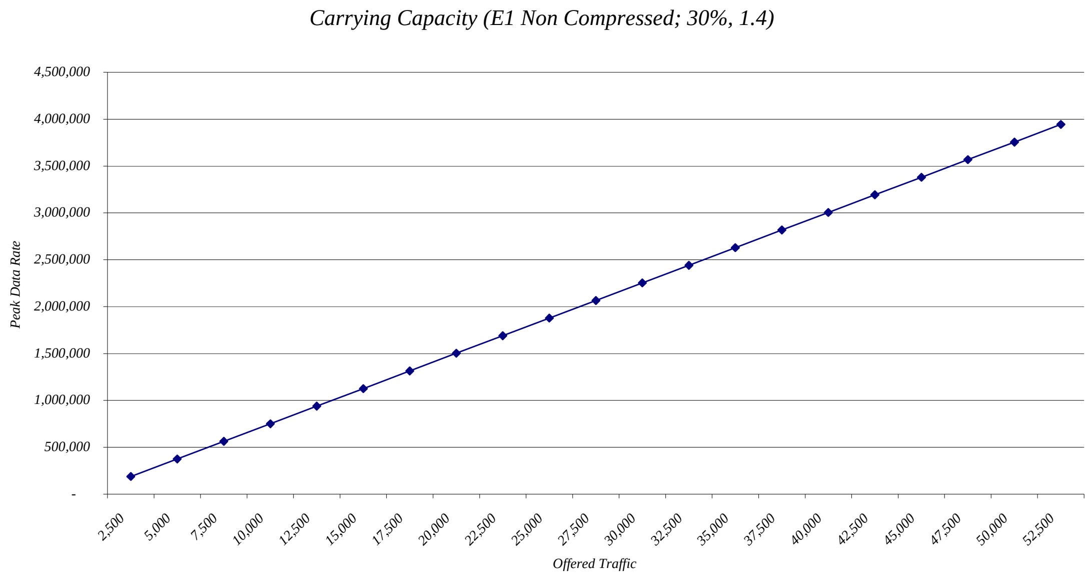


This above chart shows that the Offered Load of 210,000 minutes per day saturates an E1 backbone network using an 8 Kbps compressed voice channel as is typically used. This yields a monthly continuous rate of 6,300,000 min per month. This analysis uses a fractional day of peak, namely 30% of the day is peak, consistent with the Pilipenko data, and that the Peak to Average ratio is 1.4. This yields a Peak to Off-Peak ratio of 2.5:1.

The above analysis is for any day. We must perform the analysis for a month, and thus take into account the weekend to weekday variances. Thus, if the traffic is 2:1 on weekends, then if we design for weekend peaks, the average loading is: 2/7 + 2.5/7 = 4.5/7 = 65% or an effective carrying of 4,000,000 min per month per E1. There are 4 E1s to Poland thus the backbone capacity is 16,000,000 minutes, accounting for daily peak and weekend peak. This also yields 140,000 min per day per E1.

Router: This is the Cisco router. The router is configured to handle header compression. The implementation requires some additional processor speed.

VIPR: This is the Motorola IP telecom unit. It terminates at a local E1 rate. The following is an analysis of the VIPR terminating capacity onto an E1. It shows a capacity of 28,000 min per day. Using the same weekend peak analysis, we have and effective daily rate of 18,000 min per day per terminating E1.



Switch: This is a switch which connects to the VIPR at E1 and to any other network at E1.

Meet Point: This is the local meet point.

TPSA Network: This is the local termination on to the local PTT network. This may be highly dependent on how the PTT has engineered their network and especially the trunking on that network.

The carrying capacity of each element is shown below.

Element	*Capacity*
Router	The Cisco 4000 has a capacity of 50,000 min per day per E1 The Cisco 7000 has four times the capacity, or 200,000 min per month per E1.
IPL	140,000 min per day per E1 4,000,000 min per month per E1 16,000,000 min per month for Poland
DPL	140,000 min per day per E1 4,000,000 min per month per E1 4,000,000 min per month for each E1 in Poland, there are 8 E1s, thus 32,000,000 min per month.
VIPR	18,000 min per day 20 VIPRs yield 360,000 min per day 11,840,000 min per month for 20 VIPRs With 52 VIPRs the growth is proportional.
Switch, Local Carrier	E1 to E1
Switch, Domestic PTT Carrier	Issues depend upon local and national trunking.
Meet Point	E1 to E1 or T1 to T1

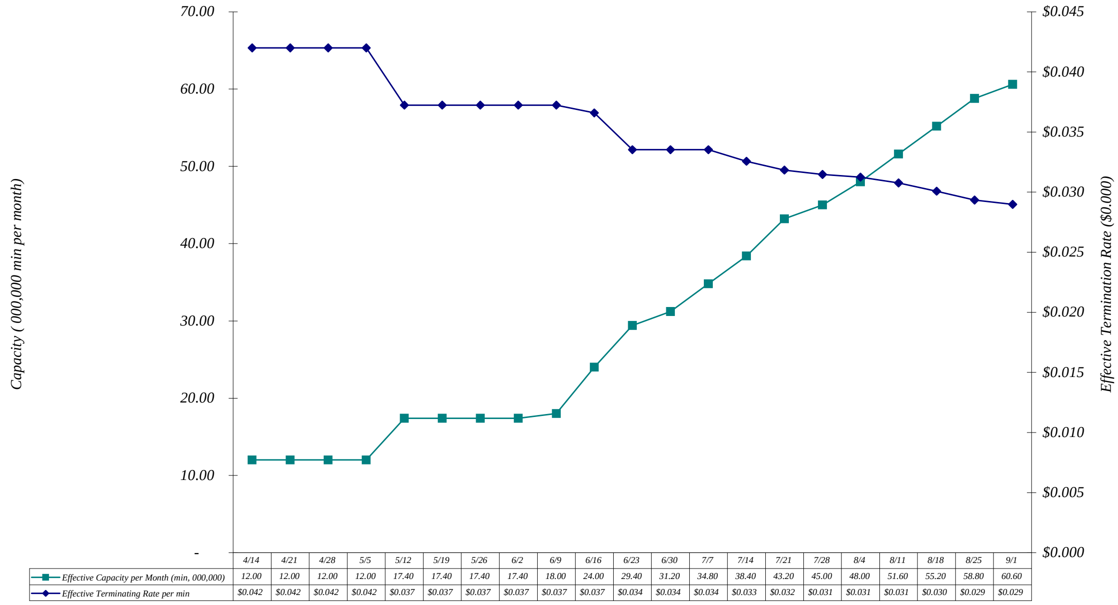
6.2 Circuit Traffic

6.2.1 Fact, the circuits connected are as shown below, and the consequence of loading at 22,000 min per month per VIPR is also shown.

The following chart depicts the locations of the Polish terminations as of this time and as planned. The table lists the cities and carriers as well as the number of E1s and the total capacity. Currently we have 12,000,000 min per month capacity and we have almost 32,000,000 available by June 30th.

City	*Company*	*City Code*	*Traffic Distribution*	*28-Apr-00*		*30-Jun-00*	
				Number E1	*Capacity per Month (min)*	*Number E1*	*Capacity per Month (min)*
Lomza	*Szeptel*	*86*	*6.11%*	*7*	*4,200,000*	*7*	*4,200,000*
Gdynia	*ElTerix*	*58*	*4.13%*	*2*	*1,200,000*	*6*	*3,600,000*
Krakow	*Netia*	*12*	*5.29%*	*-*	*-*	*3*	*1,800,000*
Posnan	*Netia*	*61*	*1.65%*	*-*	*-*	*3*	*1,800,000*
Lublin	*Netia*	*81*	*2.48%*	*-*	*-*	*3*	*1,800,000*
Katowice	*Netia*	*32*	*4.25%*	*3*	*1,800,000*	*4*	*2,400,000*
Rzeszow	*Centralna*	*17*	*5.32%*	*3*	*1,800,000*	*6*	*3,600,000*
Lodz	*Dialog*	*42*	*1.00%*	*-*	*-*	*3*	*1,800,000*
Torun	*Netia*	*56*	*0.77%*	*-*	*-*	*3*	*1,800,000*
Bialystok	*Centralna*	*85*	*6.11%*	*-*	*-*	*3*	*1,800,000*
Wroclaw	*Dialog*	*71*	*3.09%*	*4*	*2,400,000*	*6*	*3,600,000*
Warsaw	*Netia*	*22*	*5.88%*	*-*	*-*	*4*	*2,400,000*
Opole	*Netia*	*77*	*1.65%*	*-*	*-*	*-*	*-*
Krosno	*Centralna*	*13*	*1.00%*	*-*	*-*	*-*	*-*
Szczcecin	*Telefonia Zachodnia*	*91*	*1.00%*	*-*	*-*	*-*	*-*
Bielsko-Biala	*TPSA*	*33*	*1.00%*	*-*	*-*	*-*	*-*
Bydgoscz	*ElNet*	*52*	*1.00%*	*-*	*-*	*-*	*-*
Warsaw	*TPSA*	*22*	*5.88%*	*1*	*600,000*	*1*	*600,000*
Kalisz	*Netia*	*62*	*0.60%*	*-*	*-*	*-*	*-*
Kielce	*Netia*	*47*	*1.00%*	*-*	*-*	*-*	*-*
Pila	*Netia*	*67*	*0.34%*	*-*	*-*	*-*	*-*
Silescia	*Netia*	*25*	*1.00%*	*-*	*-*	*-*	*-*
Jelenia Gora	*Dialog*	*75*	*0.89%*	*-*	*-*	*-*	*-*
Gorzow	*Dialog*	*95*	*1.00%*	*-*	*-*	*-*	*-*
Walbrozych	*Dialog*	*74*	*1.00%*	*-*	*-*	*-*	*-*
Swidnik	*Netia*	*68*	*1.00%*	*-*	*-*	*-*	*-*
Summary			*64.44%*	*20*	*12,000,000*	*52*	*31,200,000*

The following chart depicts the summary of terminating capacity and the resultant effective per minute rate. Note that the current rate is less than $0.05 per minute and the estimated rate by full buildout mid Q3 is $0.028 per minute.



There are however certain limiting factors that reduce the effective carrying rate, namely I the traffic is all weekend and not more evenly distributed.

6.2.2 Fact, if we use the above assumption, we have the following result for traffic on an off net.

The following Table assumes that everything works and that we can carry traffic anywhere in the network. It further assumes that the weekends are 2:1 the weekdays and that we design only for weekends. It further assumes that we have Szeptel, Warsaw, and four other cities, which is what we had in March. It assumes that we can carry only 8,500,000 min on net due to the heavy weekend peaking and that to carry 12,000,000 minutes we need 3,600,000 off net. This is 25% off net, which is what we have designed for. This still yields a high positive gross margin.

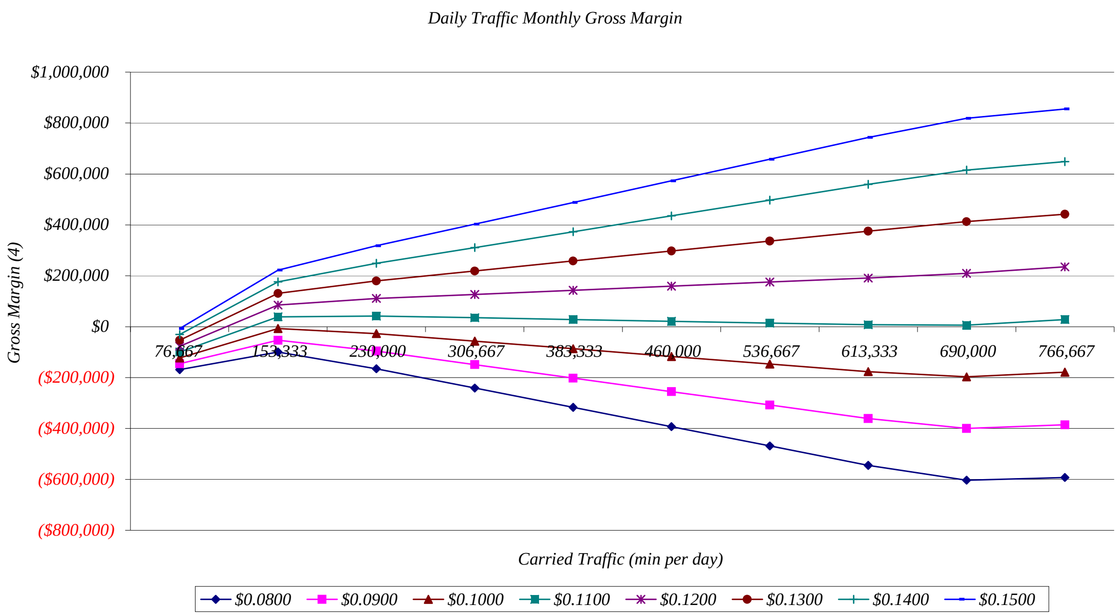
Total Offered US	*Total Offered Germany*	*Total Offered*	*E1 US to Germany*	*E1 Germany to Poland*	*E1 US to Poland*	*Offnet*	*Total*
5,000,000	*-*	*5,000,000*	*-*	*-*	*5,700,000*	*-*	*5,700,000*
6,000,000	*-*	*6,000,000*	*-*	*-*	*6,740,000*	*-*	*6,740,000*
7,000,000	*-*	*7,000,000*	*-*	*-*	*7,400,000*	*-*	*7,400,000*
8,000,000	*-*	*8,000,000*	*-*	*-*	*7,600,000*	*400,000*	*8,000,000*
9,000,000	*-*	*9,000,000*	*-*	*-*	*7,800,000*	*1,200,000*	*9,000,000*
10,000,000	*-*	*10,000,000*	*-*	*-*	*8,000,000*	*2,000,000*	*10,000,000*
11,000,000	*-*	*11,000,000*	*-*	*-*	*8,200,000*	*2,800,000*	*11,000,000*
12,000,000	*-*	*12,000,000*	*-*	*-*	*8,400,000*	*3,600,000*	*12,000,000*
13,000,000	*-*	*13,000,000*	*-*	*-*	*8,500,000*	*4,500,000*	*13,000,000*
14,000,000	*-*	*14,000,000*	*-*	*-*	*8,500,000*	*5,500,000*	*14,000,000*
15,000,000	*-*	*15,000,000*	*-*	*-*	*8,500,000*	*6,500,000*	*15,000,000*
16,000,000	*-*	*16,000,000*	*-*	*-*	*8,500,000*	*7,500,000*	*16,000,000*
17,000,000	*-*	*17,000,000*	*-*	*-*	*8,500,000*	*8,500,000*	*17,000,000*
18,000,000	*-*	*18,000,000*	*-*	*-*	*8,500,000*	*9,500,000*	*18,000,000*
19,000,000	*-*	*19,000,000*	*-*	*-*	*8,500,000*	*10,500,000*	*19,000,000*

Rev/Min
$0.1200

		Szeptel	*Warsaw*	*City 1*	*City 2*	*City 3*	*City 4*
Capacity	*-*	*2,500,000*	*500,000*	*2,000,000*	*1,500,000*	*1,500,000*	*1,000,000*

Percent	*0.00%*	*20.00%*	*8.00%*	*3.00%*	*3.00%*	*3.00%*	*3.00%*
Gross Margin	*$0.0000*	*$0.0700*	*$0.0950*	*$0.0700*	*$0.0700*	*$0.0700*	*$0.0700*

Based upon this analysis, the following chart depicts the gross margin per month based on the traffic per day. It is parameterized upon price per minute.



6.3 Conclusions

6.3.1 Conclusion, if the traffic is as above, then at 15 million minutes we have 5 million off net or 30%. At 12 million minutes we have 2.5 million off net.

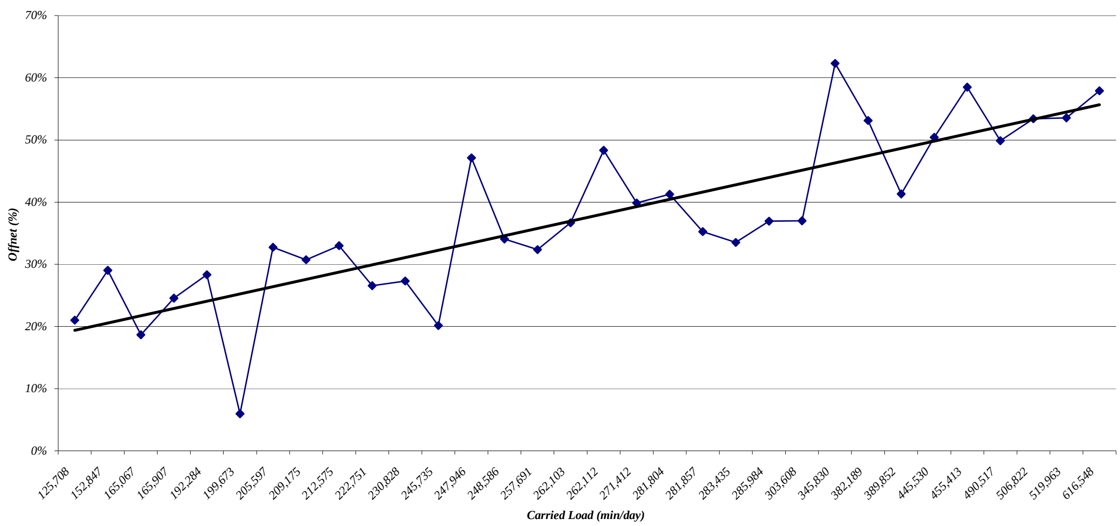
The conclusion is self evident from the Table. The table assumes normal traffic loading and follows the detailed analysis in the Zephyr M&P. As shown above the analysis also assumes that at the existing sites of the 4 Cities we can terminate anywhere in Poland as had been requested and as had been represented.

6.3.2 Fact, this has not been the case in March, we have had almost 6 million on and 3.5 million off.

This data must be more carefully assessed but what is clear is that on peak days we have a peak problem as expected. On peak days our traffic was 700,000 minute per day and the network on-net can handle 250,000 minutes per day not the 330,000 as we had expected on net due to the fact that we have not engineered the network. Thus on peak days we have an off-net percentage of 65%. The week days in March were at 400,000 to 500,000 per day, or an off net of say 50%. This used on a weighted basis, namely 500,000 per weekend and 250,000 per week day leads to an average of 320,000 per day, or an off net percent of slightly in excess of 50%. This is indeed what we are seeing. The conclusion, as will be shown below is that the engineering of the network is the problem and the problem is most likely the router issue since all other issues have been eliminated.

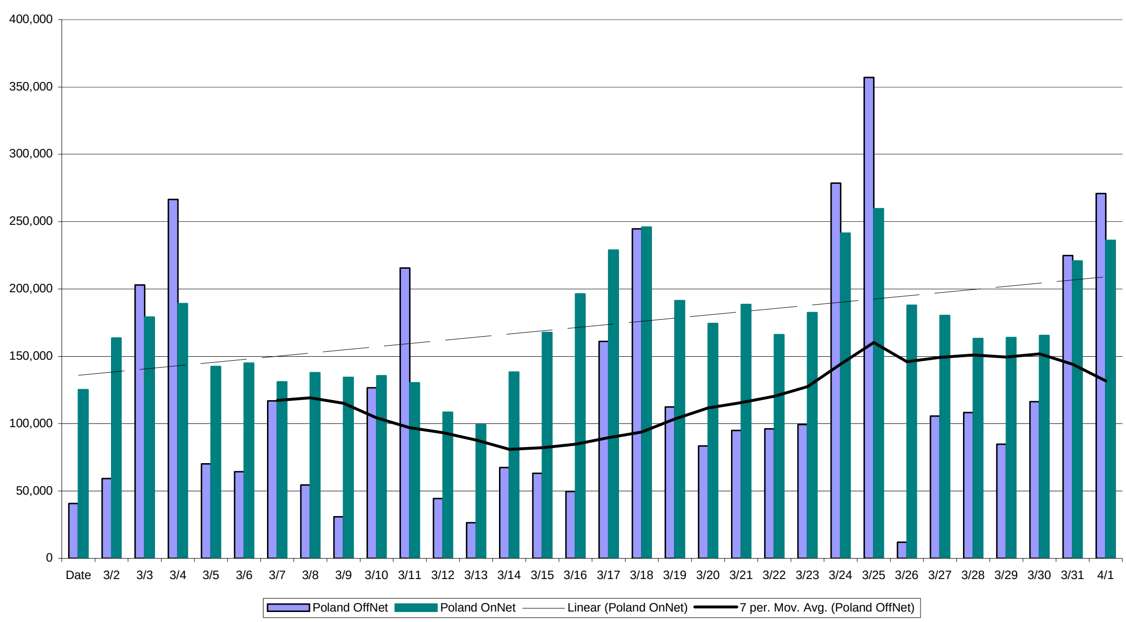
The actual traffic is as shown below for March. From the previous analysis, we have 20 VIPRs operational, and if we assume that we have a capacity of only 15,000 min per day per VIPR, or 450,000 min per month, then we should have less than 20% off net at 300,000 min per day due to statistical peaking. The data below shows that it is 40% or twice that value. This means that with off net rates being $0.01 above price, we are at a negative margin at 40% and a positive margin at 60% of the carried traffic.

Offnet vs Load



In fact the current network handles 250,000 per day on net peak. This is shown below. The problem therefore is not the VIPR, not the backbone, not the switch, but more likely the router issue which is what I identified in January and we told Motorola to remedy. The remedy was tested in late February with one Cisco 7000 series router using header compression, and we demanded retrofitting of the entire Polish network.

The following chart depicts the Poland on net and off net for the month. Note that as we built traffic in tot the off net grew proportionately.



6.3.3 Fact, if we route the traffic from the US to Poland and allow only local traffic offnet at each node, and do not fully enable or have enabled the offnet, we obtain the following:

Total Offered US	*Total Offered Germany*	*Total Offered*	*E1 US to Germany*	*E1 Germany to Poland*	*E1 US to Poland*	*Offnet*	*Total*
5,000,000	-	5,000,000	-	-	5,700,000	-	5,700,000
6,000,000	-	6,000,000	-	-	6,740,000	-	6,740,000
7,000,000	-	7,000,000	-	-	7,400,000	-	7,400,000
8,000,000	-	8,000,000	-	-	7,600,000	400,000	8,000,000
9,000,000	-	9,000,000	-	-	7,800,000	1,200,000	9,000,000
10,000,000	-	10,000,000	-	-	8,000,000	2,000,000	10,000,000
11,000,000	-	11,000,000	-	-	8,200,000	2,800,000	11,000,000
12,000,000	-	12,000,000	-	-	8,400,000	3,600,000	12,000,000
13,000,000	-	13,000,000	-	-	8,500,000	4,500,000	13,000,000
14,000,000	-	14,000,000	-	-	8,500,000	5,500,000	14,000,000
15,000,000	-	15,000,000	-	-	8,500,000	6,500,000	15,000,000
16,000,000	-	16,000,000	-	-	8,500,000	7,500,000	16,000,000
17,000,000	-	17,000,000	-	-	8,500,000	8,500,000	17,000,000
18,000,000	-	18,000,000	-	-	8,500,000	9,500,000	18,000,000
19,000,000	-	19,000,000	-	-	8,500,000	10,500,000	19,000,000

Rev/Min
$0.1200

		Szeptel	*Warsaw*	*City 1*	*City 2*	*City 3*	*City 4*
Capacity	-	2,500,000	500,000	2,000,000	1,500,000	1,500,000	1,000,000
Percent	0.00%	20.00%	8.00%	3.00%	3.00%	3.00%	3.00%
Gross Margin	$0.0000	$0.0700	$0.0950	$0.0700	$0.0700	$0.0700	$0.0700

6.3.4 Conclusion, we have only 7.4 million on net due to the routing. This assumes however that there is no local switch blocking, no GT switch blocking, no IPL outages, etc.

The issue is network engineering and not VIPR capacity. Indeed, if properly engineered the network should today handle 12 million minutes per month on-net.

6.3.5 Fact, there is some GT blocking, and from time to time some significant local Polish switch blocking from TPSA due to their internal network design. This may account for a reduction to 6.5 million minutes as observed.

We all knew the TPSA problems. These just may exacerbate the problem. We believe that we can get around this issue via the build out of the total network.

6.3.6 Conclusion, using the VIPR capacity, the data and results are consistent with, primarily, major outages due to capacity of the router and, secondarily, with poor TPSA control of termination and interconnection, and poor overall engineering by TPSA of the network.

This means that the question posed by the four walls as defined above:

"Given the traffic to Poland, having a 2:1 ratio of weekends to weekdays, having a peak busy hour of 6-7 hours, and having a max to min ratio of traffic of 2:1, what was the effective carrying capacity per VIPR?"

Is answered in favor of proper design of the Zephyr infrastructure and clearly demonstrates that the router conjecture is correct.

6.3.7 Fact, using the above model as defined in Zephyr M&P "Network Traffic Engineering", Version 2.1, the following analysis shows that if the load is as specified and if the terminating rate is an E1, namely less than 2 Mbps, then the peak number of busy hour calls is 350.

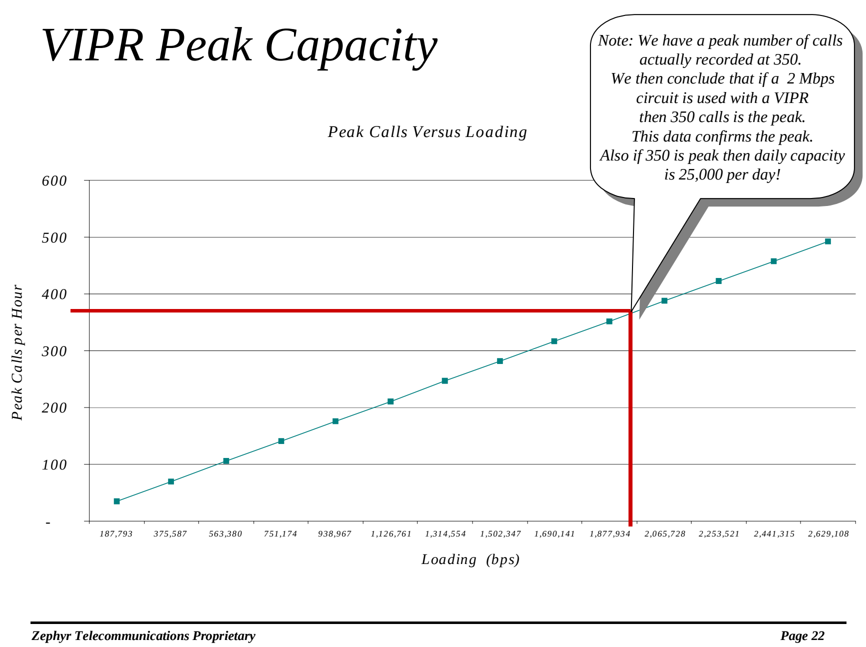
The following analysis depicts the 30% peak calling time and the 240% max to min ratio of traffic, a case more sever than what was assumed previously. In the analysis, the issue was what is the maximum number of minutes per day on an E1 termination and what does that mean in terms of maximum number of calls per busy hour. From the Pilipenko data, the maximum calls range from 300 to over 325, with an average 50% ASR meaning that there is no E1 termination blocking.

The analysis below states that if we have 300-325 peak calls, then we are delivering about a 1.75 Mbps rate to the terminating E1 and that the capacity during the day with the loading statistics agreed to is in excess of 20,000 minutes per day, not 8,000 as per the Wechsler conjecture.

Load Calls per Day	*Calling_Time Min per Day*	*Time of Peak*	*HT (min)*	*Peak to Off Peak Ratio*	*Data rate per Call*	*Data rate Peak*	*Peak Instantaneous Calls per Hour*
1,000	5,000	30%	5.00	240%	64,000	375,587	70
2,000	10,000	30%	5.00	240%	64,000	751,174	141
3,000	15,000	30%	5.00	240%	64,000	1,126,761	211
4,000	20,000	30%	5.00	240%	64,000	1,502,347	282
5,000	25,000	30%	5.00	240%	64,000	1,877,934	352
6,000	30,000	30%	5.00	240%	64,000	2,253,521	423
7,000	35,000	30%	5.00	240%	64,000	2,629,108	493
8,000	40,000	30%	5.00	240%	64,000	3,004,695	563
9,000	45,000	30%	5.00	240%	64,000	3,380,282	634

6.3.8 Fact, from Pilipenko detailed daily analysis, on March 31, 2000, on NJ 108, for example, the peak carried calls per hour were 304, with an ASR of 49%, showing no blocking.

The Pilipenko data is a clear daily analysis of each VIPR. The fact that the calling peak is in the range demonstrated also proves beyond any shadow of doubt that the VIPR capacity is in excess of 20,000 minute per day as determined. This is demonstrated in the Figure below.



6.3.9 Conclusion, the loading analysis is correct.

There is a clear documented path based on data available to all parties to verify that the capacity and carrying capability answer is correct. It is also clear that for Zephyr to be successful local termination expansion is critical and is our strategic asset.