Migration Planning for Optical Backbone Networks

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Agenda

1. Introduction
   - Project 100Get
   - Optical core networks
   - Techno economics
   - Migration

2. Migration/Planning Approaches
   - Traffic model
   - Cost model
   - ILP
   - Heuristics
   - Grooming

3. Results
   - Utilization
   - Performance
   - Publications

4. Summary
Introduction
Project 100Get-E3

- EUREKA-Initiative CELTIC (Cooperation for a sustained European Leadership in Telecommunications)
- 100 Gbit/s Carrier-Grade Ethernet Transport Technologies (100GET)
- NSN guided project part "End-to-End Ethernet (E3)"
- TUD-TK contribution
  - Network technology migration
  - Multicast resilience
- Sponsors

Bundesministerium für Bildung und Forschung
Nokia Siemens Networks

- Partners
Optical core networks

- Transport network between cities or countries
- Usually SDH, combined with MPLS
- DWDM technology

- In Germany:
  - Biggest provider DTAG
  - 74 core POP in Germany

- Metro networks connected to backbone
- Access networks connected to metro
Technoeconomics

“Calculation where in a production chain [net planning] technical innovation will bring significant cost-savings or return of investment”

- Usually working with cost functions
- Considering:
  - CAPEX
    - Cost for device introduction
  - OPEX
    - Cost to operate the device
  - IMPEX
    - Cost of software implementation
  - Models for price development
  - Models for penalty
Migration

- Transformation from an “old” network into a “new”
- Our case: IP/MPLS/SDH/WDM → IP/MPLS-TP/ETH/OTN

Questions:
- Why migration?
  - Cost reduction
  - Energy reduction
- How to migrate cost optimal?
  - Node and link order
  - Different layers
  - Constraints
  - Time
- Possible approaches
  - Exact vs. heuristic
  - Single vs. multi layer
  - Incremental vs. all period
Migration

- Current reference scenario
  - IP/MPLS/SDH/DWDM
- Evolutionary scenario
  - IP/MPLS-TP/ETH/OTN

- Expected transition of demands from IP to ETH
- WSS-OXC with defined AD-ratio
Single layer migration
Multi layer migration

Step 0

IP layer

Transport layer

Step 1

Ethernet layer
Multi period migration

- Incremental planning ("worst" case)
- All period planning (best case)
Migration/Planning Approaches

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### Phases

#### Planning of Greenfield networks (start/end)
- ILP system description (CPLEX, AMPL)
- Constraint definition
- System model definition

#### Calculation of optimal migration steps
- Heuristic approach for global optimum (change order)
- Calculate cost optimal step (local optimum)

**Calculate routing**
- Shortest path, load distribution, ...
- Grooming, wavelength and fiber distribution, ...

**Calculate migration order**
- According to constraint i.e. IP Transit Traffic
- Using meta heuristic (GRASP, ACO, ...)

**Calculate migration characteristic**
- Using traffic model, system model, ...
- Migration doctrine (granularity, oversize)

#### Presentation of migration results

<table>
<thead>
<tr>
<th>Import/Export</th>
<th>Visualization</th>
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<tbody>
<tr>
<td>Interface from Mig.-Alg.</td>
<td>Migration order (time)</td>
</tr>
<tr>
<td>Interface from Greenfield (AMPL)</td>
<td>Algorithm economic performance</td>
</tr>
<tr>
<td>Algorithm control</td>
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</table>
Current migration approach

- Cost efficient insertion of OXCs (Single layer migration)
  - Describe start/end backbone → System model
  - Calculate demands → Traffic model
  - Calculate costs → Cost model for CAPEX, OPEX, IMPEX
  - Calculate realistic reference network → ILP
  - Find most interesting migration nodes → Routing, Grooming
  - Make heuristic approach for optimal costs → GRASP, ACO
  - Budgeting → Dept redemption
  - Visualize results → GUI
Traffic model

- Reference German 17 node backbone network
- Demand creation calculated through population density
  - Currently: Layer 3 demands
  - Todo: Layer 2 demands
- Directions via assumptions
- Increase 40% per year

$$TF(y) = 1.4^y$$

- Currently no directional changes
Cost model

- **CAPEX cost model**
  - According to Nobel2-Project
  - Cost erosion 20% reduce per device per year

- **IMPEX cost model**
  - Complicated to model due to:
    - Travelling costs
    - Extra charges (i.e. holidays)
    - Penalty fee
  - Simplify: 20% of (initial) CAPEX of node +10% every year

- **OPEX cost model**
  - Complicated to model due to:
    - Energy/Cooling costs
    - Security costs
    - Rental costs
  - Simplify: 2% of (initial) CAPEX of node
Cost model - IP/MPLS CAPEX

• Every node:
  • Basic node 640 GBit/s (16 Slots): 16.67 CU
  • Slot card 40 GBit/s: 9.17 CU
    ▪ Filled depending on traffic
    ▪ (4x) Port card 4x STM16, LR (1550nm, 80km): (4x) 6.67 CU

• Example:
  • IP Router (max 40 GBit/s throughput) costs:
    \[ C[CU] = 16.67 + 9.17 + 4 \times 6.67 = 52.52 \text{ CU} \]

• 1 CU == costs for 10G WDM Transponder

\[
C_{\text{IP-Router}} = C_{\text{Basic-Node}} + C_{\text{Slotcard}} \cdot N_{\text{Slots}} + \sum_{K} C_{\text{Port}}^{K} \cdot N_{\text{Port}}^{K}
\]
Reference network generation - ILP

- Find appropriate start (and final) network
  - Give Locations
  - Give Demands
  - Give (possible) Edges
- Searched: Dimensions
  - For minimal costs
  - For working network
  - With given constraints

Problem formulation
Mathematical model

Make AMPL formulation with model and data

Find a relaxation with CPLEX

Find integer problems with CPLEX

Solution
Migration heuristics

- **Selective randomized search heuristic (SRSH)**
  - Simple hardware insertion scheme
  - Follows predefined constraints

- **Ant colony optimization (ACO)**
  - Device granularities as possible states
  - Partial deviation from initial path
  - Best results to elite pool
  - What is most cost efficient granularity set

- **Greedy randomized adaptive search procedure (GRASP)**
  - Delivers potential migration order
  - Construction phase
  - Local search phase
  - (ev.) Path relinking
Migration heuristics SPP - ACO

Minimize Calculation time (CNF)

Total migration costs

STEP 4

STEP 3

STEP 2

STEP 1

G1 (OXC) G2 G3

G1 (IPR) G2 G3

Initial random path

Ant follow path

Add or replace better results

Elite pool

Actualize pheromone trails

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Grooming – Future Perspective

2 * K_{demand} < Ch_{capacity}

• **Link-by-Link Grooming**

  Requirements:
  IP: 6 * K_{demand} interface cards
  Phy: 1 wavelengths

• **End-to-End Grooming**

  Requirements:
  IP: 4 * K_{demand} interface cards
  Phy: 2 wavelengths + 1 OXC

• **Traffic Grooming**

  Requirements:
  IP: 4 * K_{demand} interface cards
  Phy: 1 wavelengths + 1 OXC
Grooming – Future Perspective

Grooming

Cost    Energy    Impairment    TE/QoS    Resilience

Energy Costs

Lambda set

Migration decision

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Migration Planning for Optical Backbone Networks

Slide 22
Results
Results – Resource utilization

Component expenses per step:
- CAPEX
- OPEX
- IMPEX

CAPEX per step:
- Optical basic node (OPBN)
- IP basic node (IPBN)
- IP port card (IPPC)

to be published ...
Results – Algorithm performance

Integral CAPEX per node:
- Optical basic node (OPBN)
- IP basic node (IPBN)
- IP port card (IPPC)

Algorithm result improvement:
- ACO
- Selective random

...to be published...
Results – Scientific publications


Summary
Project progress

- Tasks done:
  - Network topology definition for GER17 and EUR67
  - Routing: 3 grooming algorithms (SH,MH,CO)
  - Sorting: IP transit traffic
  - Sorting: GRASP, PR, ev. PR
  - Hardware insertion doctrine (OXCs and IPRs)
    - Randomly selective
    - ACO, GRASP

- Future work to be done or under investigation:
  - Adaption of the GRASP to real network situations
  - Improvement of current routing strategy
    - Implementation of intelligent grooming
  - Improvement of current hardware insertion
    - Forecasting (All-Period-Planning)
    - Granularity
    - Layer-2 devices
  - Introduction of Layer-2 demands
    - Change of traffic model
  - ...
References

[Ble] Bley, Andreas: “Multi layer network design a model based optimization approach”
[Ver] Verbrugge, Sofie: “Strategic Planning of Optical Telecommunication Networks in a Dynamic and Uncertain Environment”
[Ve2] Verbrugge, Sofie: “Capex comparision between link-by-link and end-to-end grooming in a European backbone network”

Student work:
[Gan] Gang, He: „Conception and visualization of network migration processes”
[Lar] Larrañaga, Javier: “Investigation of traffic grooming in optical backbone networks”
[Loz] Lozano, Paloma: „Design of IP over WDM planning algorithms using ILP”
Thanks !!