Dynamic Approach to Service Level Agreement Risk

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Motivation

- Networks in operation differ from planned networks due to failure events, failures present in operational network
- Thus
  - Resilience in network changes spatially and temporally
  - No-single-point-of-failure networks becomes locally single-point-of-failure network during some periods in network operation. Where? When? Impact on services? Impact on risks?
  - How to incorporate this into network operations and planning.
- *Aim: Illustrate the impact of router/link failure events or accumulated service downtime in terms of SLA risks in the currently operated network.*
  - Our contribution is proof-of-concept type, we rush forward to demonstrate the end result and new view points
  - Work greatly influenced by co-operation with human factors field research at network operations center
  - Practical contribution to RESS white paper "Towards risk-aware communications networking", 2013.

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SLA-risk

- SLA, during $T_{n+1} - T_n \equiv T$, service downtime D_t at most d_{SLA} time units, otherwise penalty $w(\equiv 1, \text{from now on})$.
- Dynamic SLA-risk at time t, is conditional expectation

$$R_t = E\left[1_{\{D_t > d_{SLA}\}} \,\middle|\, \mathcal{F}_t\right] \cdot w, \tag{1}$$

  where $\mathcal{F}_t$ contains the history of network and SLA state processes up to t.
  - If service is up, R_t is decreasing in t.
  - It jumps up if a network component failure occurs even if service is still OK (risk has increased)
  - accumulated service downtime affects the level of R_t.

SLA-risk importance measure of a network component

- Motivated and inspired by various risk importance measures, i.e., Fussell- Vesely
- SLA-risk importance measure for up/down component c at t

$$\mathrm{Imp}_t(c) = 1 - \frac{\sum_a R_t(a/c)}{\sum_a R_t(a)}, \tag{2}$$

where $R_t(a)$= dynamic risk of SLA a, and $R_t(a/c)$ = value that $R_t(a)$ would take if component c would change its state at t.

  - $\mathrm{Imp}_t(c) < 0$: component c is up, the smaller the value the more critical the *functioning* of c
  - $\mathrm{Imp}_t(c) \in [0, 1]$: c is down, the larger the value the more critial the *repair* of c
  - priorizing repairs is typical, importance of not failing is new insight
  - all assessments done in terms of SLA-risks

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Challenges:

- Analysis of service disruption events
  - precalculation of the simplest system component failure scenarios leading to service downtime
- Stochastic modeling of failures
  - on-off process modeling of single and joint failures
  - interval availability approximation

Note: We assume independent network components → level of results optimistic
Our example case is used to demonstrate the dynamic SLA-risk model. Missing data or information is replaced by heuristics. Results can not be used to infer dependability or risks levels of the network in question.

NOTE! This work does NOT involve any failure simulations, all work is analytical.

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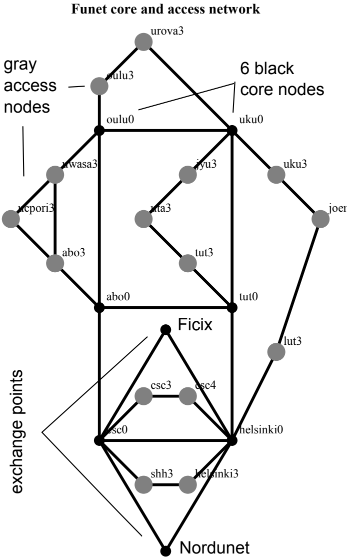
Example case, Funet: analysis of service discuption events

- service = connections to exchange points Ficix and Nordunet according to routing rule “access → core → exchange”
- topology (physical = logical)
- simplest service failure due to 2-component (router or link) joint failure
- calculated automatically 112 minimal 2-cutsets (=minimal events for service disruption) + list of access routers affected in each 2-cutset



Example case, Funet: ideas used in stochatic modeling

- On-off modeling (can also think that QoS too low → off, but our data is on real 0/1 failures)
- $J_\ell = c_i \wedge c_j$ is a-cutset, if joint failure of c_i and c_j causes service outage to access router a
- c_i, c_j router/link with on(Poisson) – off(Pareto) - model → closed form approximations for access router on-periods and durations of off-periods [1]
- interval availability approximation
  - SLA tracking period T short (i.e., month scale) and component failure events are rare
  - simple service failure events are most likely

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[1] P.Kuusela, I. Norros. *On-Off Process Modeling of IP Network Failures, DSN 2010*

Interval availability approximation, ideas

Assume history $\mathcal{F}_t$ containing i)component states and current lengths of ongoing downtimes $(U_t(c))_{c \in \mathcal{C}}$ and ii)accumulated downtimes $D_t(a)$ of all access routers. Denote the still allowed downtime by $x := d_{SLA} - D_t(a)$.

For 2-element cutset $J_\ell = c_i \wedge c_j$ approximate

$$P_t(\text{SLA broken during remaing period}) = P(D_{T-t}(c_i \wedge c_j) \geq x | \mathcal{F}_t)$$

in 3 cases by: (see paper for formulas)

"2 up" single joint downtime longer than x occurs during $T - t$

"1 down" condition on accumulated downtime, single joint failure occurs as "2 up" either before failed component is repaired or after that

"2 down" condition on accumulated downtimes and calculate $P(\text{joint failure lasts at least time } x)$

For access router a affected by k a-cutsets approximate SLA-risk by

$$R_t(a) \approx \sum_{\ell=1}^{k} P(D_{T-t}(J_\ell) \geq d_{SLA} | \mathcal{F}_t),$$

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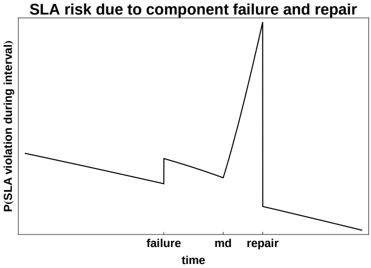
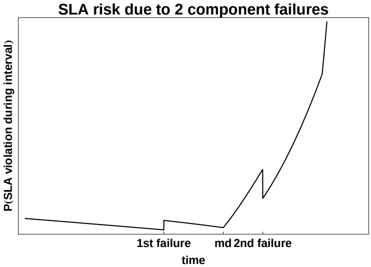
Interval availability: time and failure dynamics of $c_i \wedge c_j$



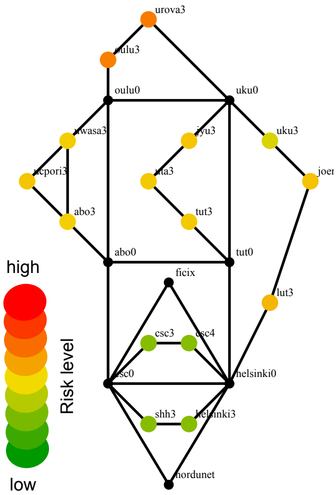
one failure and repair, only elevated risk for service downtime



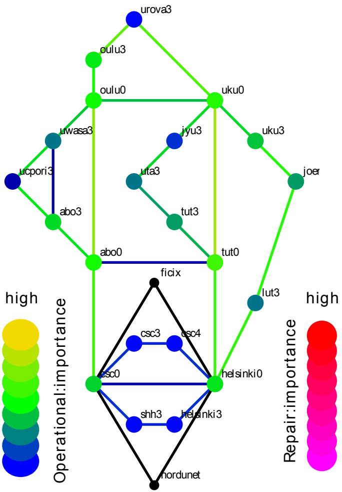
joint failure and service downtime

SLA-risks and component importance at the beginning of 1-month SLA period, uniform downtime limit in access routers, all components up

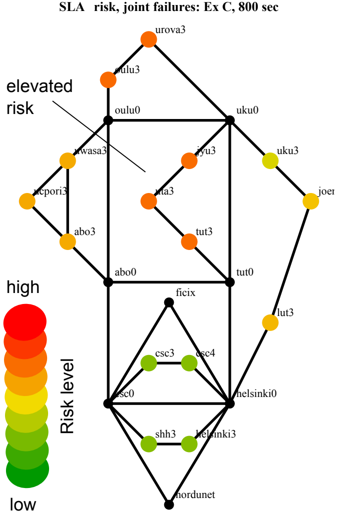
SLA risk, joint failures: Ex A



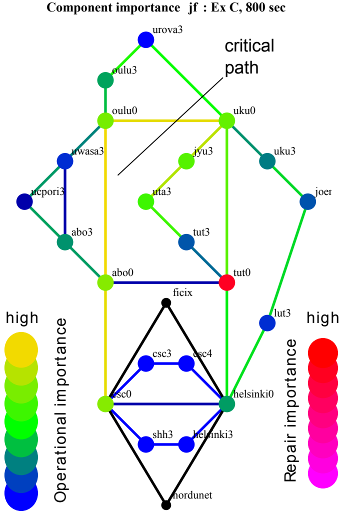
Component importance jf : Ex A



SLA-risks and component importance at core router `tut0` failure, downtime so far 800 sec, no accumulated downtime is access routers

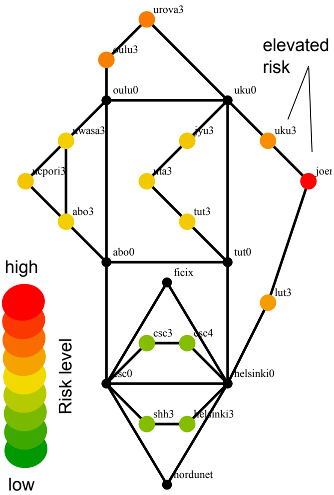

SLA risk, joint failures: Ex C, 800 sec

elevated risk

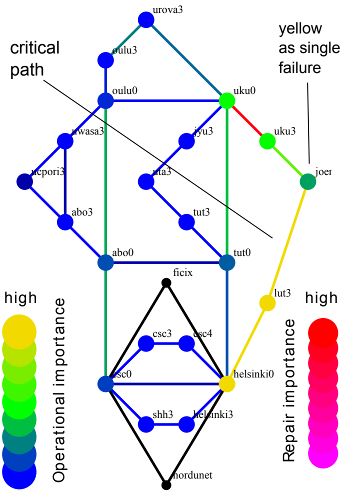

Component importance jf : Ex C, 800 sec

critical path

SLA-risks and component importance when access router `joen` has accumulated downtime and link `(uku0,uku3)` has just failed



SLA risk, joint failures: Ex F



Component importance jf : Ex F

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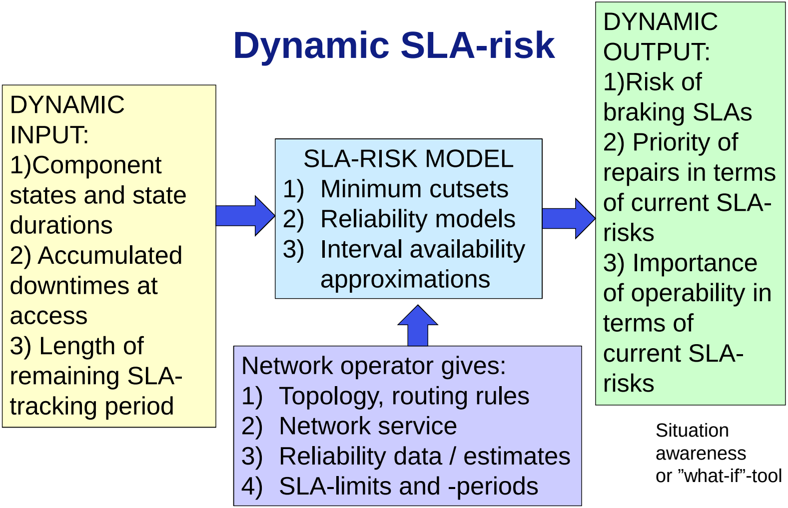
Dynamic SLA-risk



DYNAMIC INPUT:
1)Component states and state durations
2) Accumulated downtimes at access
3) Length of remaining SLA-tracking period

SLA-RISK MODEL
1) Minimum cutsets
2) Reliability models
3) Interval availability approximations

Network operator gives:
1) Topology, routing rules
2) Network service
3) Reliability data / estimates
4) SLA-limits and -periods

DYNAMIC OUTPUT:
1)Risk of braking SLAs
2) Priority of repairs in terms of current SLA-risks
3) Importance of operability in terms of current SLA-risks

Situation awareness
or ”what-if”-tool