



Pattern Based Spatio Temporal QoS Analysis - Goal



- Analysis of QoS behaviour for different periods (hourly, daily, weekly) for capacity planning and enhanced QoS provision.
- Practical approach for spatio-temporal analysis of QoS time series data based on QoS pattern detection and analysis.
- Statistical methods to study QoS patterns in different periods (hourly, daily, weekly)
- Bucket histograms based on QoS thresholds (levels) for pattern oriented QoS analysis
- Spatio-temporal QoS analysis - 2 aspects:
 - 📅 temporal pattern analysis in the time series data of QoS parameters obtained for network connections
 - 📍 spatial dependency analysis of patterns considering spatial (topological) relationships of network elements .
- Practical real measurement scenarios.



Temporal QoS pattern characteristics - introduction



- Specific behaviour of the time series data (QoS parameter) for some time interval (time window) is called pattern.
- Pattern analysis is based on pattern characterisation and comparison for a given time window.
- QoS "outliers" - outliers due to route failure [PMFT 02], delay "congestion" pattern [NLANRSurveyor], "delay break" patterns [SDG 00].
- Diurnal and step function patterns [CL 03]



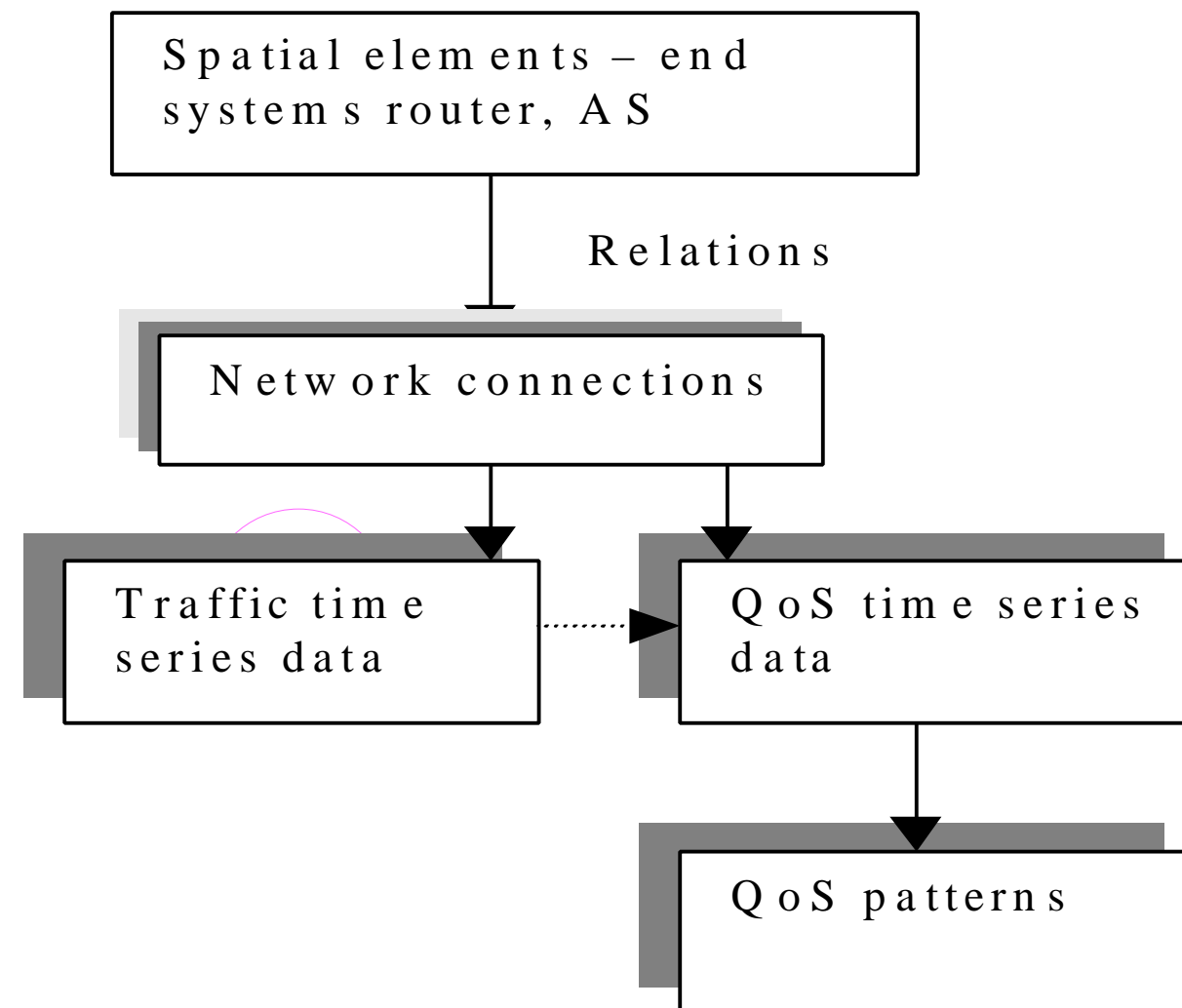
QoS pattern characterisation based on QoS threshold histograms



- Let $\{X_t\}$ be time series data consisting of QoS parameter values. With $q_1, \dots, q_i, \dots, q_n$ the QoS thresholds values are given so that $0 = q_0 < q_1 < q_i < \dots < q_n = q_{\max}$ where q_{\max} is the maximum possible QoS threshold value.
- A bucket b_i is defined by $[q_i, q_{i+1}]$ with q_i as low boundary and q_{i+1} as high boundary.
- A QoS parameter value x_t observed at time t belongs to bucket b_i if $q_i < x_t \leq q_{i+1}$

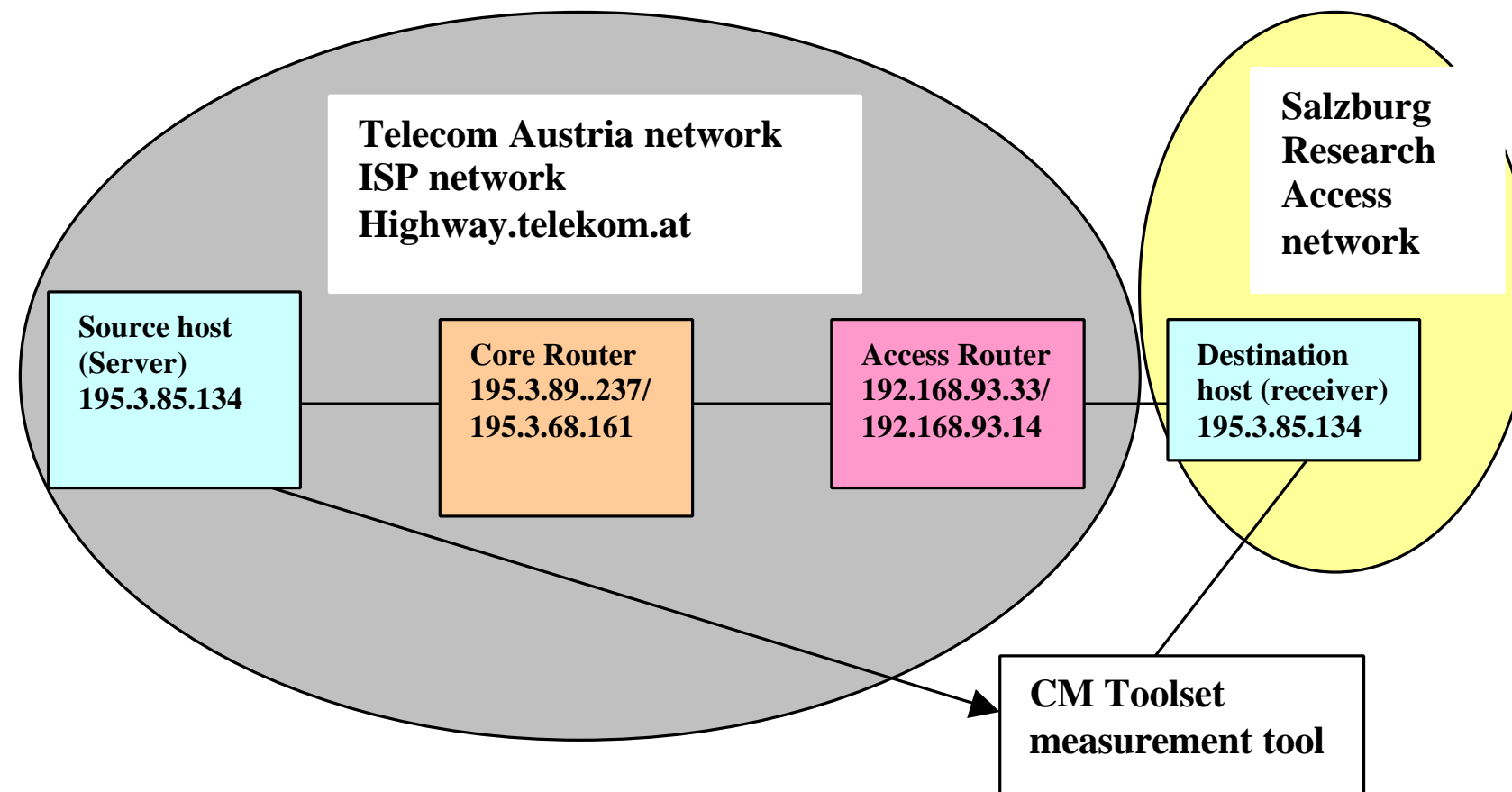


Spatio-temporal pattern analysis across network connections



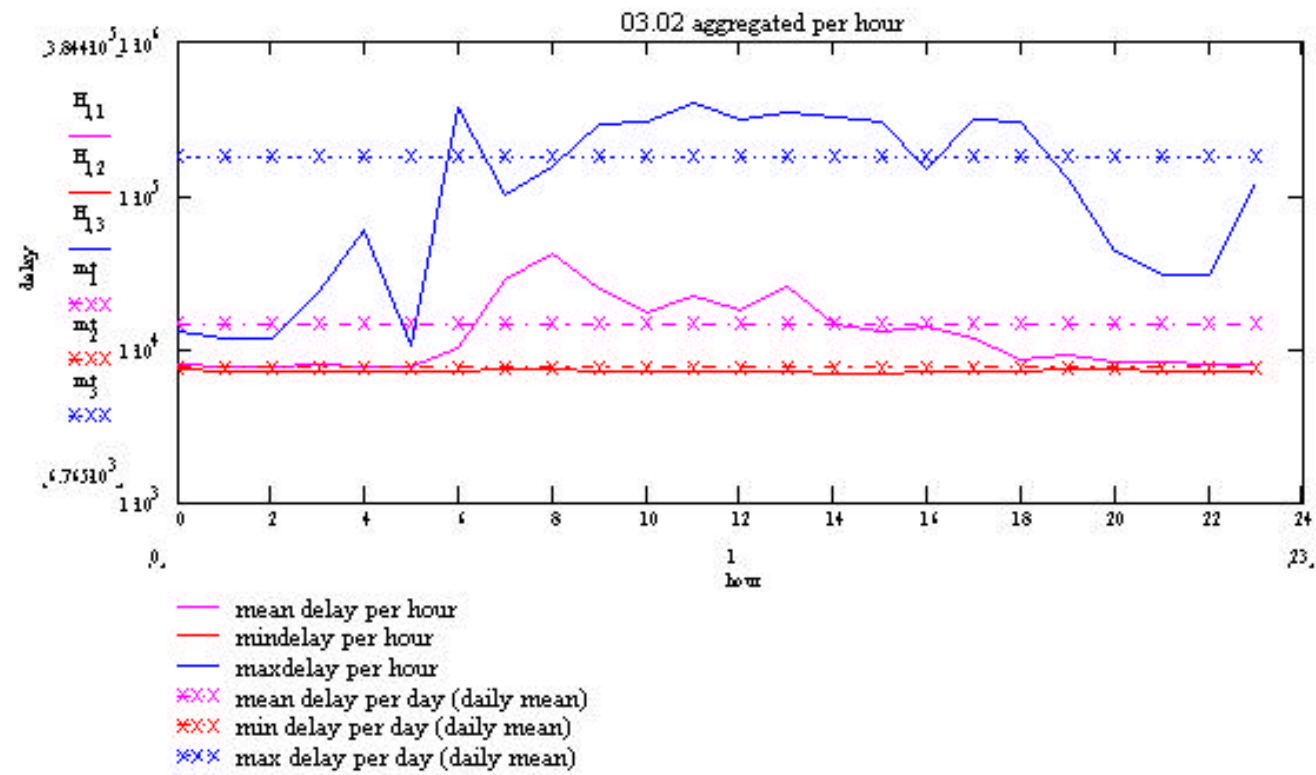


Experimental testbed for QoS pattern studies



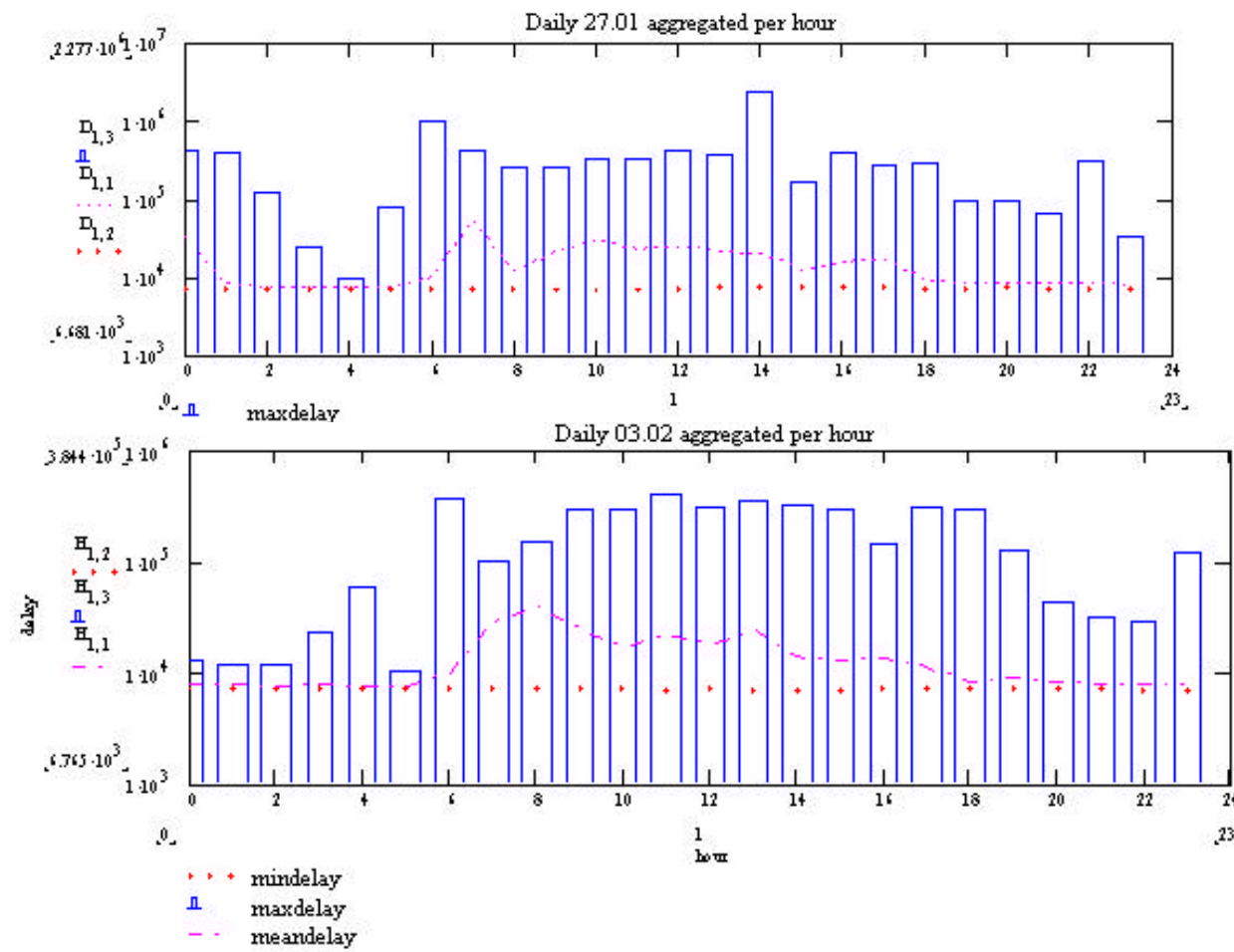


Hourly QoS patterns



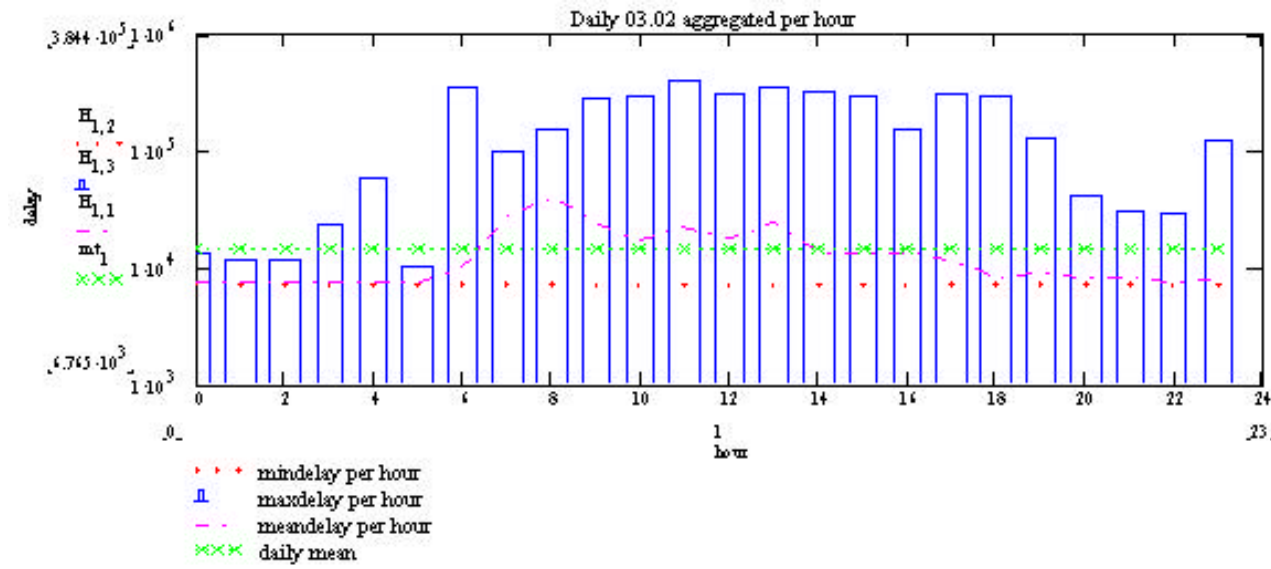


Daily QoS patterns aggregated per hour



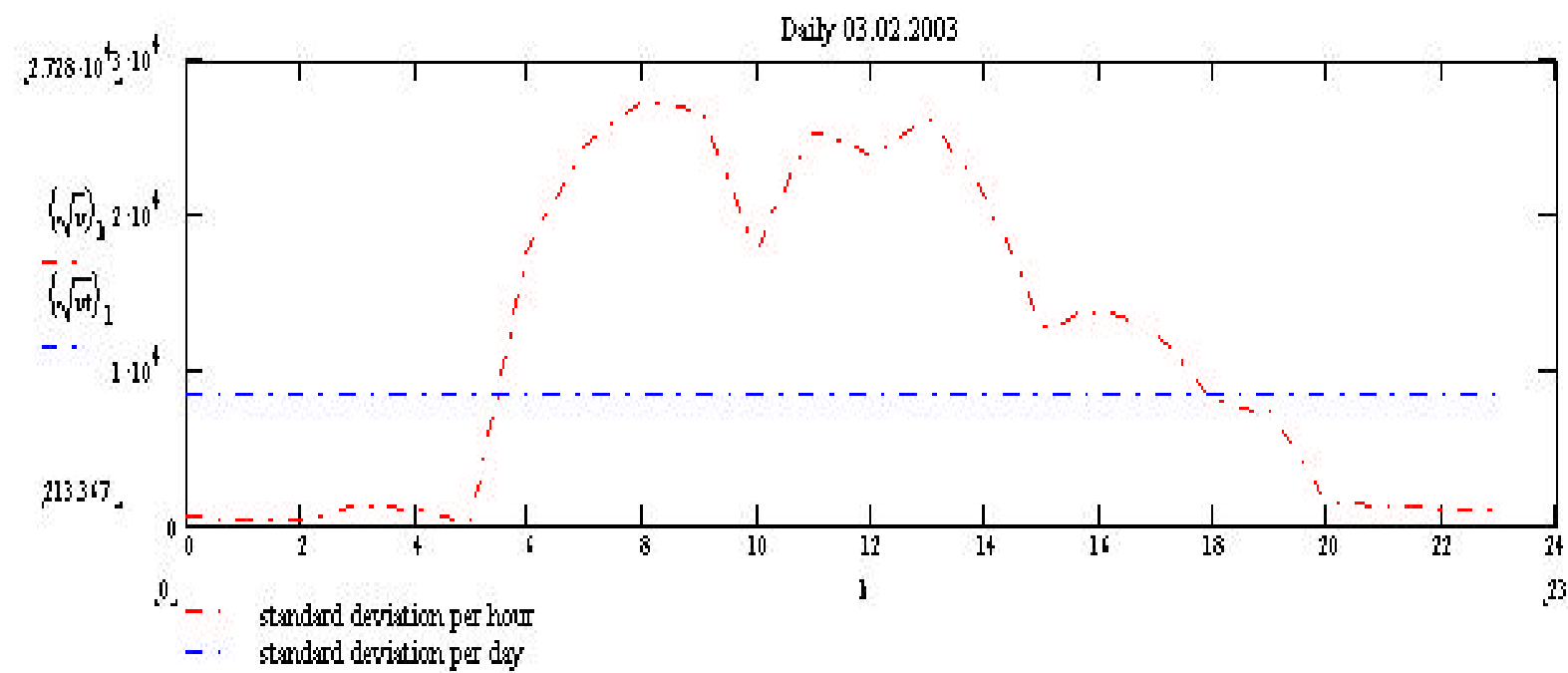


Combined Daily QoS patterns aggregated per hour with daily mean values





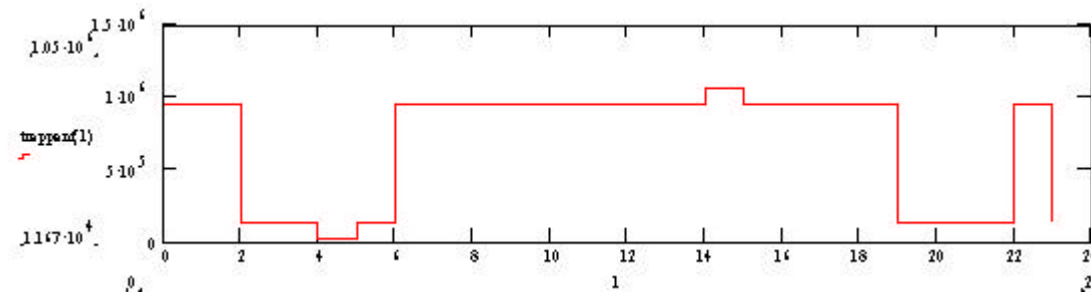
Daily QoS patterns with hourly and daily standard deviations



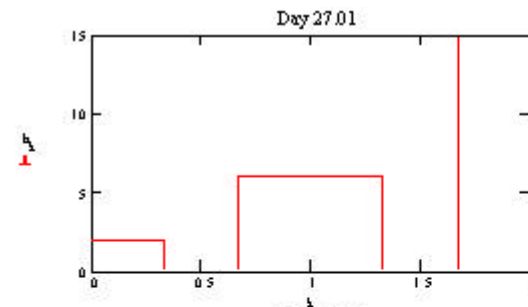


Daily Time and Threshold Based Histogramm

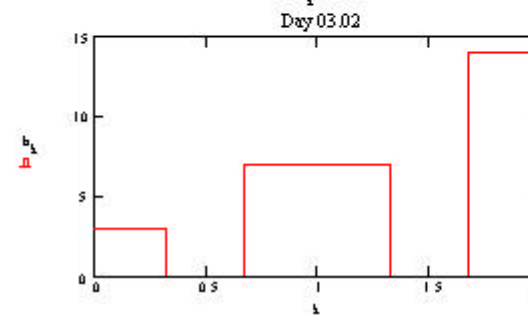
e.g to locate stable, crucial hours for capacity planning



Daily Threshold based Histogram, e.g to characterize the quality of the day



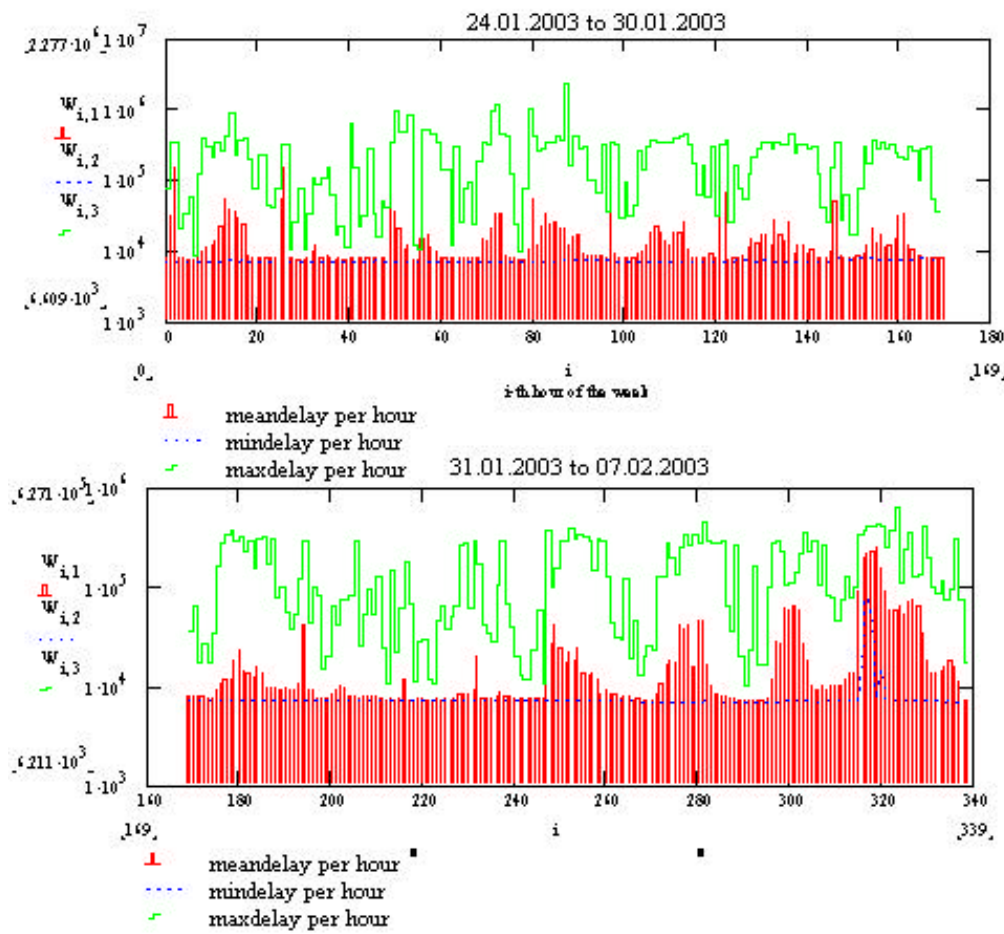
2 Measures lie within Interval 0 and thresh0
 6 Measures lie within Interval thresh0 and thresh1
 15 Measures lie within Interval thresh1 and thresh2



3 Measures lie within Interval 0 - thresh0
 7 Measures lie within Interval thresh0 and thresh1
 14 Measures lie within Interval thresh1 and thresh2

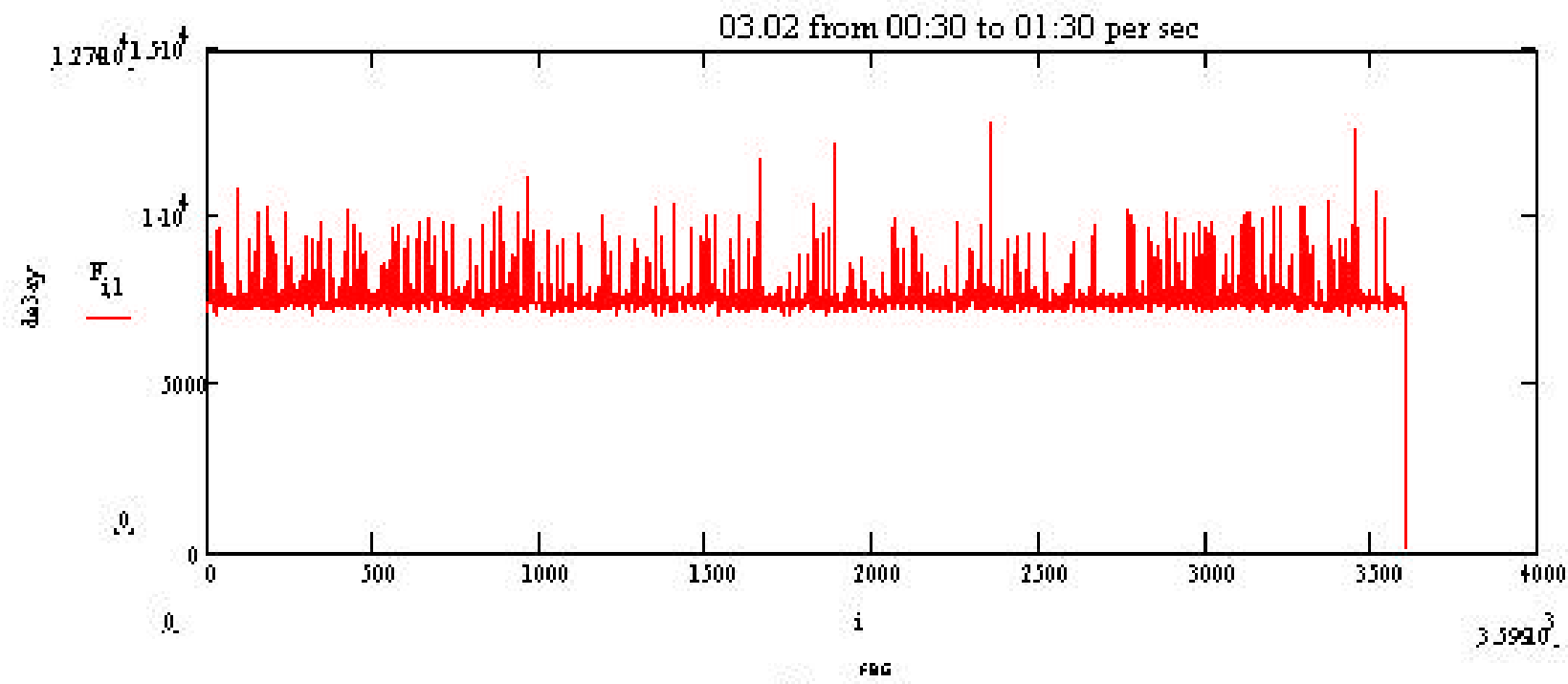


Two Weekly Patterns to compare similar or periodical daily patterns





Hourly pattern considering second as time scale





Further work



- Spatio-temporal and spatial composition studies in inter-domain environment considering patterns
- Combination of spatio-temporal QoS pattern analysis with forecasting techniques based on learning historic QoS patterns and fuzzy classification [HC 99]. .