



## **Dependability indices**

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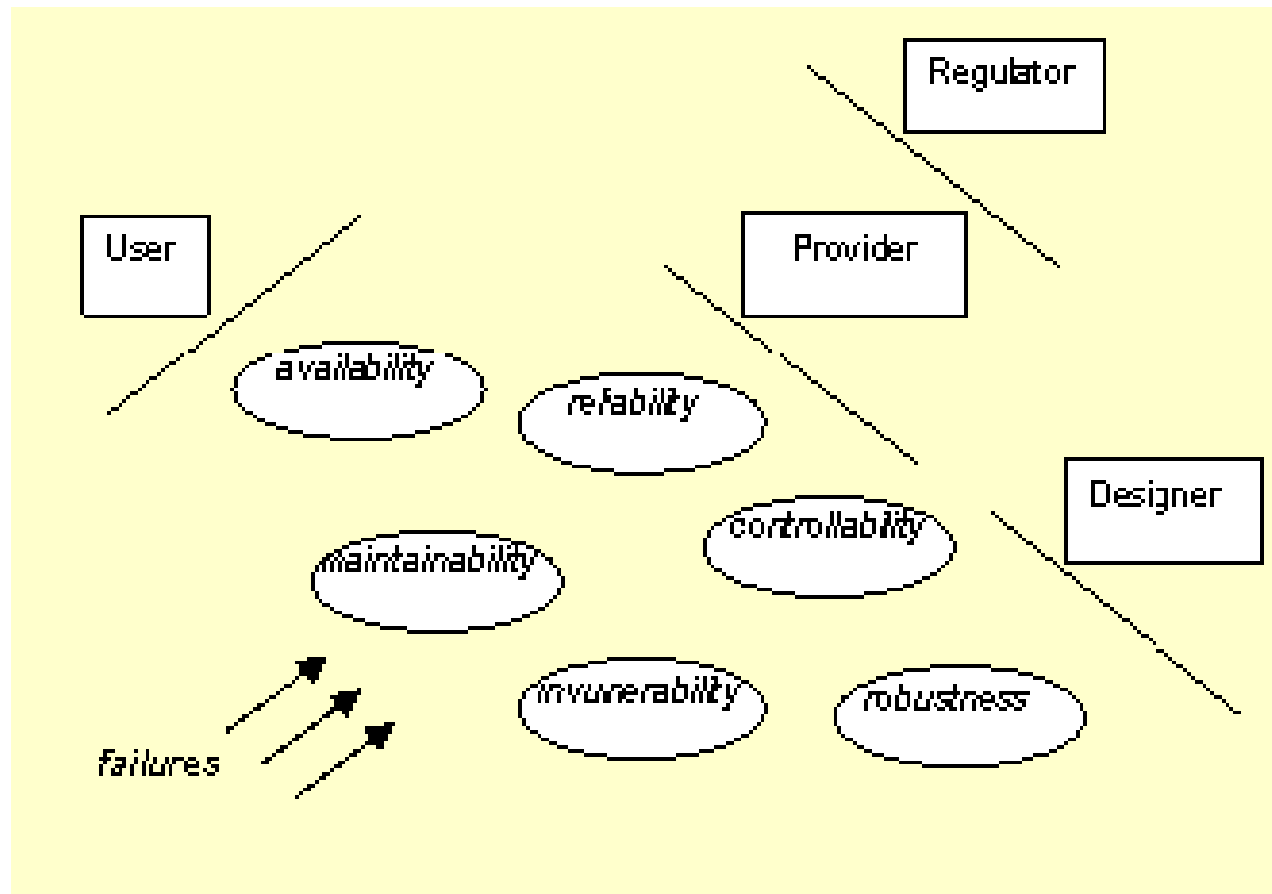
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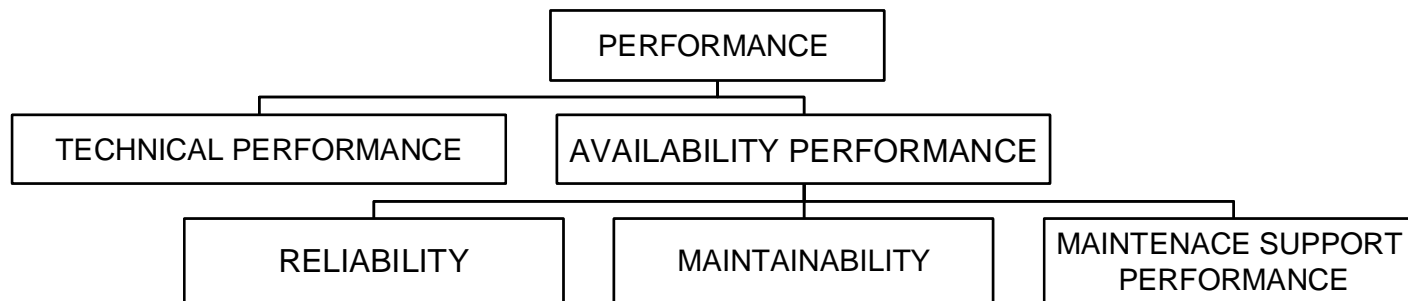
## INTRODUCTION

- Measurement of dependability is needed for
  - Monitoring network performance
  - Comparing design solutions
  - Planning maintenance and renewals
  - Formulating service level agreements
  - Discussing network reliability in more rational way
- All actors need a consistent measurement system
  - Users
  - Providers
  - Designers
  - Regulating authorities
- Dependability/reliability as an economic issue

# ASPECTS OF DEPENDABILITY



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- **Availability**
  - Long-term average part of time that a user has a connectivity of satisfactory quality to most of the normally accessible end-devices connected to the Internet
  - Statistical concept
- **Reliability**
  - Ability of the component/part/subsystems of the network to operate without failures
  - Partially statistical concept
- **Maintainability**
  - Ability of a system to be brought back to operation after a failure, ability of a system to be renewed; depends on the skills of the maintaining organisation
  - Partially statistical concept
- **Quality of service**
- **Vulnerability**
- **Robustness of design**
- **Controllability**

## DEPENDABILITY INDICES

- Indices for various levels of network
  - o Components (links, switches, routers, protocol implementations)
    - q Both hardware and software components
  - o Subsystems (parts of network, peripheral tree-like networks)
  - o Services and functions of components and systems
  - o Networks
- Indices for various purposes
  - o Performance monitoring
  - o Design
  - o Planning of maintenance
  - o Definition of service level agreements
  - o Asset management
  - o Etc.

## DEPENDABILITY INDICES

- Indices based on observations
  - o The state of the network systems is monitored to certain extend
  - o Dependability can be calculated on the basis of observed characteristics
    - q Observed failure rate
    - q Observed availability
- Predictive/model-based indices
  - o Indices for systems must take into account the (reliability)structure and the dynamics of the system
    - q Redundant systems
    - q Systems dependent on other systems
    - q Reliability models must be used in defining the indices
  - o Predictive indices e.g. future availability, future failure rate
  - o Indices for design and planning



## DEPENDABILITY INDICES

- Indices for various failure types
  - o The failures are caused by
    - q Design errors
    - q Manufacturing errors
    - q Installation errors
    - q Software errors
    - q Human errors
  - o Possibility of common cause failures
  - o Software errors and human errors are most difficult to be modelled (and measured)

## DEPENDABILITY INDICES

Examples of (possible) indices

Level of measurement	Dependability indices	Comments
Components	<ul style="list-style-type: none"><li>• Observed failure rates, component availabilities and down times</li><li>• Modelled/predictive failure rates, component availabilities and down times</li></ul>	<ul style="list-style-type: none"><li>• Require component reliability models</li><li>• Measures for software components and human actions may be problematic</li></ul>
Functions of components	<ul style="list-style-type: none"><li>• observed failure probabilities, failure rates and availabilities</li><li>• modelled failure probabilities, failure rates and availabilities</li></ul>	

## DEPENDABILITY INDICES

Examples of (possible) indices (cont.)

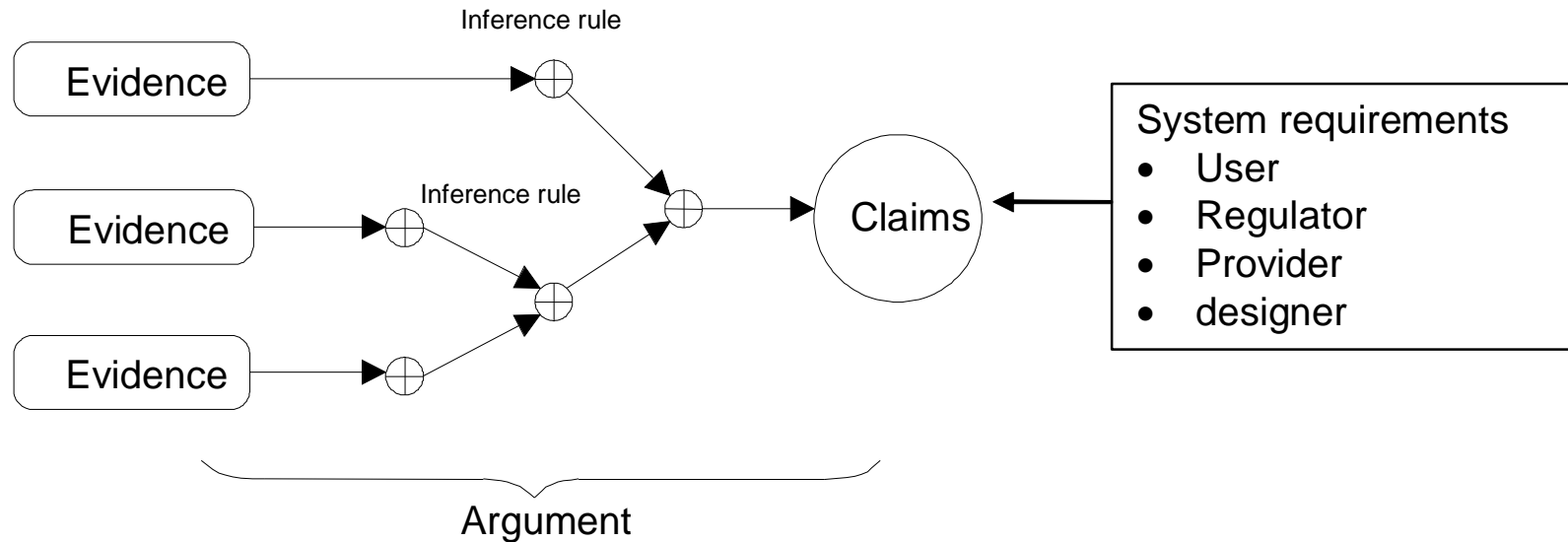
Level of measurement	Dependability indices	Comments
Simple subsystems, single connections,	<ul style="list-style-type: none"> <li>• observed and modelled failure rates, component availabilities and down times</li> <li>• duration curves, the probability (or percentage of time) that the system provides certain level of service during the time period under consideration</li> </ul>	<ul style="list-style-type: none"> <li>• systems have often redundancy, which must be modelled</li> <li>• subsystem reliability models needed</li> </ul>
Networks, services	<ul style="list-style-type: none"> <li>• e.g. expected or mean number of clients (connections) being served at least on certain service level certain percentage of time</li> <li>• the long-term average part of time that the network provides full connectivity of satisfactory quality between all (or certain set of) nodes of the network.</li> </ul>	<ul style="list-style-type: none"> <li>• Models of network structure required</li> <li>• Dependencies on protocols must be taken into account</li> <li>• Impact of human errors must be taken into account</li> </ul>

## DEPENDABILITY INDICES

- Requirements for dependability measurement
  - o (automatic) monitoring of network components disturbances and failures
  - o (automatic) monitoring of network state
  - o Qualitative analysis of disturbances and failures (failure modes, failure causes, failure consequences)
  - o Models of network components and subsystems
  - o Description of systems dependencies on its parts

## DEPENDABILITY INDICES

Indices for “a dependability case”



- System requirements (by user, regulator....) define what properties the system should have
- Requirements can be translated to claims about systems dependability, structure, robustness, economy, etc.
- Evidence from the use (and design) of the system can be used to infer which claims are satisfied
- Inference rules  $\sigma$  models, e.g. reliability model
- The “case” collect the relevant indicators or reliability indices

## RELIABILITY MODELLING

- Reliability modelling of single nodes, links and peripheral parts of network seems possible
  - Conventional reliability models apply at least on certain conceptual level
- Software and human errors problematic
- Physical network structure of core networks/ASs in some cases simple enough to be described by (graph theoretic) network reliability models
  - Minimal cut sets, connectivities, etc. can be determined
- Dynamic features ?

## CONCLUSION

- Certain dependability features can be measured
- Indices  $\hat{\circ}$  models  $\hat{\circ}$  requirements
- Observed  $\hat{\circ}$  predictive  $\hat{\circ}$  model-based indices
- Indices of various levels of network