About Cost to Build Dependable All-IP Networks

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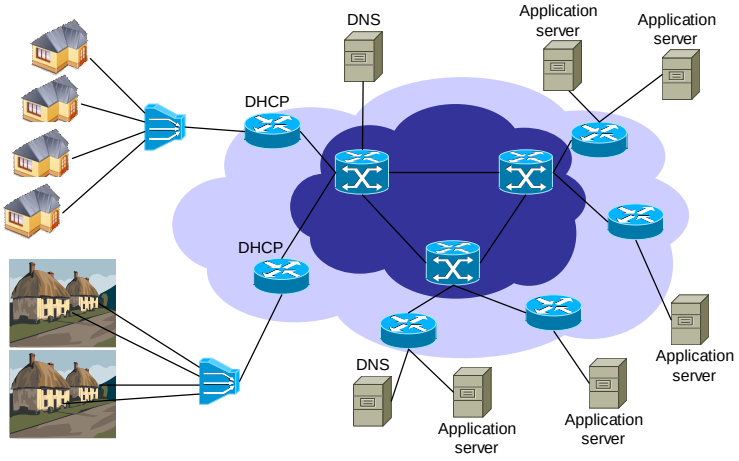
Business from technology

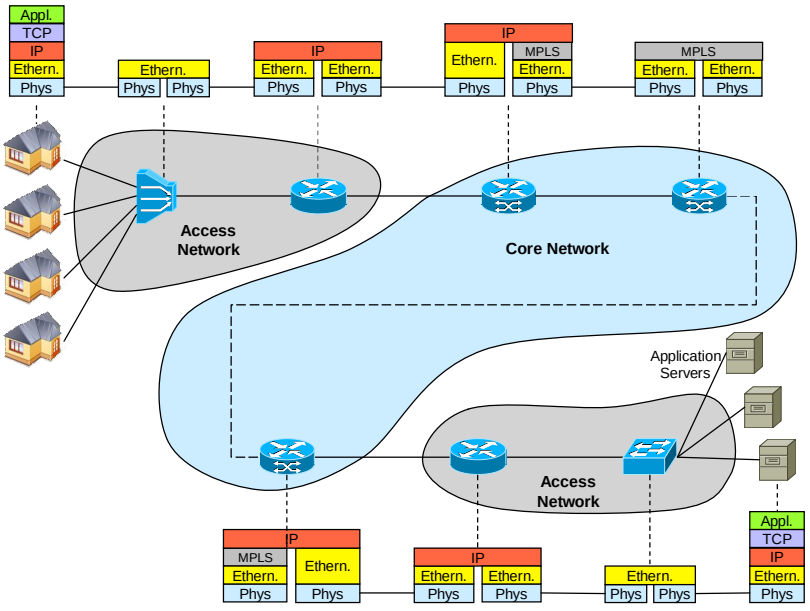
Outline

- Starting point
- Layered view to dependability
- Objectives for dependable communication
- Methods to increase dependability
- Cost of dependability
- Concluding remarks

IP network architecture



Layered IP concept



Perspectives to dependable networking

Operational:

- service usage
- running of end-user applications
- access/transport services
- network operations
- network and its facilities

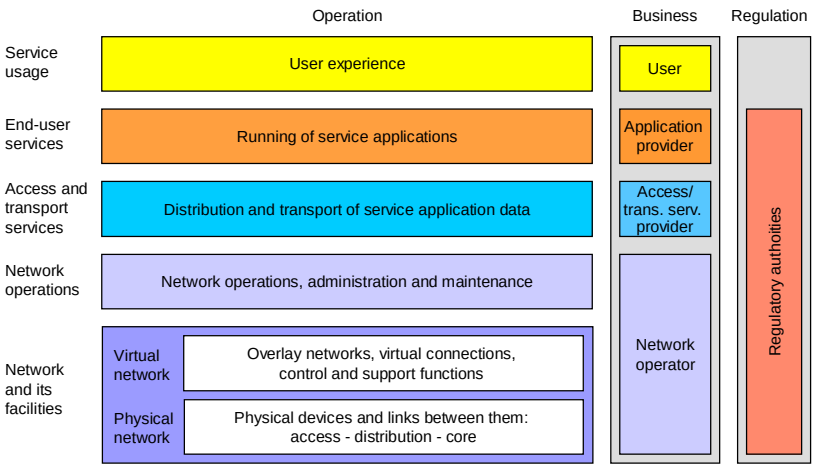
Regulation:

- consumer
- retail
- network and its operations
- etc.

Business:

- user
- application provider
- access/transport service provider
- network operator

Layered view to dependability of an all-IP network



Objectives for dependable communication

- **Network and its facilities layer:**
  - adequate network resources (e.g. bandwidth)
  - good transport quality (i.e. low bit-error-ratio, accurate timing, low delay and delay variation and low packet-loss-rate)
  - fault tolerant hardware and software solutions
  - powerful network devices, i.e. capacity to process the offered load
  - minimization of disturbances, e.g. downtimes, outages
  - automatic fast recovery from faults (and malfunctions)
  - ability to minimize harmful and/or malicious use of network resources
  - ease of installation, upgrade and update

Objectives for dependable communication (cont.)

- **Network operations layer:**
  - fast and resilient control operations
  - fast and versatile allocation of network resources
  - resilient installation and configuration of network devices
  - steady routines for fast recovery from network failures
  - automatic fast recovery from faults (and malfunctions)
  - controllability of maintenance
  - ease of network management, incl. software updates
  - detection and prevention of harmful network usage
- **Access/transport services layer:**
  - secure and reliable access to network
  - secure connections between end-points and secure access to applications
  - secure and reliable transfer of data
  - reliable authentication, authorization and accounting of users
  - removal of harmful/disturbing users

Objectives for dependable communication (cont.)

- **End-user services layer:**
  - service availability and accessibility
  - service usability
  - authentication, authorization and accounting of usage/users
  - security of service usage
  - prevention of malicious use
- **Service usage layer:**
  - services available when they are needed
  - services run smoothly and reliably
  - security of the used services

Methods to increase dependability

- Redundancy
- Control of resources and functions
- Design activities
- OAM activities
- Purchasing activities
- Other methods:
  - Network topology
  - Location of network facilities
  - Agreements
  - Lessons learned from the history
  - Alternative technology

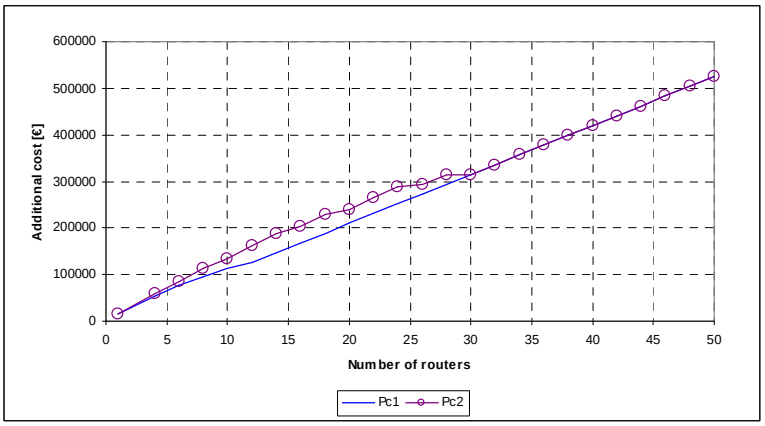
Cost estimation of dependability

- Capex evaluation
  - only product's purchasing cost considered
- Cost to buy *n* pieces of a product

$$P_c = n\,(1 - \min\{\varepsilon_m, \mathrm{floor}[n/n_{dv}]\varepsilon\})\,P_{unit}$$

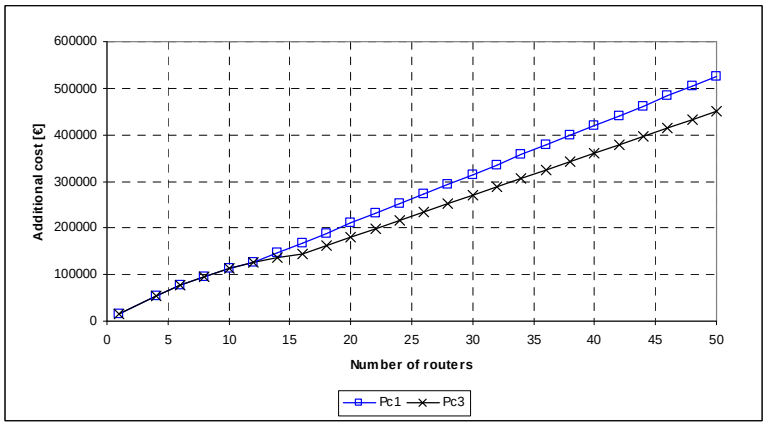
- ε step size of the discount ($0 \le \varepsilon < 1$)
- ε_m maximum obtainable relative discount value ($0 \le \varepsilon_m < 1$)
- n_{dv} number of product units that triggers increase of the discount
- P_{unit} unit price of a product

Example Capex increase as a function of the number of additional routers



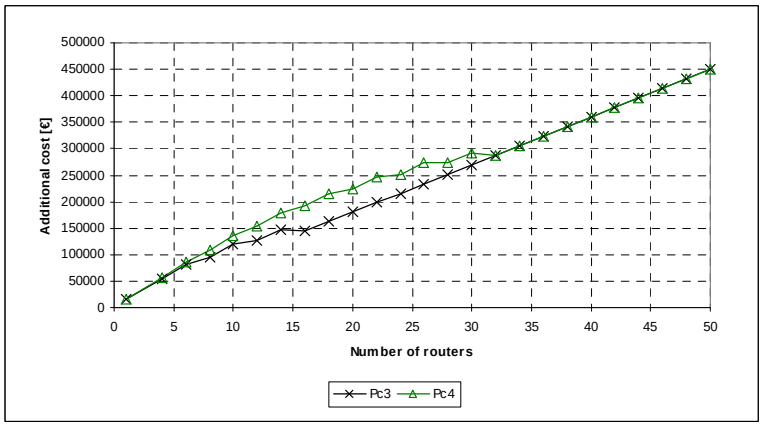
	ε_m	ε	n_{dv}	P_{unit} [€]
P_c1	0.3	0.05	2	15 000
P_c2	0.3	0.05	5	15 000

Example Capex increase as a function of the number of additional routers



	ε_m	ε	n_{dv}	P_{unit} [€]
P_c1	0.3	0.05	2	15 000
P_c3	0.4	0.05	2	15 000

Example Capex increase as a function of the number of additional routers



	ε_m	ε	n_{dv}	P_{unit} [€]
P_c3	0.4	0.10	4	15 000
P_c4	0.4	0.05	4	15 000

Cost estimation of dependability (cont.)

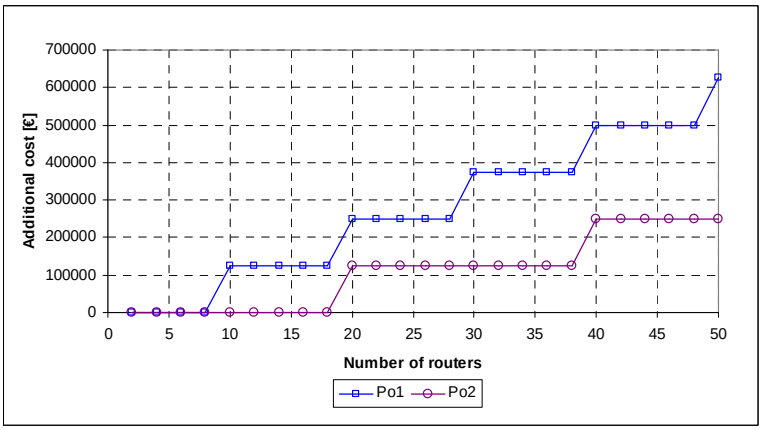
Opex evaluation

- covers installation, operation and maintenance cost

$$P_o = n\,P_{inst} + floor[n/n_{tv}]\,p_{o\_unit}\,T_o + m\,p_{tr\_unit}\,T_{tr}$$

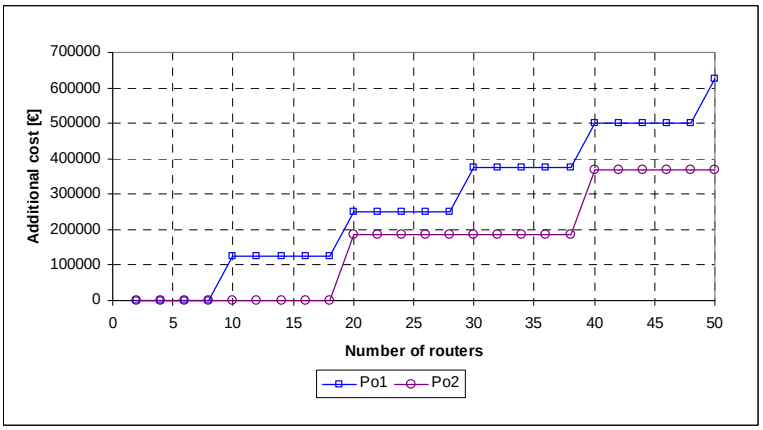
- n number of installed product units
- P_{inst} installation cost of one unit of a product
- n_{tv} indicates number of product units that triggers jump in the workload
- p_{o_unit} cost to operate n_{tv} units of a product for duration of one time unit
- T_o gives the observation period in the given time units (e.g. a month or a year)
- m number of trainees
- p_{tr_unit} known trainee cost per time unit
- T_{tr} training period in the given time units

Example Opex increase as a function of the number of additional routers



	n_{tv}	p_{o_unit} [€]	$T_o = T_{tr}$ [months]	p_{tr_unit}	P_{inst}
P_o1	10	10 000	12	5 000	0
P_o2	20	10 000	12	5 000	0

Example Opex increase as a function of the number of additional routers



	n_{tv}	p_{o_unit} [€]	$T_o = T_{tr}$ [months]	p_{tr_unit}	P_{inst}
P_o1	10	10 000	12	5 000	0
P_o2	20	15 000	12	5 000	0

Cost vs. dependability methods

Method	Capex increase	Opex increase	Note
Redundancy	**X**	**X**	Usually larger impact on Capex than Opex
Enhanced control	**x**	**X**	Usually minor impact on Capex and lager on Opex
Design activities	**-**	**-**	May require sharpening of processes
OAM activities	**x or X**	**x, X or X**	Cost effect is activity dependant - may have substantial or minimal effect on Capex and Opex
Purchasing activities	**-**	**-**	May require sharpening of processes
Network topology	**- or X**	**X**	Logical topology method usually increases only Opex, physical topology method has large impact on Capex
Location of network facilities	**x, X or X**	**X**	May have substantial effect on Capex
Agreements	**-**	**X**	Opex increase caused by highly-paid personnel
Lessons learned from the history	**x**	**x**	Minor effect on Capex or Opex
Alternative technology	**X**	**X**	Highest Capex and Opex increase in short time-scale

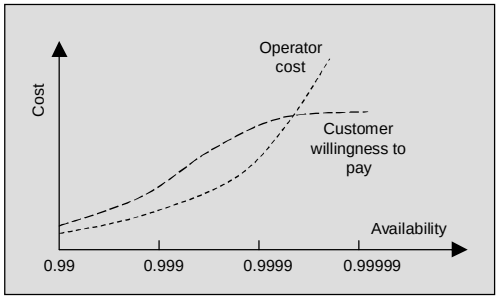
X substantial effect x minor effect
X moderate effect - negligible effect

Concluding remarks

- Financial impact of the different enhancement methods assessed only based on the expenses caused by them
- Pay-back time or benefits of the different methods to the operator's business are not discussed
- More information on the real operator business is needed to evaluate the entire financial effects of the different methods
- One objective could be to find out which enhancement methods offer the best "cost-to-dependability increase" ratio
- This information could be used in giving preferences to the methods when selecting them for practical use

Future directions

- Closer analysis of some dependability methods, e.g. redundancy and topology methods
- Objective to obtain understanding of general business dimension of dependability



Future directions (cont.)

- Marked Point Process is a standard way to model risks and costs in insurance business
- Objective is to model revenue loss of an operator due to failures (that cause loss of availability => sanctions, customer churn)