Adapative Bandwidth Allocation (ABA): Efficient Traffic Engineering with Admission-Controlled Capacity Tunnels
Outline

▷ Overview
  - Static bandwidth allocation (SBA)
  - Adaptive bandwidth allocation (ABA)
    - Complete capacity reassignment (CCR)
    - Selective capacity reassignment (SCR)
▷ Bandwidth savings potential of ABA
  - With opportunistic traffic model
  - With various dynamic traffic models
  - Comparison of capacity requirements
    - Bandwidth savings of ABA vs. SBA
    - Link specific analysis
▷ Conclusion
Problemstellung

- (Virtual) capacity tunnels used for traffic engineering
  - Border-to-border budgets for network admission control (KING)
  - General tunnels, e.g. label switched paths (LSPs) in (G)MPLS

- **Problem**: Adequate tunnel sizes required for **changing traffic aggregates**

- Static bandwidth allocation (**SBA**): Tunnel capacity dimensioned statically for busy hours

- Adaptive bandwidth allocation (**ABA**): Tunnel capacity adapted dynamically to current demand

**Fig**: Border-2-border budget based network admission control
Mechanisms for Adaptive Bandwidth Allocation

Complete capacity reassignment (CCR)
- Measurements for all b2b traffic aggregates
- Redimensioning and reconfiguration of all tunnels
- Entire network capacity assigned to tunnels
- Triggers for CCR:
  - In regular time intervals
  - In case of significantly changed offered load (tolerance interval for tunnel blocking probability)

Selective capacity reassignment (SCR)
- Measurements for all b2b traffic aggregates
- Redimensioning and reconfiguration of necessary tunnels
- Parts of the network capacity retained in free resource pool (FRP)
- Trigger for SCR:
  - In case of significantly changed offered load (tolerance interval)

Simple to implement but high processing/signalling overhead
Less provisioning overhead but more complex implementation
KING Test Network for Opportunistic Traffic Model

Fig: Network topology of the KING test network

Tab: City population in the KING network

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Opportunistic Traffic Model

▷ Traffic matrix construction proportional to city population

▷ Traffic matrix scaled by average b2b offered load $a_{b2b}$

▷ Overall offered load $a_{tot}$ identical for SBA / ABA comparison

▷ Opportunistic Traffic:
  - Complementary oscillating b2b aggregate rates on each link
  - Constant cumulated aggregate rate on each link
  - Maximum bandwidth savings of 50% possible
Capacity Dimensioning for SBA / ABA

- **Capacity Dimensioning for SBA**
  - Time-independent traffic matrix $A_{\text{max}}$ containing peak aggregate rates
  - Time-independent required link capacities $c_l$
  - Calculation of overall required network capacity
    \[
    C^{\text{SBA}} = \sum_l c_l
    \]

- **Capacity Dimensioning for ABA**
  - Reoptimization of capacity tunnels every 5 minutes
  - Multiple, time-dependent traffic matrices $A(t)$
  - Multiple, time-dependent required link capacities $c_l(t)$
  - Calculation of overall required network capacity
    \[
    C^{\text{ABA}} = \sum_l \max_t (c_l(t))
    \]
Bandwidth Savings with Opportunistic Traffic Model

- Bandwidth savings depend on offered load
- Small capacities on average less utilized
- Large capacities on average better utilized
- Bandwidth savings increases with tunnel capacities
  → Economy of scale

**Fig:** Bandwidth requirements for SBA / ABA
Test Network for Dynamic Traffic Model

Fig: Network topology, population, and timezones of a world-wide test network
Node Activity Model

- B2b aggregate oscillations based on **ACTIVE** population
  - Not strictly opportunistic
  - Produced / consumed traffic increases with growing active population
  - Traffic oscillation according to **24h node activity model**

![Graph showing node activity over 24 hours]

**Fig:** Node activity over 24 hours
Dynamic Traffic Models

Different traffic models according to correlation with node activity

- Linearity to Provider Activity (LPA)
  - Aggregate rates scale linearly to corresponding provider activity
  - Interpretation: client – server apps. (client push, e.g. backup)

- Linearity to Consumer Activity (LCA)
  - Aggregate rates scale linearly to corresponding consumer activity
  - Interpretation: client – server apps. (client pull, e.g. web)

- Linearity to Provide and Consumer Activity (LPCA)
  - Aggregate rates scale linearly to corresponding provider and consumer activities
  - Interpretation: peer-to-peer apps.

Similarity of LPA and LCA model
Bandwidth Savings with Dynamic Traffic Models

Fig: Bandwidth savings with dynamic traffic models

- Aggregation level with less impact on bandwidth savings
- Almost no (~2%) bandwidth savings for LCA model
- ~18% bandwidth savings for LPCA model
Fig: Time-dependent link capacity requirements

- Constant capacity requirements for SBA
- Strongly oscillating capacity requirements for ABA
- LCA: almost no bandwidth savings with ABA
- LPCA: ~50% bandwidth savings with ABA
- Busy hours of aggregates occur at different times
Link Analysis Bangkok → Beijing (16 Aggregates)

- Busy hour of LPCA shorter than LCA
- Busy hours of aggregates occur at the same time
- Almost identical capacity requirements for ABA and SBA
- No bandwidth savings possible on this link

Fig: Time-dependent link capacity requirements
Conclusions

- Virtual tunnels used for traffic engineering
  - b2b budget network admission control (KING)
  - General tunnels, e.g. LSPs in (G)MPLS

- Bandwidth allocation strategies
  - Static and adaptive bandwidth allocation (SBA, ABA)
  - ABA mechanisms: CCR and SCR

- Investigation of the bandwidth savings potential
  - Savings of ABA vs. SBA depend on traffic model
  - Opportunistic traffic model: savings increase with offered load
  - Dynamic traffic model: 2% for LCA and 18% for LPCA
  - Savings on links depend on traffic composition
  - Savings can be increased by suitable time-aware routing/load balancing