Proactive self-healing mechanisms for IP networks

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Overview

- Goal: extra-resilient IP networks
- How: new “autonomic” capability
  - Proactive and adaptive
    based on learning and knowledge building
- Tested on OSPF, G/MPLS protocols

Issue

- How to ensure high availability and QoS?

- Fault management mechanisms
  - Vital and working, but…
  - Reactive
  - Expensive (e.g. resource-wise),
  - Imperfect (e.g. failure effects mitigation)
  - Complex (e.g. to configure and deploy)

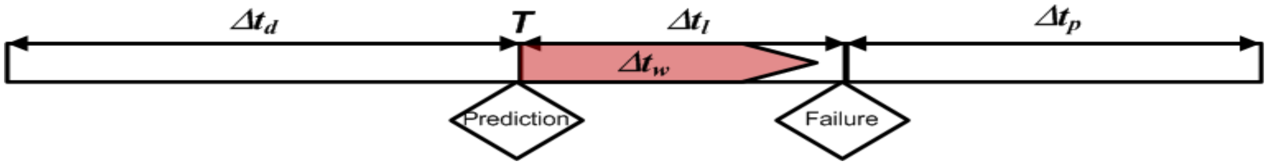
Idea: Proactive self-healing

- A new capability:
  - Monitor network devices health
  - Compute real-time failure probabilities
  - Adapt fault-management strategy
  - Proactively trigger network reconfiguration
  - Reduce unstable state when the failure occurs
  - Save time in stressing situations
  - Complement existing reactive recovery mechanisms

Proactive self-healing

- Failure prediction methods
  - Failure Tracking
    [PC02] J. D Pfefferman et Al. : A nonparametric nonstationary procedure for failure prediction. IEEE Transactions on Reliability, 12/2002.
  - Symptom monitoring
    [CGM02] K. Cassidy et Al. : Advanced pattern recognition for detection of complex software aging phenomena in online transaction processing servers. DSN, 2002.
  - Detected Error Reporting
    [SSM06] F. Salfner et Al. : Predicting failures of computer systems : a case study for a telecommunication system, IPDPS, 2006

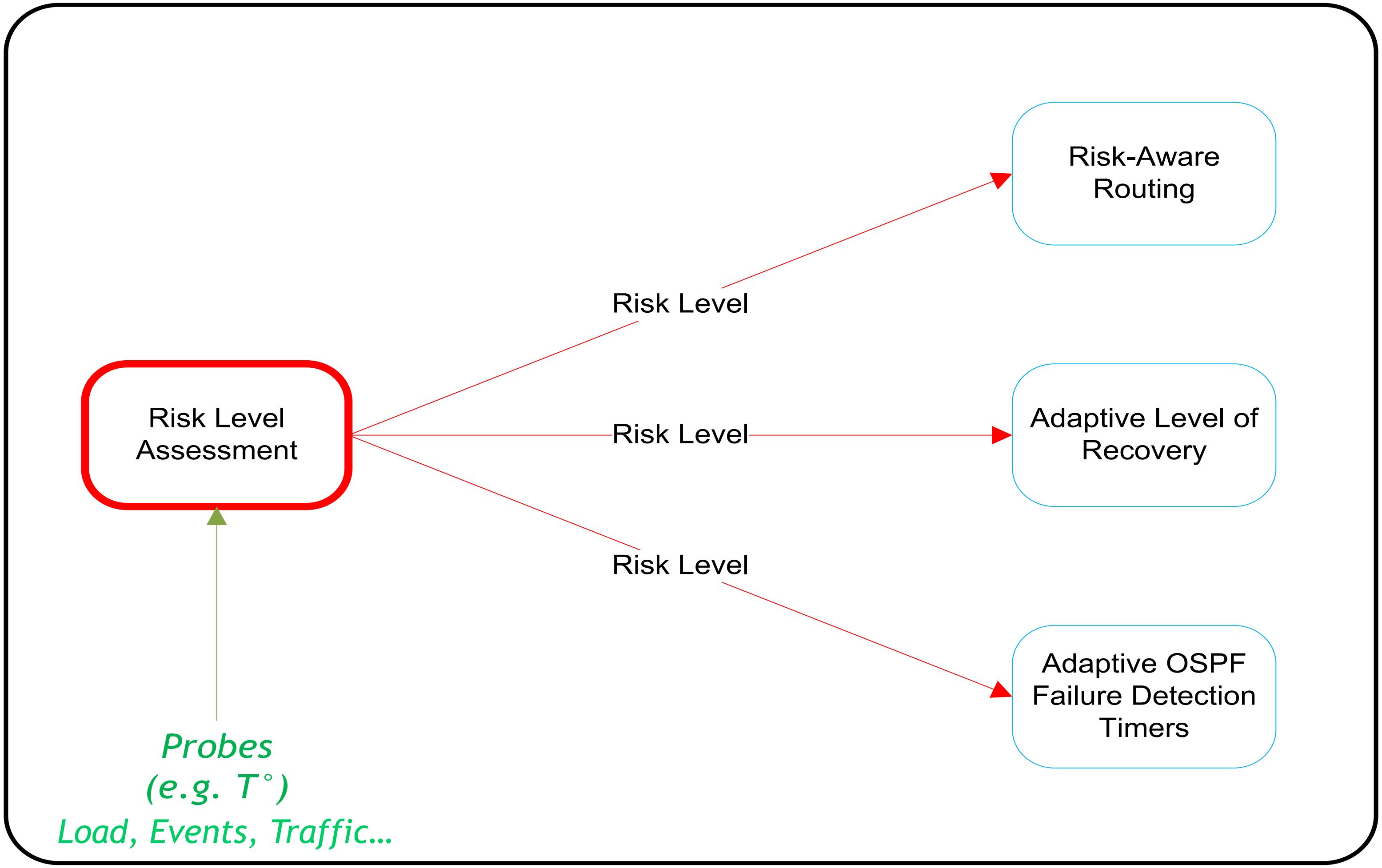
- Online failure prediction timeline



  - Recall > 90% (predicted failures), Precision > 80% (correct prediction)
  - Lead time ~1 min, Validity period ~ 5 sec

[SM07] F. Salfner et A. : Using hidden Semi-Markov models for effective online failure prediction. SRDS, 2007.

Applied to IP, GMPLS protocols



IP restoration (1)

- Convergence process: $T_C=T_D+T_F+T_S+T_U$
  - Failure detection (T_D) , Link State Advertisement (LSA) flooding (T_F) , Shortest paths computation (T_S) , Routing and forwarding table update (T_U)

- Reactive approach, only triggered after the failure occurrence
  - Up to several seconds of service interruption
    - Loss of packets, routing loops

IP restoration (2)

- Sample of proposed improvements:
  - Faster failure detection

[GRF03] M. Goyal et Al.: Achieving faster failure detection in OSPF networks,", ICC, 2003.

  - Use temporary back-up path until end of the convergence process
    - IP Fast Reroute

[FB05] P. Francois et Al. : An evaluation of IP-based fast reroute techniques, CoNEXT, 2005

  - Use long term statistic to choose routes

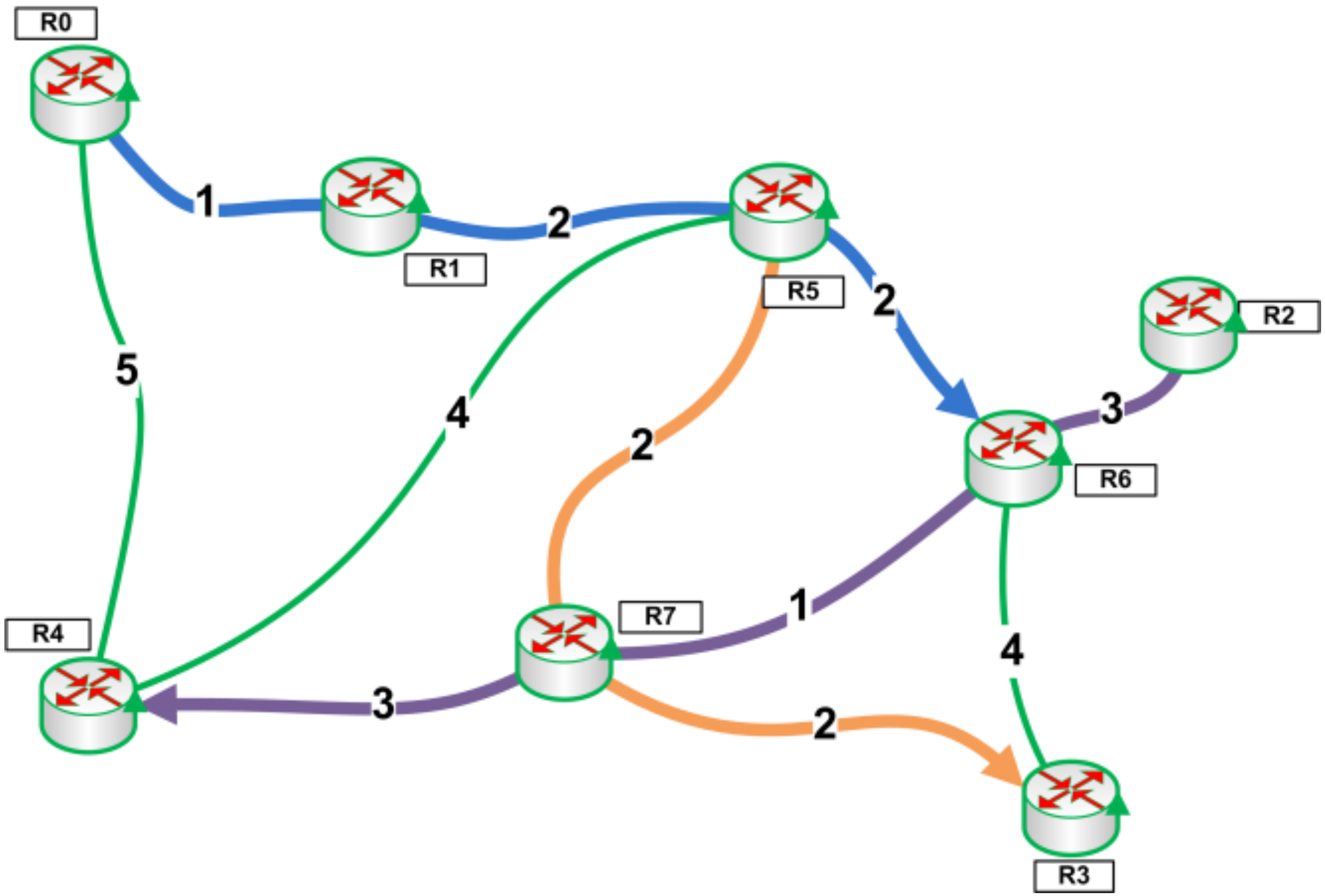
[XTMM10] M. Xia et Al. : Risk-Aware provisioning for optical WDM mesh networks. IEEE/ACM Transactions on Networking, 2010

RAR mechanism overview

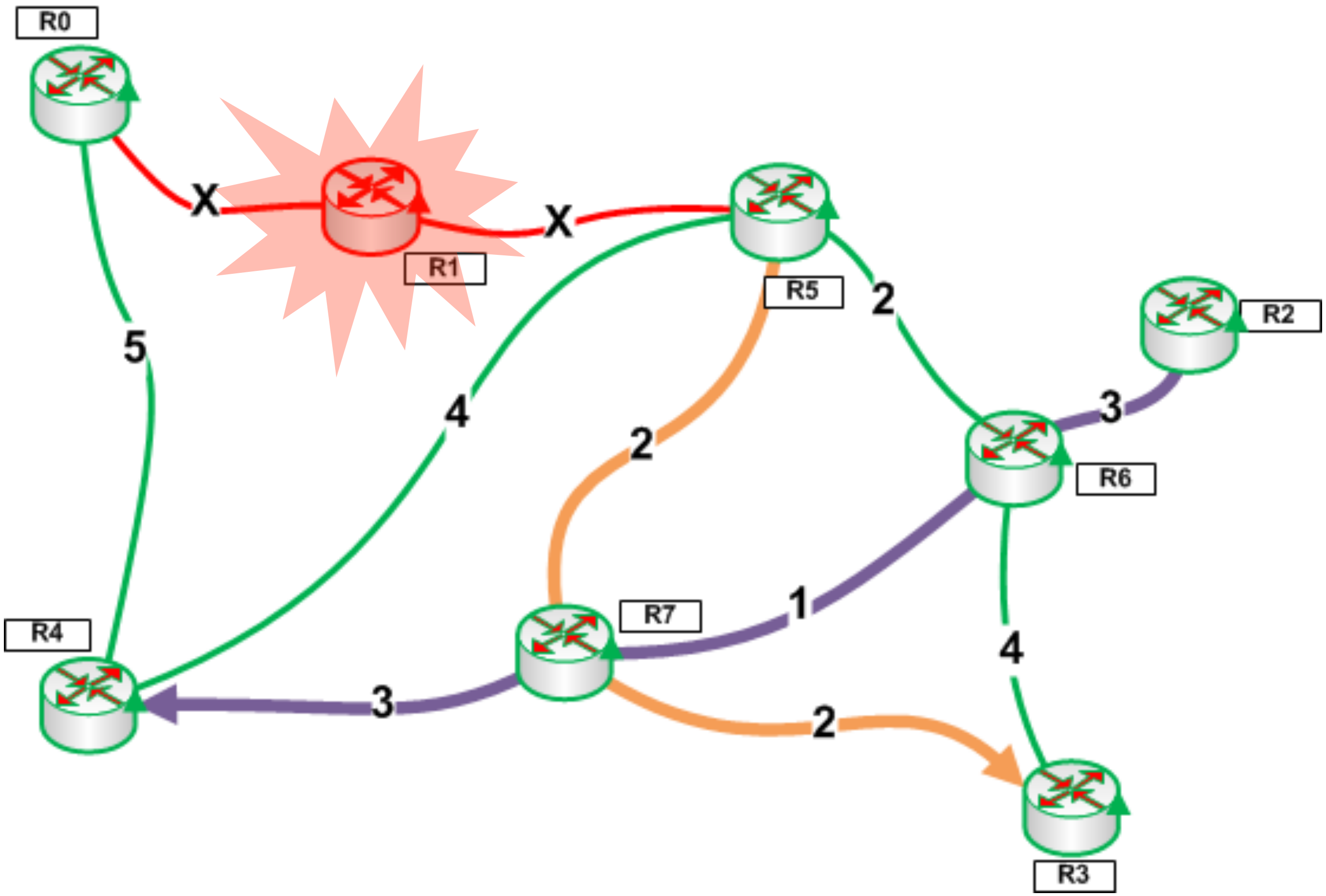
- Use failure prediction to proactively steer traffic away from risky network nodes/links
  - Use initial metric value when the risk of failure is low
  - Temporally set a high/prohibitive metric value to interfaces concerned by a failure prediction
    - MaxPossibleCost – MaxInitialCost + InitialCost($link_i$)
    - Iterative increment to avoid routing loops

[FB07] P. Francois et O. Bonaventure : Avoiding transient loops during the convergence of link-state routing protocols, IEEE/ACM Trans. Netw.,2007.

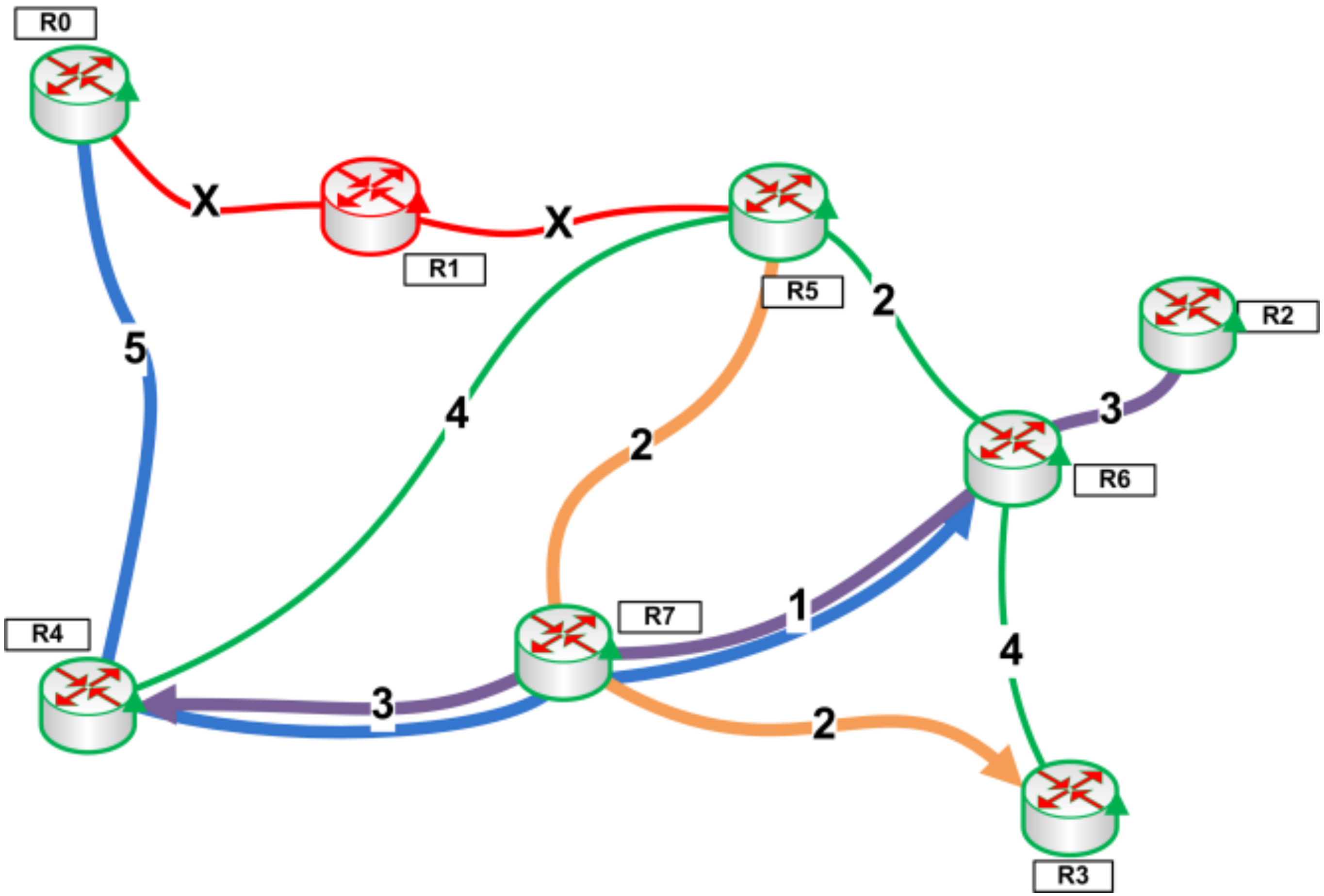
Default OSPF - Steady state



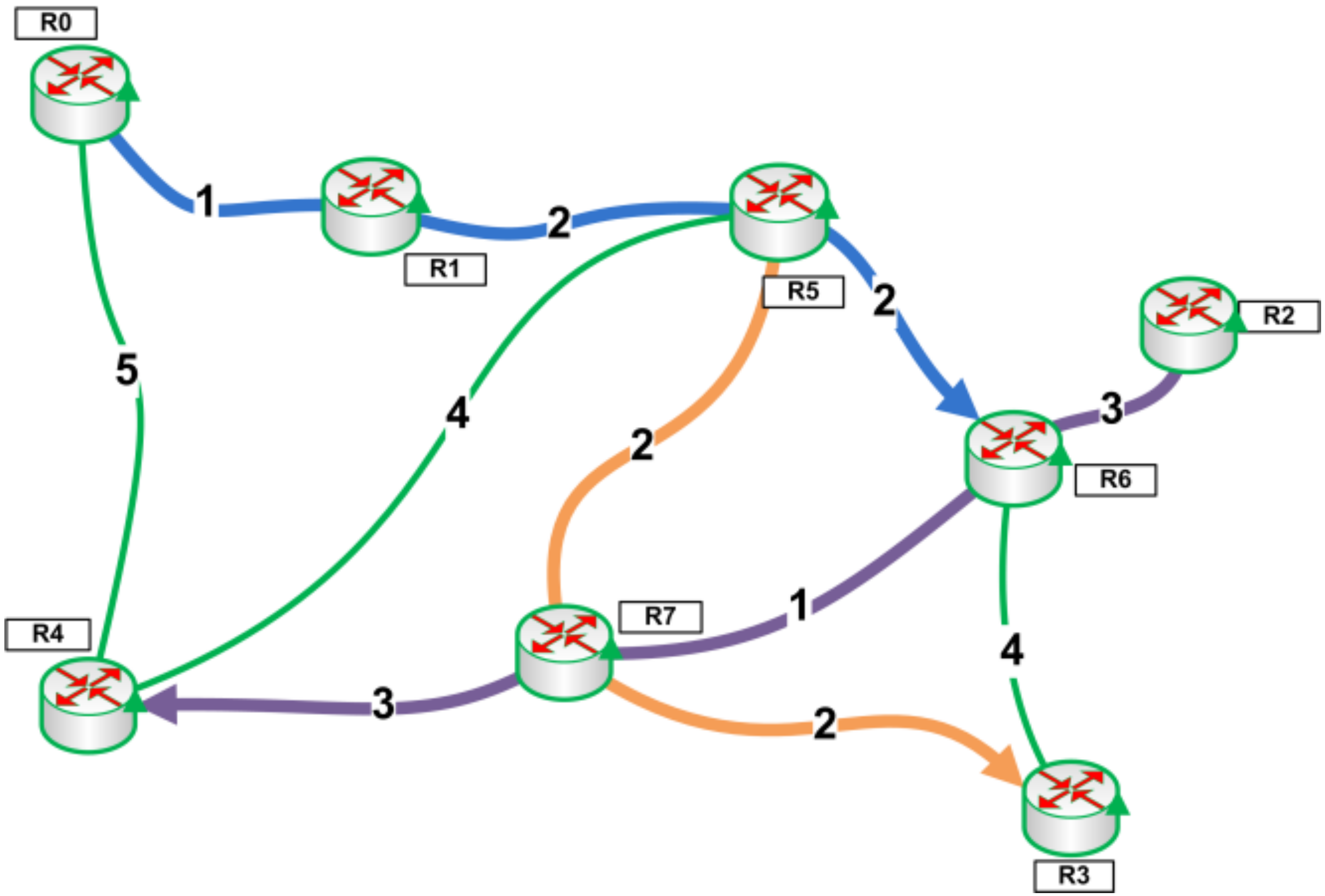
Default OSPF - Failure



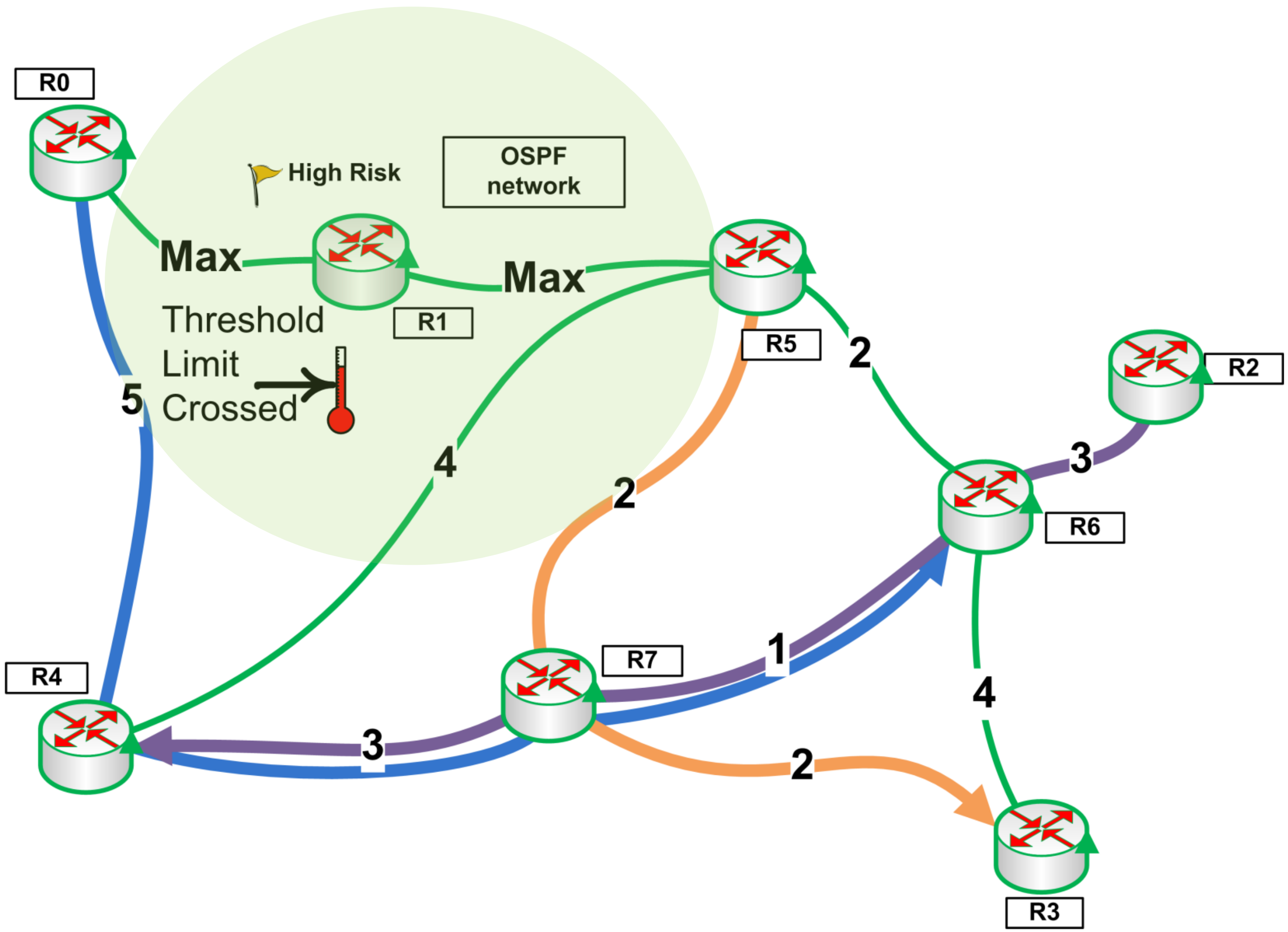
Default OSPF - Restoration



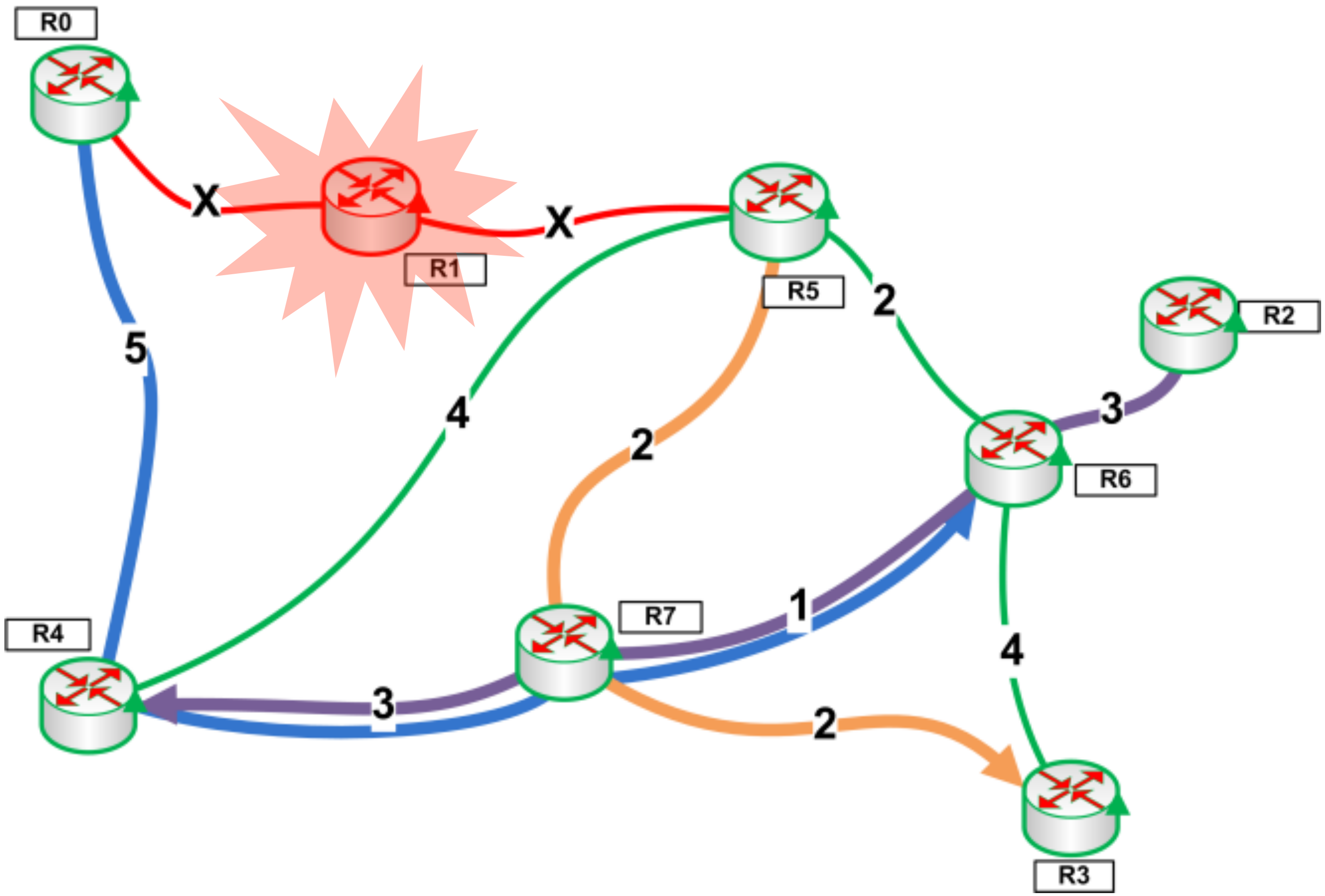
Risk-Aware OSPF - Steady state



Risk-Aware OSPF - Failure anticipation



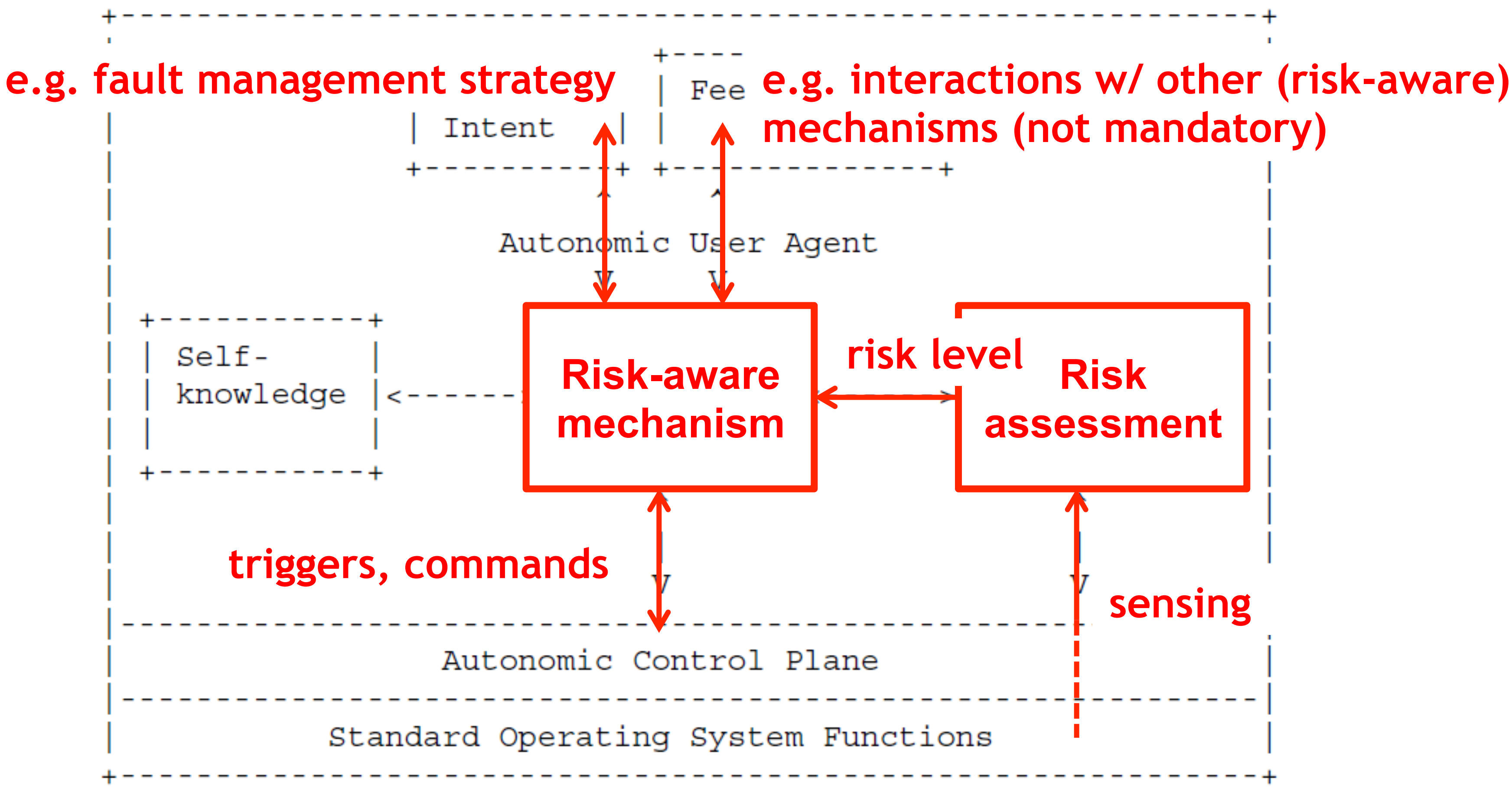
Risk-Aware OSPF - Proactive rerouting



Results/Observations

- Completely avoid service interruption for predicted failures
- Routing flaps kept low
- Limitation due to congestion with too many/long predictions
- Compatible with current protocols

(tentative) Mapping to reference model



Take away messages

- New, simple, autonomic capability
- Light and Pluggable
  - seamless integration with node control software
  - distributed in each node, local decision-making
- **Adaptive and Context-sensitive**
  - **multiple parameters monitoring and real-time risk evaluation**
  - **learning-aided decision refinement**
- Versatile
  - applicable in multiple contexts: IP routing, (G)MPLS…
  - complementary to recovery mechanisms (dual effect)
  - customizable to operator’s traffic engineering strategy

Further reading

- Risk-aware routing for IGP-LS protocols [IM2013]
- Adaptive level of recovery for GMPLS networks [ICC2012]
- Adaptive Failure Detection Timers for IGP Networks [NETWORKING2013]