UNIVERSITÄT PADERBORN
Die Universität der Informationsgesellschaft

Computer Networks Group

Optimizing Energy Efficiency in Bulk Transfer Networks

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Problem Statement

Given a network and a set of bulk transfers (instead of flows),

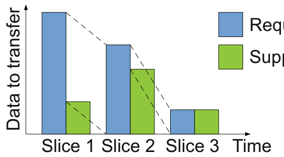
what is the most energy-efficient route for the bulk transfers?

Background

Comparing Bulk Transfers to Flows

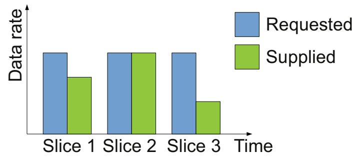
Bulk transfers

- Model for large amounts of data (e.g. CDN)
- Specify amount of data to transmit
- Done after predefined amount of data has been transmitted



Flows

- Model for streams or aggregation of many small transfers
- Specify required data rate
- Continue for an unknown time



Slices of time

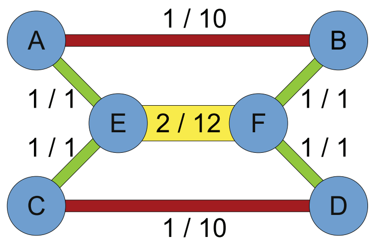
- Needed to optimize energy efficiency using mixed integer programming
- Constant data rate in a single slice
- A bulk transfer can take several slices to finish

Assumption

Network hardware can be disabled to conserve energy

Model – Definition of the Network and Bulk Transfers

Network Graph



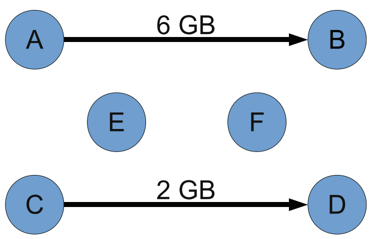
Bandwidth (width) [GB/slice] / Energy Consumption (color) [J/slice]

Undirected graph
$G=(V,E)$

Capacity of edges
$c: E \to \mathbb{Q}$

Energy consumption of edges
$\varepsilon: E \to \mathbb{Q}$

Requested Bulk Transfers

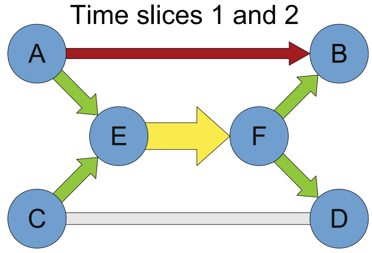


Set of bulk transfers: B

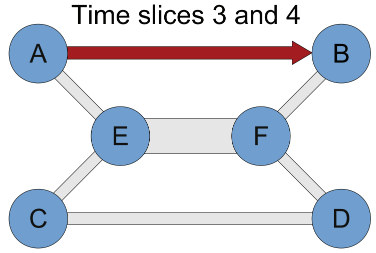
$\forall b \in B$: Source $s_b \in V$, Destination $d_b \in V$, Transfer size $a_b \in \mathbb{Q}$

Solution – Finding Routes with Optimal Energy Efficiency using MIP

Time slices 1 and 2



Time slices 3 and 4



Optimal solution needs multi-path routing!

Minimize $\sum_{t\in T}\sum_{e\in E} x^t(e)\,\varepsilon(e)$ (total enery consumption)

Where $x^t(e)=\begin{cases}0, & \text{if } \forall b\in B: f_b^t(e)=0\\ 1 & \textit{else}\end{cases}$ (edge activity)

T set of needed slices

$f_b^t: E\to\mathbb{Q}$ (flow transmitted for $b\in B, t\in T$)

With flow constraints:

$\forall t\in T, e\in E: \sum_{b\in B} max(0, f_b^t(e)) \le c(e)$ (capacity constraint, full duplex)

$\forall b\in B, t\in T, (u,v)\in E: f_b^t((u,v)) = -f_b^t((v,u))$ (skew symmetry)

$\forall b\in B, t\in T, u\in V\setminus\{s_b,d_b\}: \sum_{v\in N(u)} f_b^t((u,v))=0$ (flow conservation)

$\forall b\in B: \sum_{t\in T}\sum_{v\in N(s_b)} f_b^t((s_b,v)) = a_b$ (complete transfer)

(with $N(v)$ being the set of vertices incident to v)

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