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
  - 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 $w(\equiv 1$, from now on).
- Dynamic SLA-risk at time $t$, is conditional expectation

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

(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 $R_t$. 
Motivated and inspired by various risk importance measures, i.e., Fussell-Vesely

SLA-risk importance measure for up/down component $c$ at $t$

\[
\text{Imp}_t(c) = 1 - \frac{\sum_a R_t(a/c)}{\sum_a R_t(a)},
\]

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 $t$.

- $\text{Imp}_t(c) < 0$: component $c$ is up, the smaller the value the more critical the functioning of $c$
- $\text{Imp}_t(c) \in [0, 1]$: $c$ is down, the larger the value the more critical the repair of $c$
- Prioritizing 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 disruption 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 stochastic modeling

- On-off modeling (can also think that QoS too low $\rightarrow$ off, but our data is on real 0/1 failures)

  $\mathcal{J}_\ell = c_i \land c_j$ 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 $\rightarrow$ 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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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 $J_\ell = c_i \land c_j$ approximate

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

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-risks and component importance at core router tut0 failure, downtime so far 800 sec, no accumulated downtime is access routers
SLA-risks and component importance when access router joen has accumulated downtime and link (uku0, uku3) has just failed.
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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