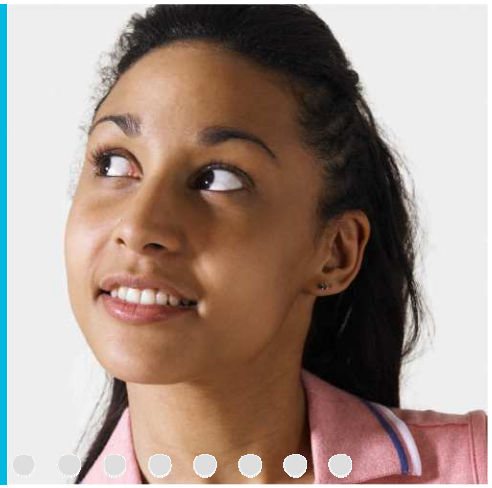
Optimized synergy between 10 Gb/s and 40 Gb/s channels on a partially transparent network



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Networks2008, Wednesday October 1st 2008, Budapest

Agenda

1. Network background
2. Synergy concept
3. Network hypotheses
4. Results
5. Conclusions

1 Network background

Network evolution

Two trends for future optical networks:

1. Transparency
   1. Increase of reach of optical systems
   2. Introduction of ROADM and OXC

   ✓ Reduction of systematic OEO devices

   ✓ Independence to signal characteristics
2. Introduction of higher bit rate
   1. Increase of foreseen traffic in the core network ✓ To decrease cost of the increase of transported information

As the system reach decreases when the bit rate increases, these two trends go in opposing directions

For the near future we can imagine:

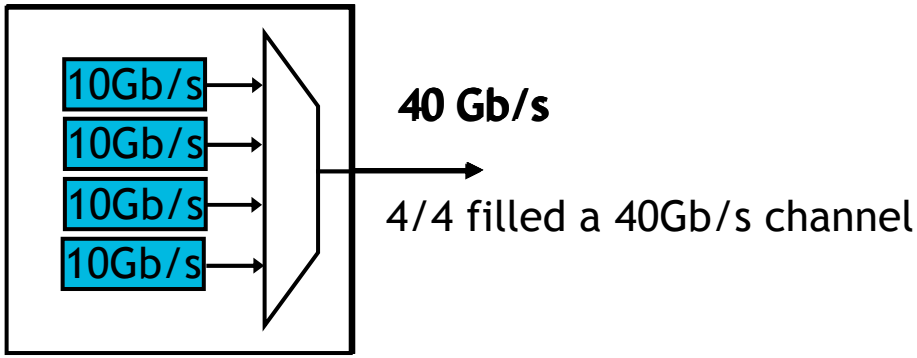
- Transparence = above all for 10 Gb/s
- High bit rate = 40 and 100 Gb/s

Coexistence of channels with different bit rates

2 Synergy concept

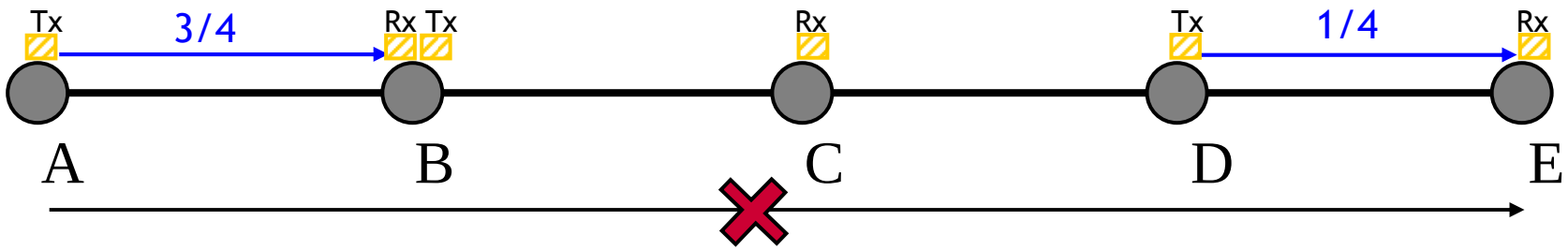
Hypothesis on the channel bit rate

- All incoming demands are at 10 Gb/s granularity
  - So a 10 Gb/s channel are all fully loaded
  - A 40 Gb/s channel is obtained by combining up to 4 signals at 10 Gb/s



- To investigate the interest of a better synergy between 10 Gb/s and 40 Gb/s resources:
  - Different traffic matrix loads and distributions are considered but always blocking for the reference case so that the need for 40 Gb/s transmissions is justified
  - We consider different number of 40 Gb/s channels per fiber (5 or 10)
  - The reference case is the translucent network with only 10 Gb/s channels

Context of the synergy (1)



Rx Tx = 1 OEO device

10 Gb/s transparent connection

40 Gb/s connection already lighted-up but not fully loaded

40 Gb/s OEO already into service

Envisaged 10 Gb/s OEO

Transparent connection between ‘A’-‘E’ at 10 Gb/s not feasible because:

- Too harmful physical impairments
- Wavelength contention

An wavelength-tunable transponder (OEO devices) is required to enable the connection

3 possible OEO placements:

Context of the synergy (2)

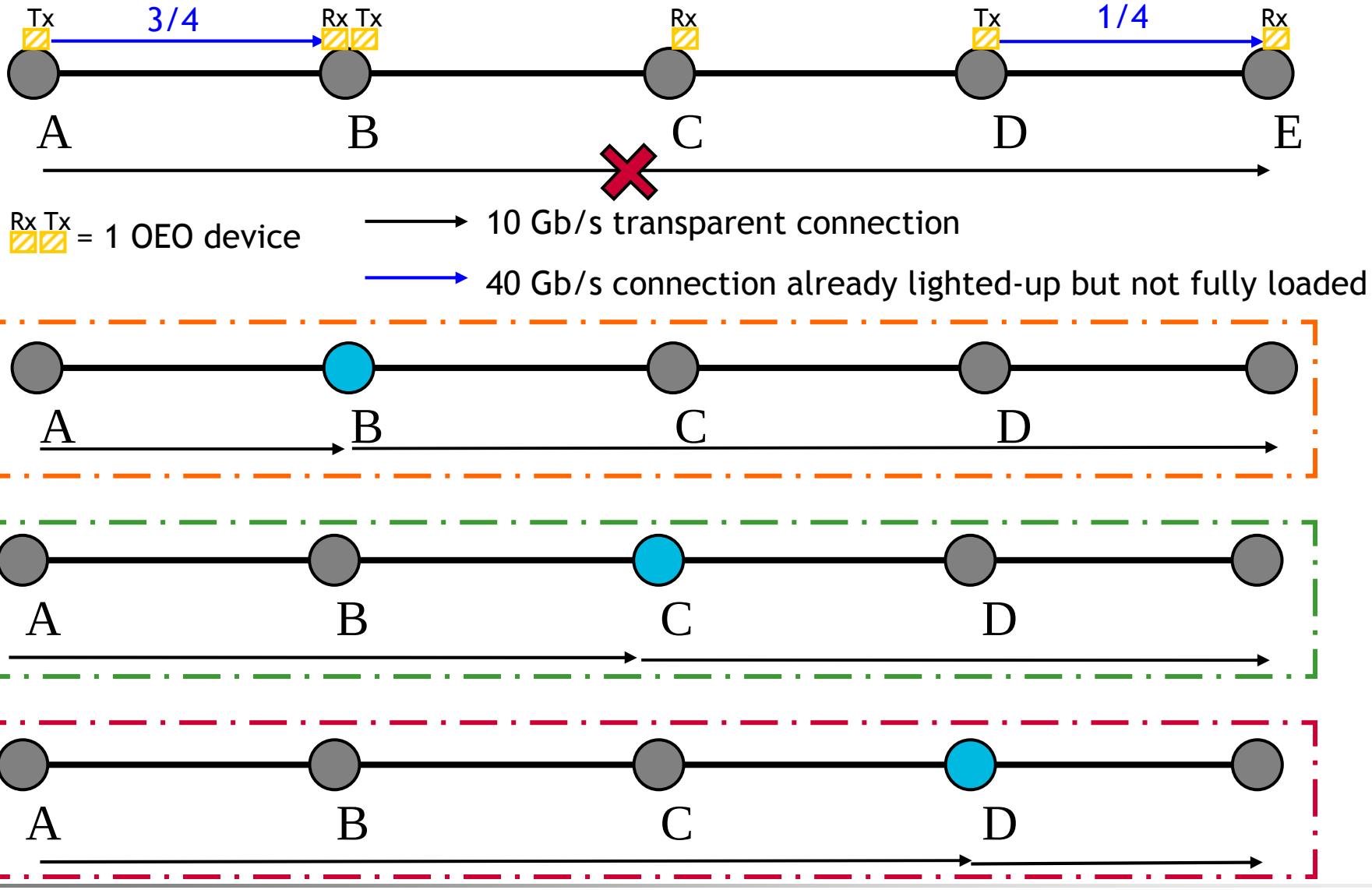


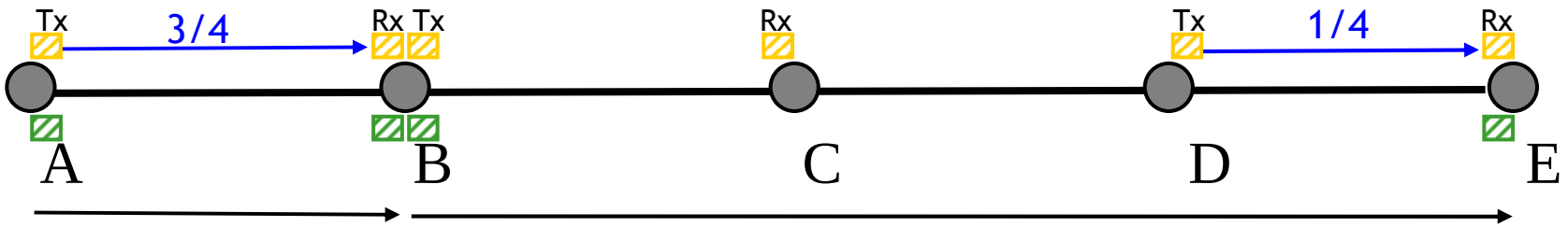
Illustration of the synergy (1)

Our idea of *Synergy* consists in using available capacity in 40 Gb/s channels to transport part of the 10 Gb/s connections that cannot reach destination transparently

Aim: minimize the total number of 10Gb/s and 40Gb/s transponders (OEO device)

Rx Tx = 1 OEO device

40 Gb/s OEO already into service
Envisaged 10 Gb/s OEO



Number of occupied transponders in case of no synergy

Before 10Gb/s OEO placement

10 Gb/s OEO	40 Gb/s OEO
0	2

After 1st OEO placement

10 Gb/s OEO	40 Gb/s OEO
2	2

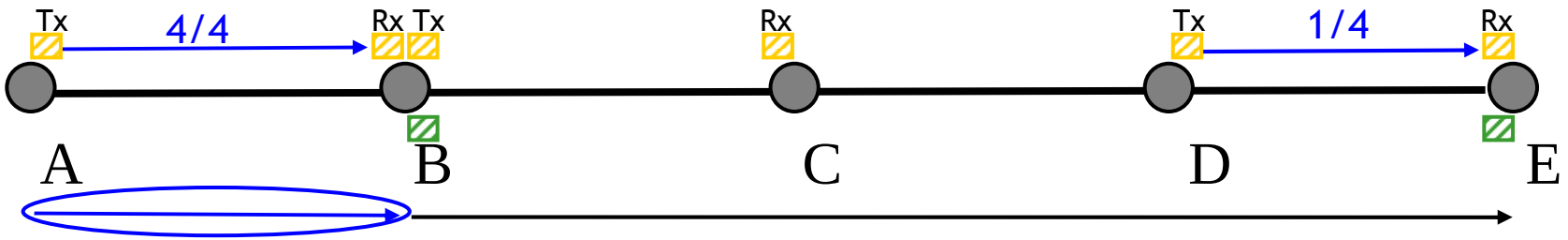
Illustration of the synergy (2)

Our idea of *Synergy* consists in using available capacity in 40 Gb/s channels to transport part of the 10 Gb/s connections that cannot reach destination transparently

Aim: minimize the total number of 10Gb/s and 40Gb/s transponders (OEO device)

Rx Tx = 1 OEO device

40 Gb/s OEO already into service
Envisaged 10 Gb/s OEO



Number of occupied transponders in case of synergy

Before OEO placement

10 Gb/s OEO	40 Gb/s OEO
0	2

After 2st OEO placement

10 Gb/s OEO	40 Gb/s OEO
1	2

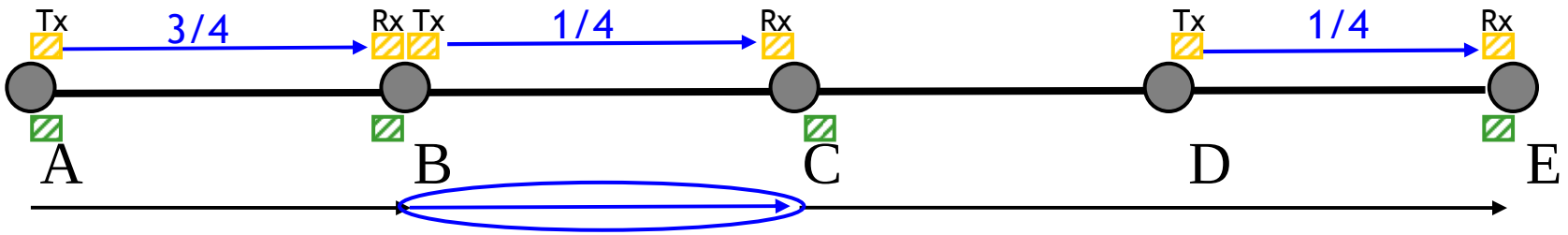
Illustration of the synergy (3)

Our idea of *Synergy* consists in using available capacity in 40 Gb/s channels to transport part of the 10 Gb/s connections that cannot reach destination transparently

Aim: minimize the total number of 10Gb/s and 40Gb/s transponders (OEO device)

Rx Tx = 1 OEO device

40 Gb/s OEO already into service
Envisaged 10 Gb/s OEO



Previous OEO placement

10 Gb/s OEO	40 Gb/s OEO
1	2

New OEO placement

10 Gb/s OEO	40 Gb/s OEO
2	3

… and so on, testing different 10/40 Gb/s combinations

Illustration of the synergy (4)

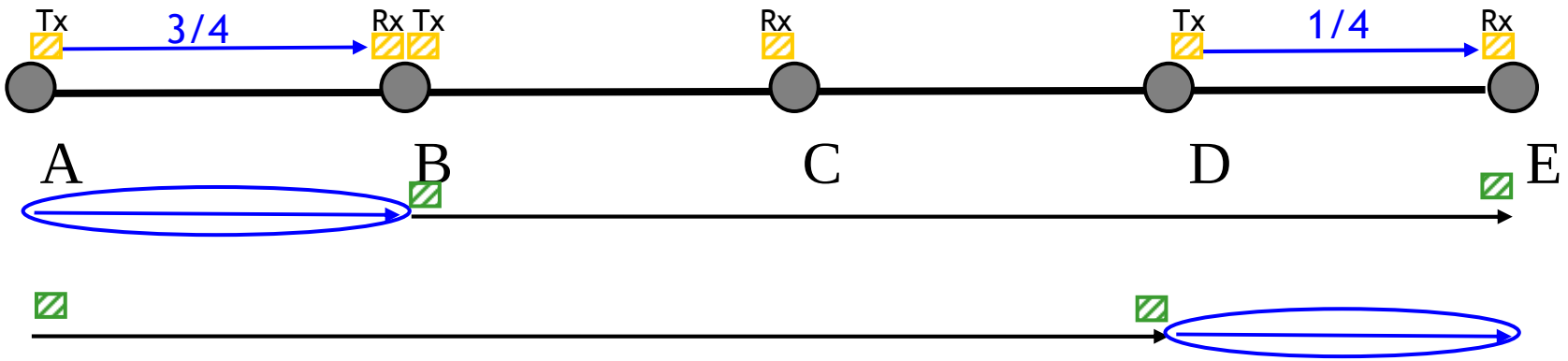
Our idea of *Synergy* consists in using available capacity in 40 Gb/s channels to transport part of the 10 Gb/s connections that cannot reach destination transparently

Aim: minimize the total number of 10Gb/s and 40Gb/s transponders (OEO device)

Rx Tx = 1 OEO device

40 Gb/s OEO already into service

Envisaged 10 Gb/s OEO



10 Gb/s OEO	40 Gb/s OEO
1	2

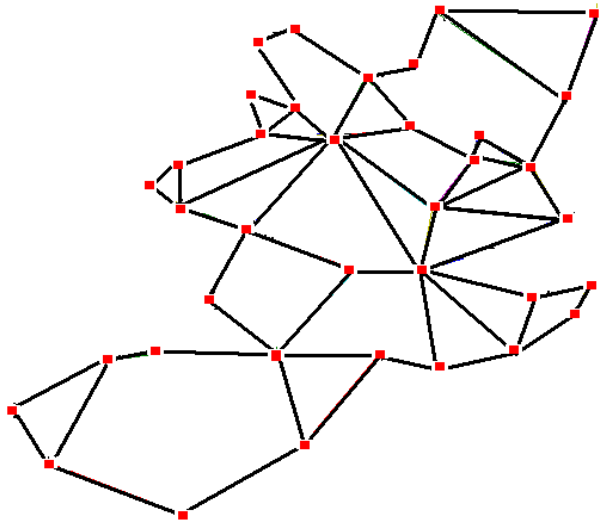
2 equivalent solutions in terms of used OEO, the first found is chosen

3 Network hypotheses

Network Hypotheses

- European network

Parameter	Value
Nodes Nb	39
Links Nb	62
Avg connectivity	3.23
Avg Link length	306 km

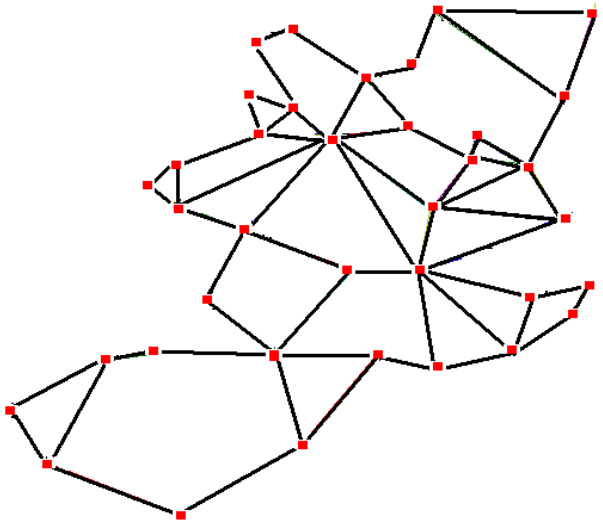


- The number of 10 and 40 Gb/s channels per fiber is identical for all fibers
- 3 traffic distributions:

Traffic name	% of 1 hop demands	% of max 4 hops demands	% of longer demands
T1	50	30	20
T2	40	40	20
T3	30	40	30

- Loads ranging from 700 to 1500 demands at 10 Gb/s with a step of 100

Physical Hypotheses



- 80 channels per fiber, 1 bi-dir fiber per link

- 10 Gb/s NRZ
- 40 Gb/s PSBT

} 50 GHz Spacing

- The Quality of Transmission of the 10 Gb/s channels estimated by accounting for OSNR, Chromatic Dispersion, PMD, Crosstalk and non-linear effects

- The reach of the 40 Gb/s channels is long enough to achieve the opaque connection between any pair of adjacent OXCs

4 Results

Advantages of introducing channels at highest bit/rate w/wo synergy

Reference: 10 Gb/s full routing: blocking ranging from 3 to 22%

Introduction of 40 Gb/s channels:

No synergy: increased capacity only for demands between adjacent OXCs

- best performance with few 40 Gb/s channels

Synergy: increased capacity for all demands

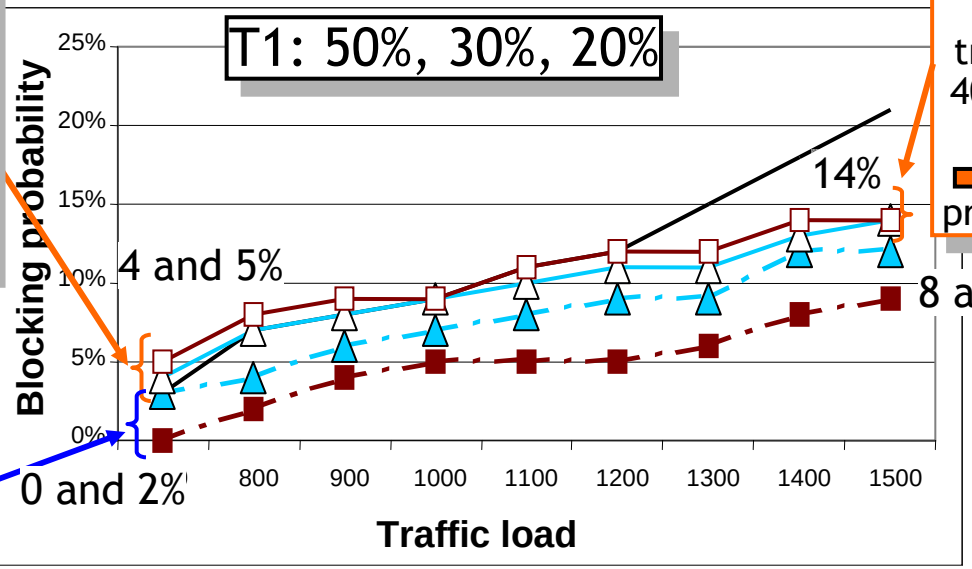
- best performance with more 40 Gb/s channels

No Synergy: for low traffic loads, channels at 40 Gb/s are partially filled;
10 Gb/s capacity is fewer than reference case

→ Greater blocking probability than reference

Synergy: channels at 40 Gb/s are filled to solve routing contention;
Fiber capacity increased

→ Fewer blocking probability than reference



No Synergy: for high traffic loads, channels at 40 Gb/s are better filled;

→ Lower blocking probability than reference

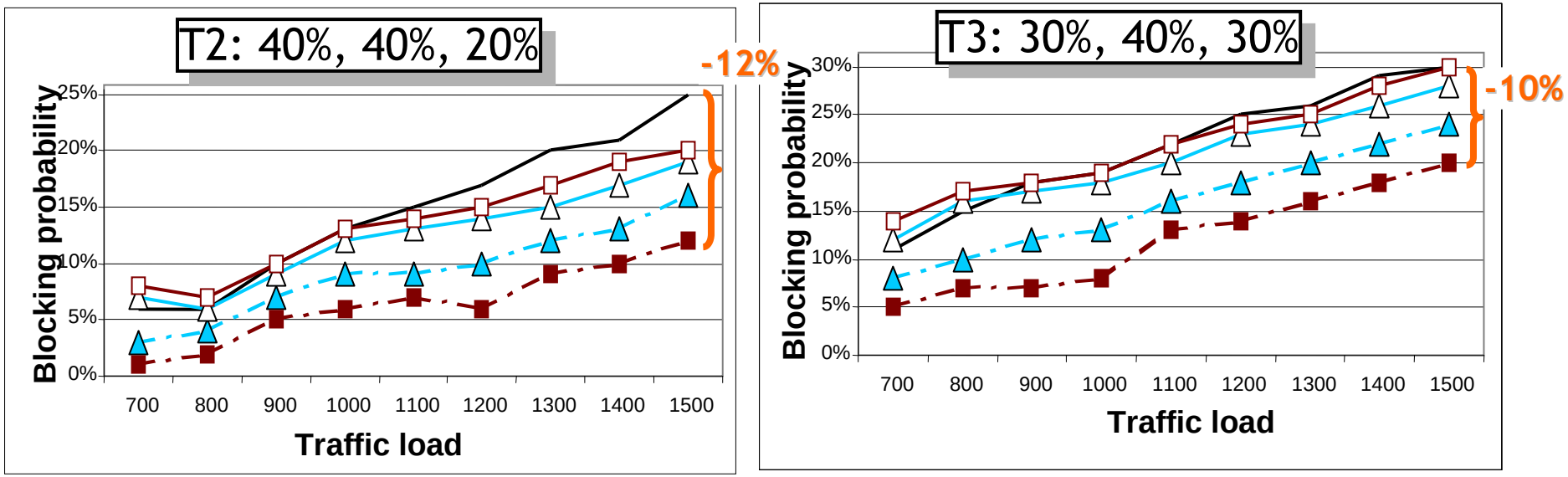
Reference
Synergy — 5Ch@40G — 10Ch@40G
No-Synergy — 5Ch@40G — 10Ch@40G

Advantages of introducing channels at highest bit/rate w/wo synergy

- The extension of connection length decrease the reduction of blocking probability:
  - ✓Longer the connection length is, more fiber capacity is required

- To obtain less blocking we have to add more channels at 40 Gb/s.

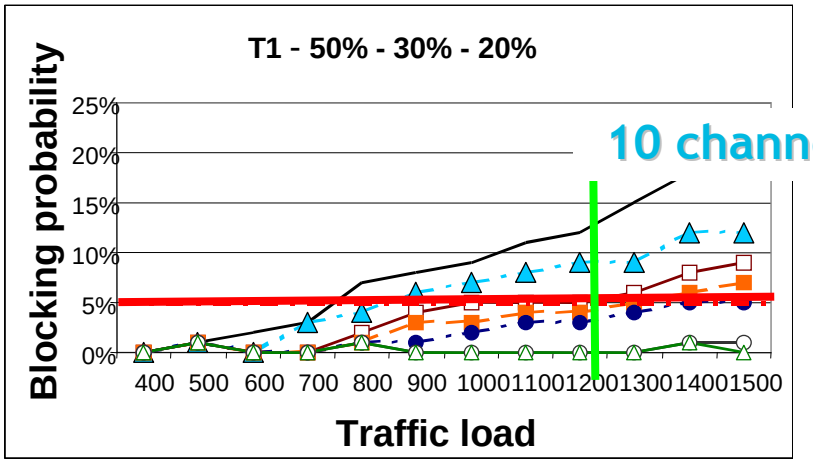
For T1 - 14%

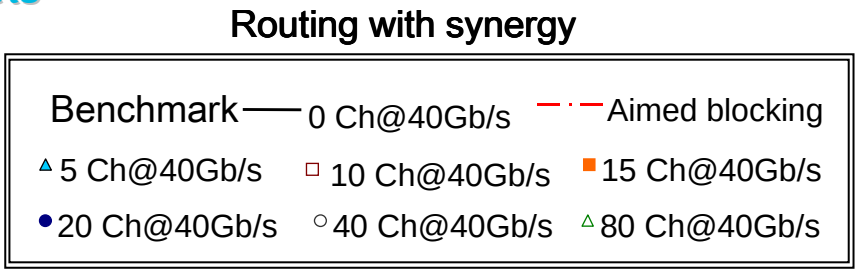


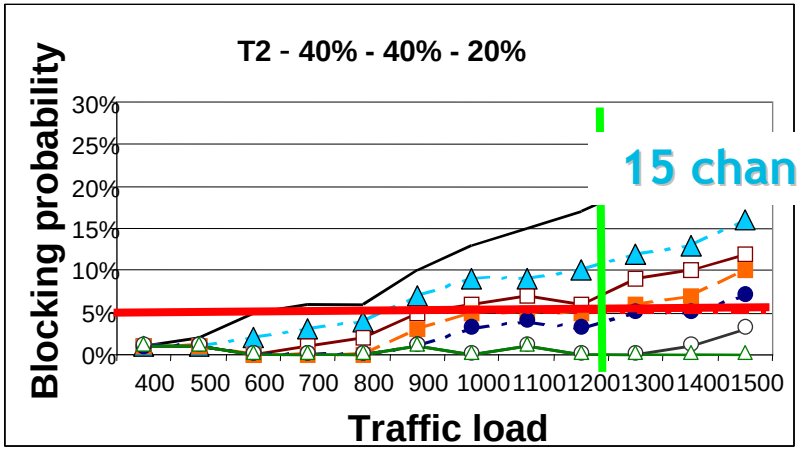
Advantages of introducing channels at highest bit/rate w/wo synergy

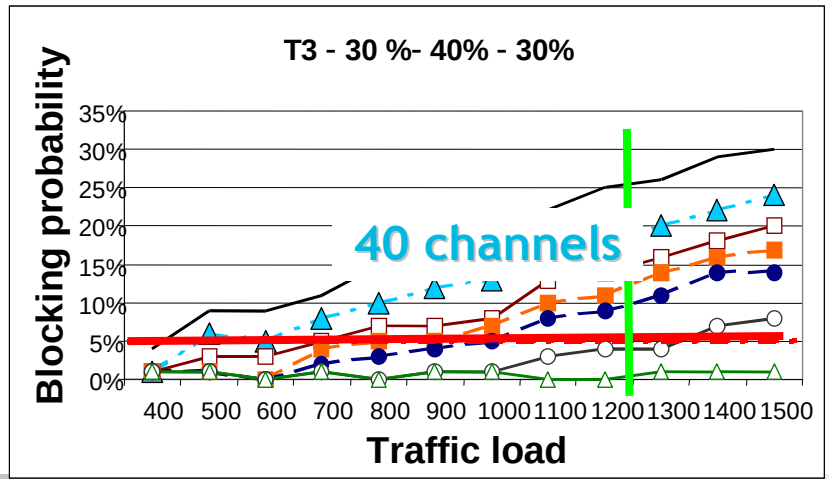
Research of blocking ratio < 5%

For longer traffic distribution more 40 Gb/s channels are required









6 Conclusions

Conclusions

- We defined a method to better exploit the introduction of 40 Gb/s channels in the network: *10-40 Gb/s synergy*
- 10-40 Gb/s synergy is able to use the unused capacity of 40 Gb/s channels in order to reduce 10 Gb/s OEO devices and blocking demands (-14%)
- Fully 40 Gb/s opaque network are not required yet, the number of 40 Gb/s channels depends on the traffic distribution and load

Possible future work:

Scenarii having links with different capacity:

Different number of 40 Gb/s channels per fiber

Different modulation format per fiber

Thank you!

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