OPS/OBS Scheduling Algorithms: Incorporating a Wavelength Conversion Cost in the Performance Analysis

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Overview presentation

- The optical backbone
- Contention resolution & scheduling basics
- Scheduling algorithms
- Performance results
- Energy consumption results
- Conclusions

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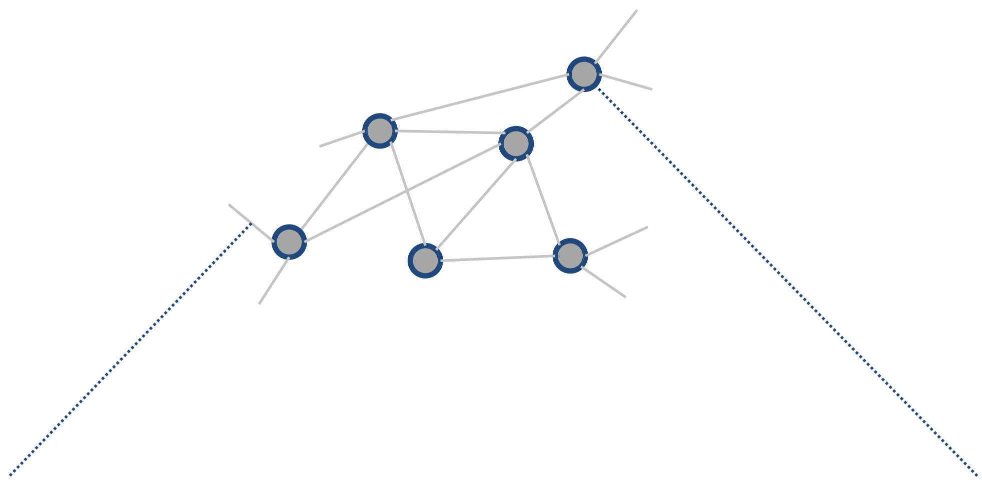
The optical backbone

technological developments &
internet-based business models ⇒ demand for bandwidth ↗



connections

links

optical fibers

‘unlimited’ capacity

intersections

nodes

switches

bottleneck

Introduction: the optical backbone

Currently: circuit switching

- dedicated communication channel

✓ guaranteed packet arrival

✓ fixed delay

✗ inefficient use of available fiber capacity (bandwidth)

Future: packet-based switching

- shared links

✓ improved usage of capacity

- contention possible
  - → ✗ potentially, packet loss
  - → ✗ no fixed delay
  - → ✗ potentially, substantial delay

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main motivation of this work: improving contention resolution

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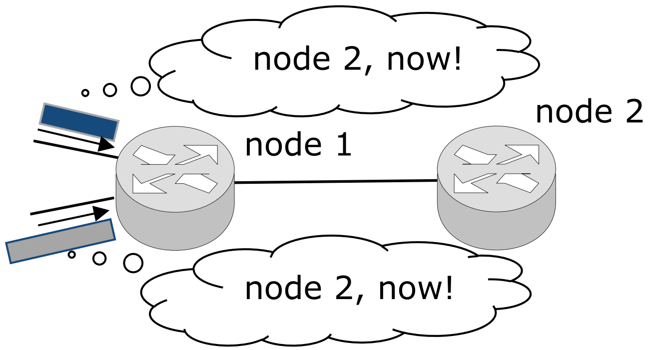
Contention & resolution

contention:



straightforward solution: electronic buffering (RAM)

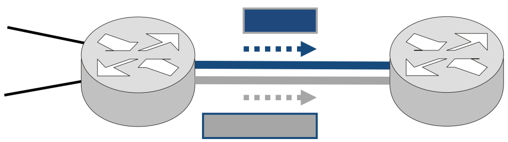
- cannot keep up with optical speeds
- energy consuming O/E/O conversions

⇨ **optical contention resolution**

Optical contention resolution: two means

1

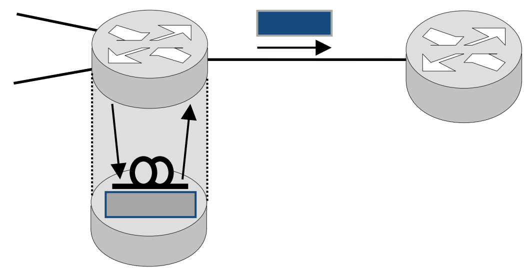
wavelength converters (WCs)



- c wavelengths
- unlimited wavelength conversion capacity
- energy consuming

2

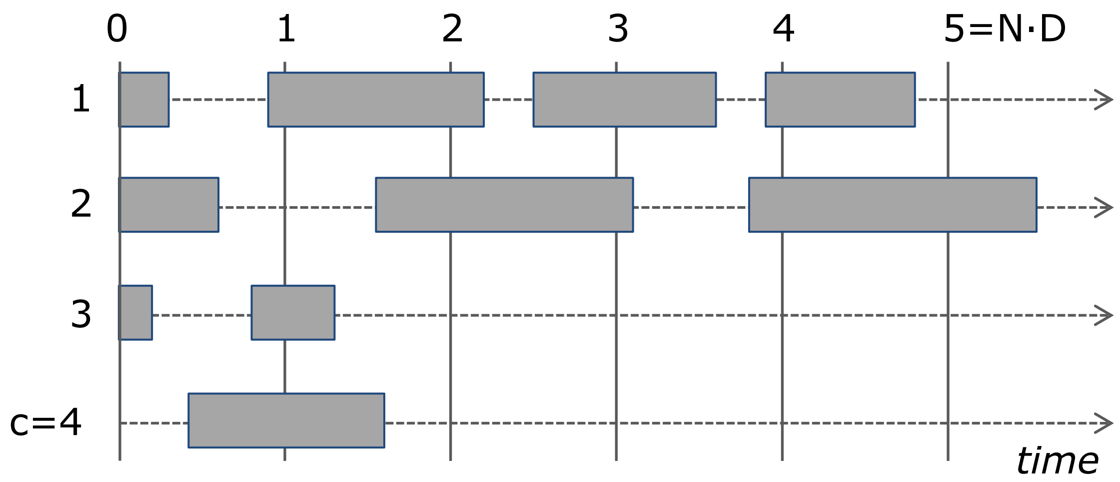
Fiber Delay Lines (FDLs)



- set of fibers, #=N+1
- lengths j·D, j=0…N
- N= buffer size
- D= granularity

Provisional schedule

wavelength conversion + Fiber Delay Lines ⇨ **provisional schedule**



- shows already scheduled packets
- updated at every arrival
- horizontal lines (dotted): outgoing wavelengths (c=4)
- vertical lines: delays of FDLs (N=5, D=1)

Schedule for minimal loss

SCHEDULING

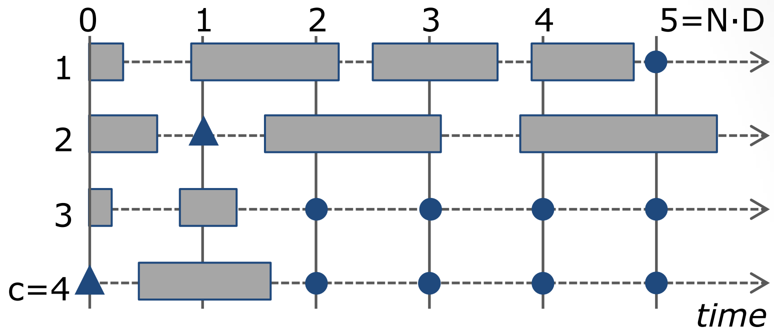
choose:

- outgoing wavelength i (i=1…c)
- delay line j (j=0…N)

constraints:

- no overlap
- type of algorithm
  - non-void-filling (NVF) ●
  - void-filling (VF) ● + ▲

satisfied: Scheduling Points (SPs)



goal:

minimize loss probability (LP)

choose SP "wisely"

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Scheduling algorithms: current

- **JSQ**(-NVF) ⓐ

join the shortest queue

=wavelength with shortest horizon

- **D-G**(-NVF) ⓑ

first priority: minimum delay

second priority: minimum gap

- **G-D**(-NVF) ⓒ

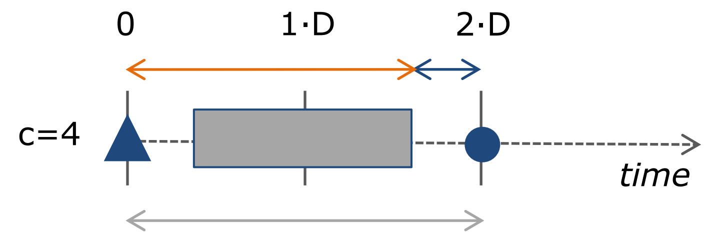
first priority: minimum gap

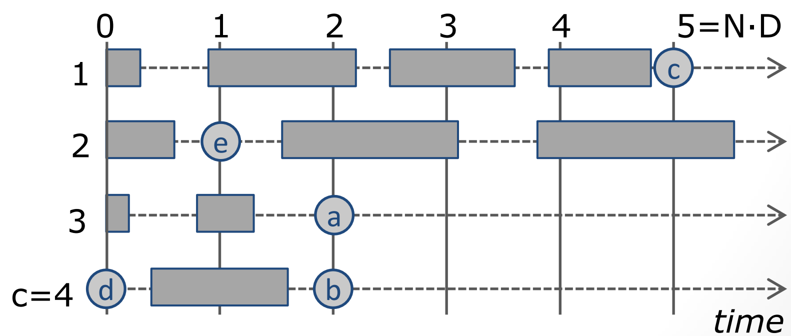
second priority: minimum delay

- **D-G-VF** ⓓ packet lenght ≤ 0,4
  ⓔ 0,4 < packet length ≤ 0,6
  ⓑ packet length > 0,6

- **G-D-VF** ⓓ packet length ≤ 0,4
  ⓒ packet length > 0,4

	horizon (channel)	gap	delay
▲	1,6·D	0	0
●	1,6·D	0,4·D	2·D





Scheduling algorithms: new

- assign cost to each SP
- choose SP with lowest cost

2 cost functions

C**:** cost of SP taking into account gap and delay:

$$C = \alpha \cdot gap + (1 - \alpha) \cdot delay$$

CW**:** cost of SP taking into account gap, delay and wavelength conversion:

$$CW = \left(\frac{1}{1+\beta}\right)^{1-\delta_{wi}} \cdot [\alpha \cdot gap + (1 - \alpha) \cdot delay] + \frac{\beta}{1+\beta} \cdot D \cdot [1 - \delta_{wi}]$$

Scheduling algorithms: C

***C*:** cost of SP (gap and delay, not wavelenth conversion):

$$C = \alpha \cdot gap + (1 - \alpha) \cdot delay$$

- α: algorithm parameter to optimise for minimal loss probability
- weighted average of gap and delay
- MOTIVATION: propose algorithms with better performance

⇨ algorithms **C**(-NVF) and **C-VF**

Scheduling algorithms: *CW*

***CW*:** cost of SP (gap, delay and wavelength conversion):

$$CW = \left(\frac{1}{1+\beta}\right)^{1-\delta_{wi}} \cdot [\alpha \cdot gap + (1-\alpha) \cdot delay] + \frac{\beta}{1+\beta} \cdot D \cdot [1 - \delta_{wi}]$$

- α: algorithm parameter to optimise for minimal LP
- β: algorithm parameter to reduce wavelength conversion (~ energy consumption)
- i: outgoing wavelength, w: incoming wavelength, δ_{wi}: Kronecker's delta
- ≠ *C*, due to extra summand to penalise use of wavelength converter
- MOTIVATION: propose algorithms with reduced energy consumption

⇨ algorithms **CW**-(NVF) and **CW-VF**

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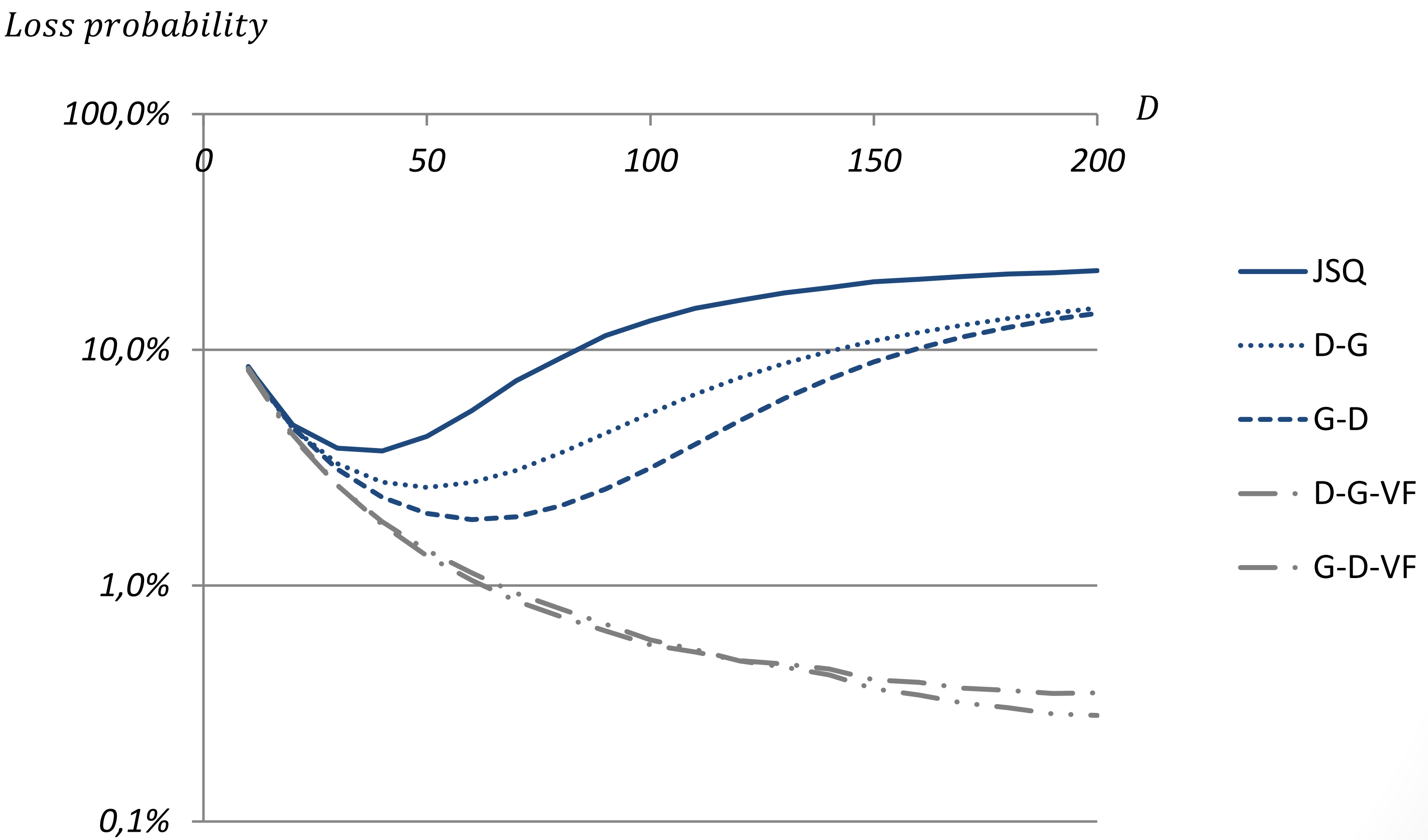
Performance results: assumptions

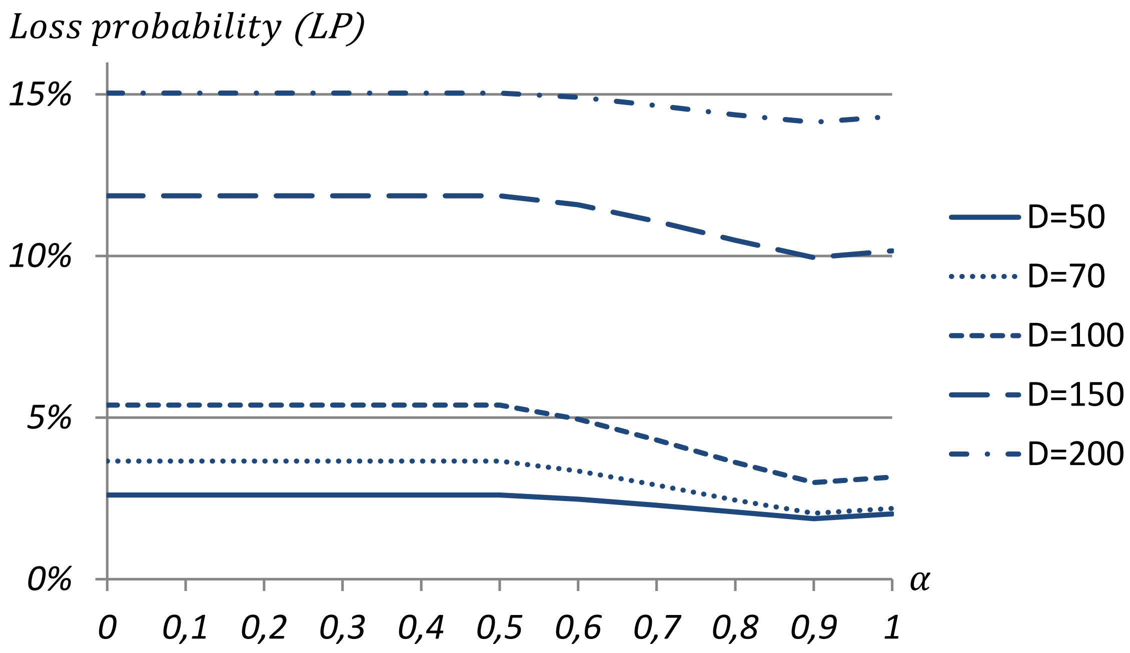
- **c** = # incoming wavelengths = # outgoing wavelengths = 4
- **N+1** = # Fiber Delay Lines = 10
- **inter-arrival time packets** = exponentially distributed, E[T]
- **packet size** = exponentially distributed, E[B]=100
- **arriving wavelength** = uniformly distributed
- **load** = $\rho = \frac{E[B]}{c \cdot E[T]} = 80\ \%$
- **D** = granularity = 10, 20, …, 200
- Monte Carlo simulation

Performance results: current algorithms



Performance results: C

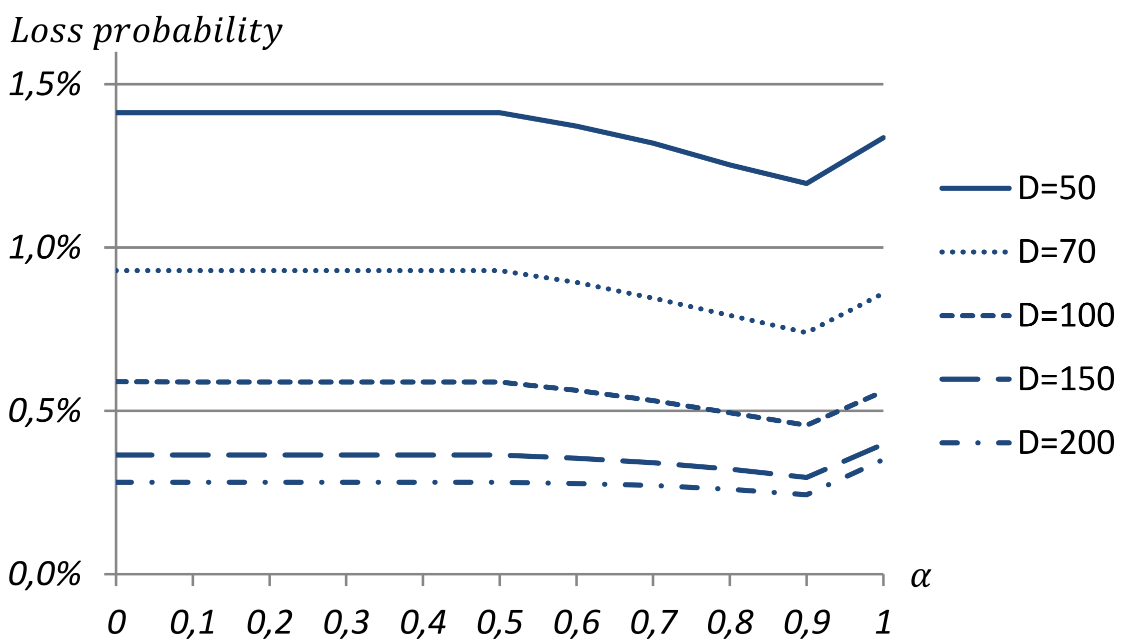
$$C = \alpha \cdot gap + (1-\alpha) \cdot delay$$



D	50	70	100	150	200
LP reduction (%)	7	7	5	2	1
α	0,9	0,9	0,9	0,9	0,9

Performance results: C-VF

$$C = \alpha \cdot gap + (1 - \alpha) \cdot delay$$



D	50	70	100	150	200
LP reduction (%)	15	21	23	19	14
α	0,9	0,9	0,9	0,9	0,9

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Energy consumption results

wavelength converters assumed only switched on when converting

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energy consumption $\sim$ payload converted packages

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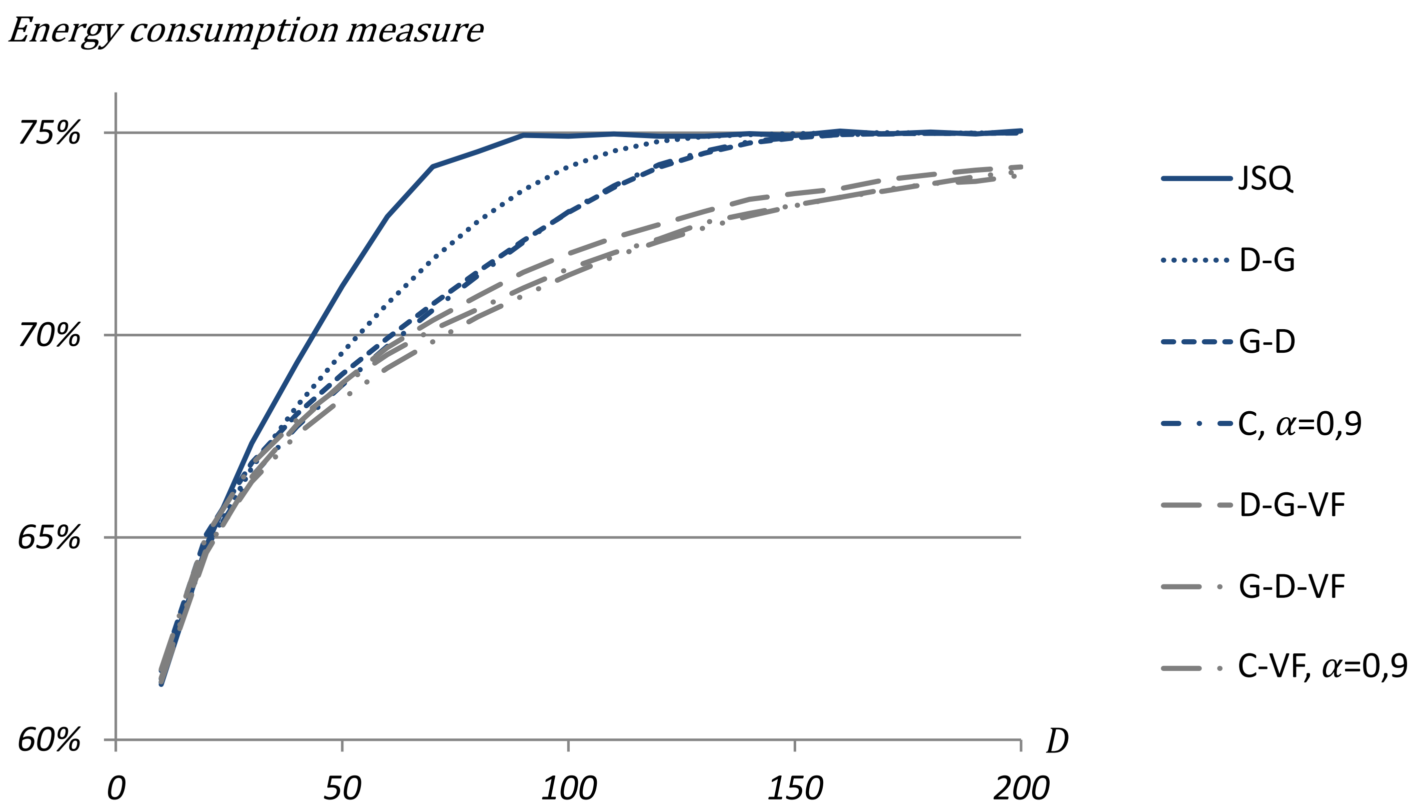
$$\textbf{energy consumption measure} = \frac{\text{payload converted packages}}{\text{payload packages not lost}}$$

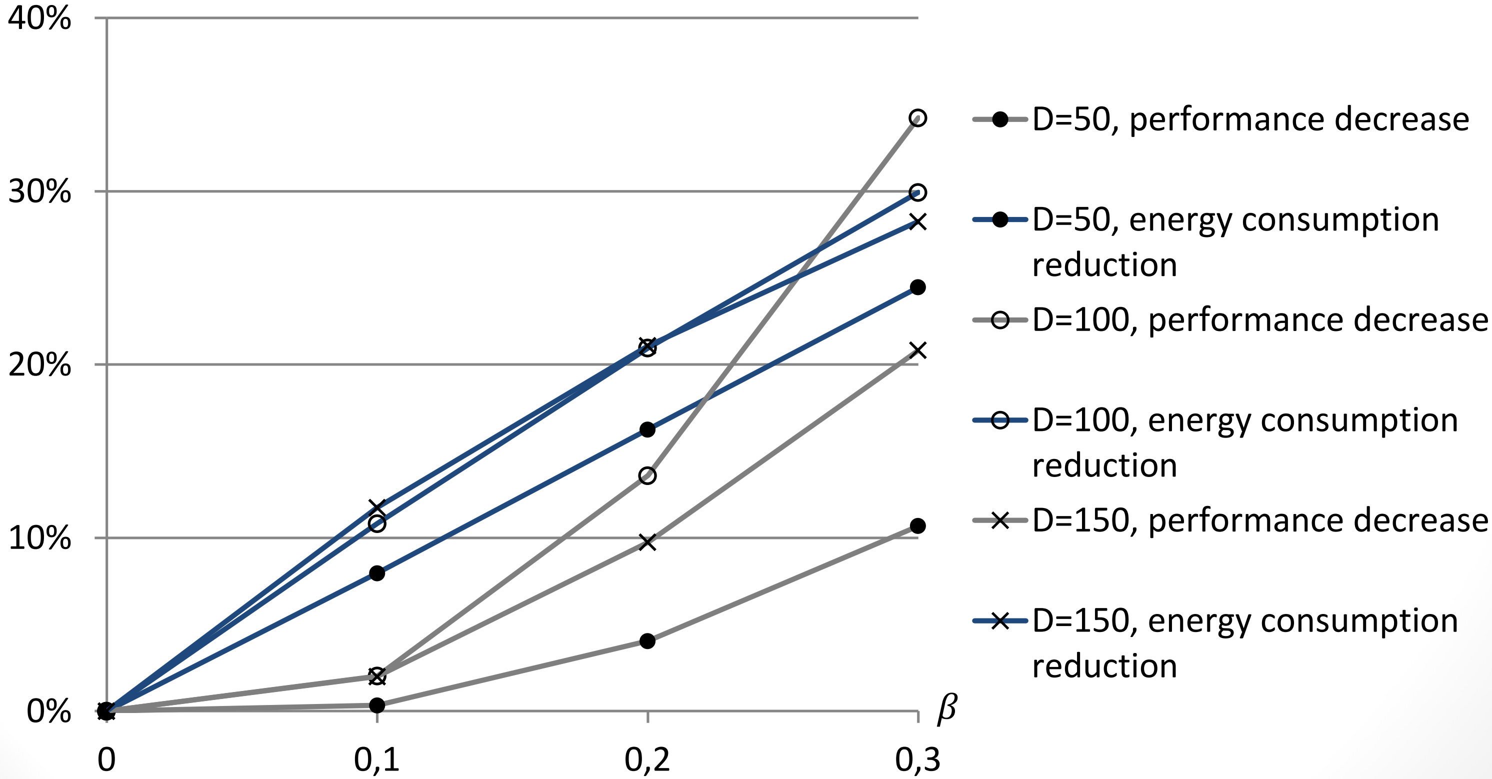
Energy consumption results



Energy consumption results: CW

$$CW = \left(\frac{1}{1+\beta}\right)^{1-\delta_{wi}} \cdot [\alpha \cdot gap + (1-\alpha) \cdot delay] + \frac{\beta}{1+\beta} \cdot D \cdot [1-\delta_{wi}]$$

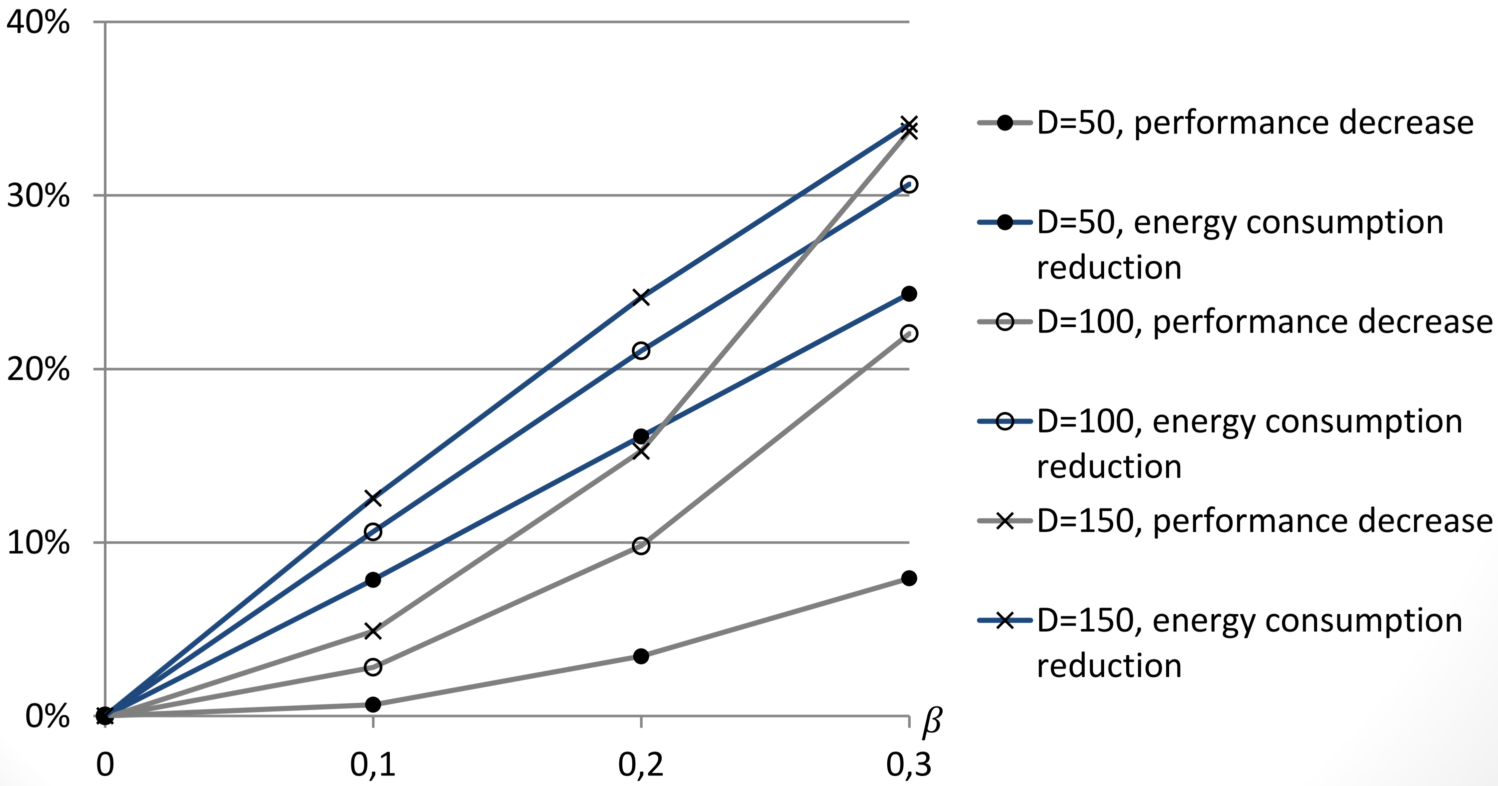
- $\alpha = 0{,}9$



Energy consumption results: CW-VF

$$CW = \left(\frac{1}{1+\beta}\right)^{1-\delta_{wi}} \cdot [\alpha \cdot gap + (1-\alpha) \cdot delay] + \frac{\beta}{1+\beta} \cdot D \cdot [1-\delta_{wi}]$$

- $\alpha = 0,9$



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Conclusions

cost based approach

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2 cost functions

C | *CW*

C:

- weighted average delay & gap
- α optimised
- C and C-VF algorithms
- improved performance

CW:

- weighted average delay & gap + penalty cost for using WC
- fixed optimal α, varying β
- CW and CW-VF algorithms
- improved performance tradeable for energy consumption reduction

Questions

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