SWITCH

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SWITCHlambda Update

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Topics

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- SWITCHlan network topology & technology
- 10Gigabit Ethernet testing on DWDM links
- Single Fiber Gigabit Ethernet

SWITCHlan topology by end of 2003

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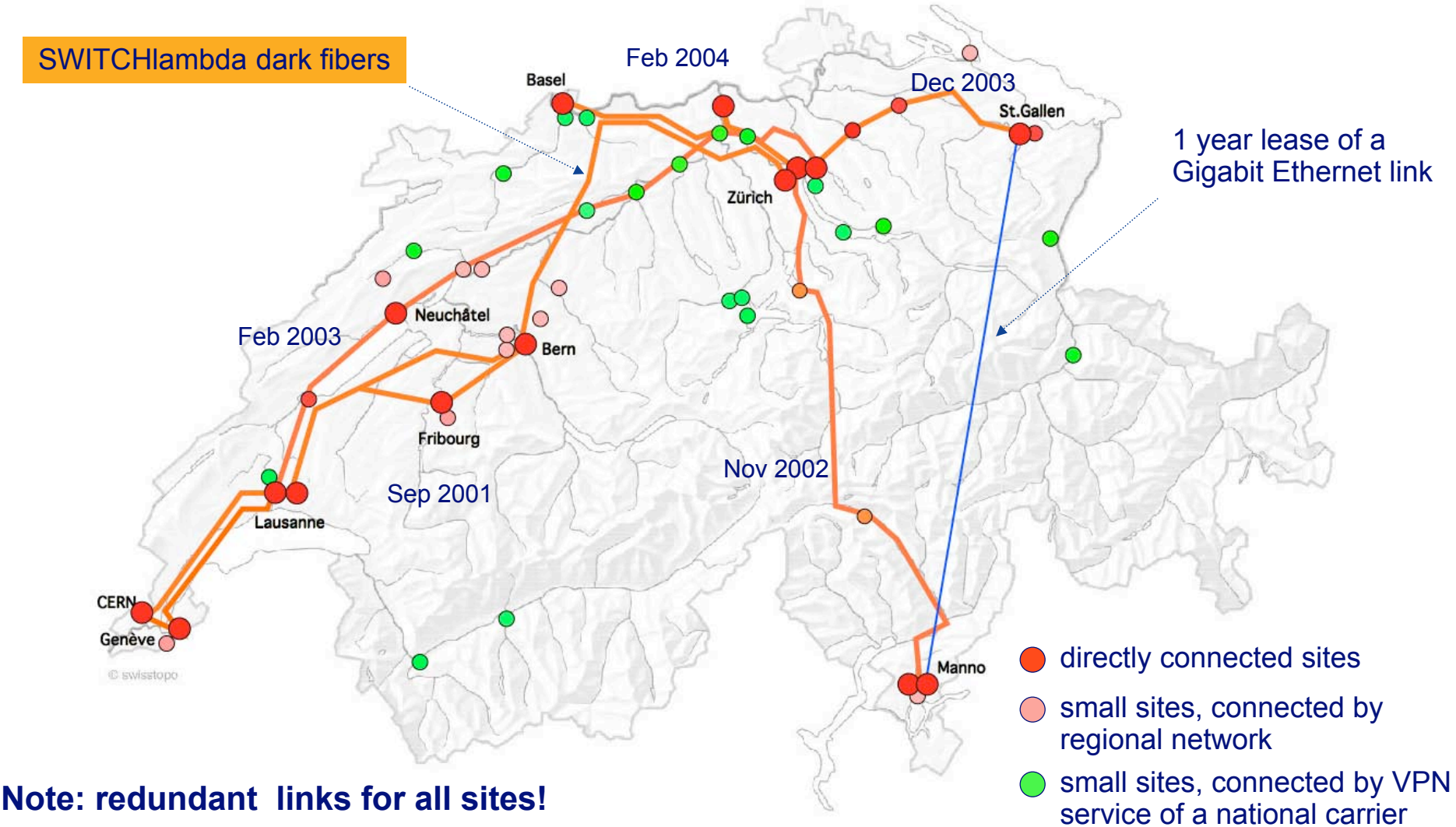

Note: redundant links for all sites!

SWITCHlan topology by end of 2004

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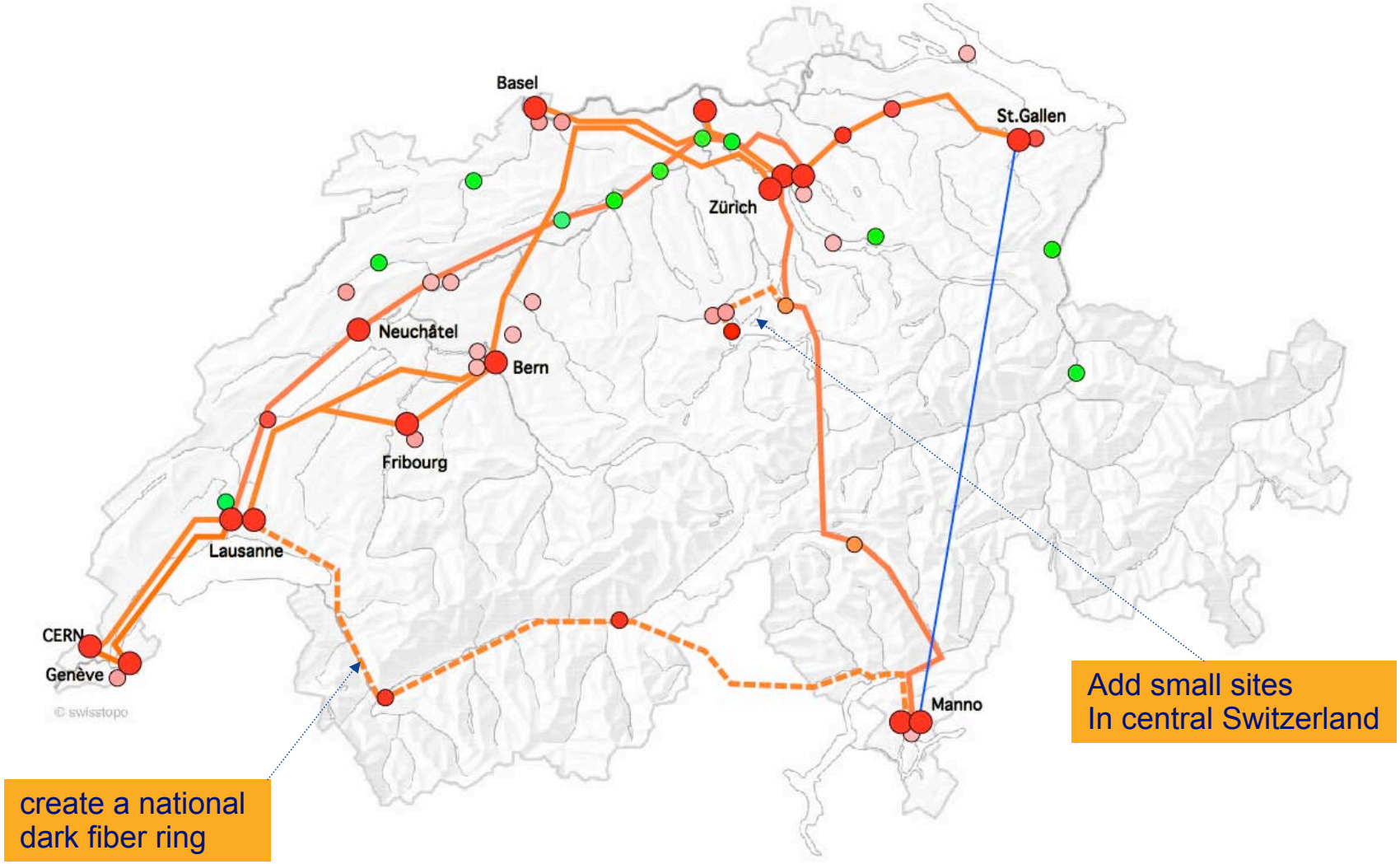

International connectivity

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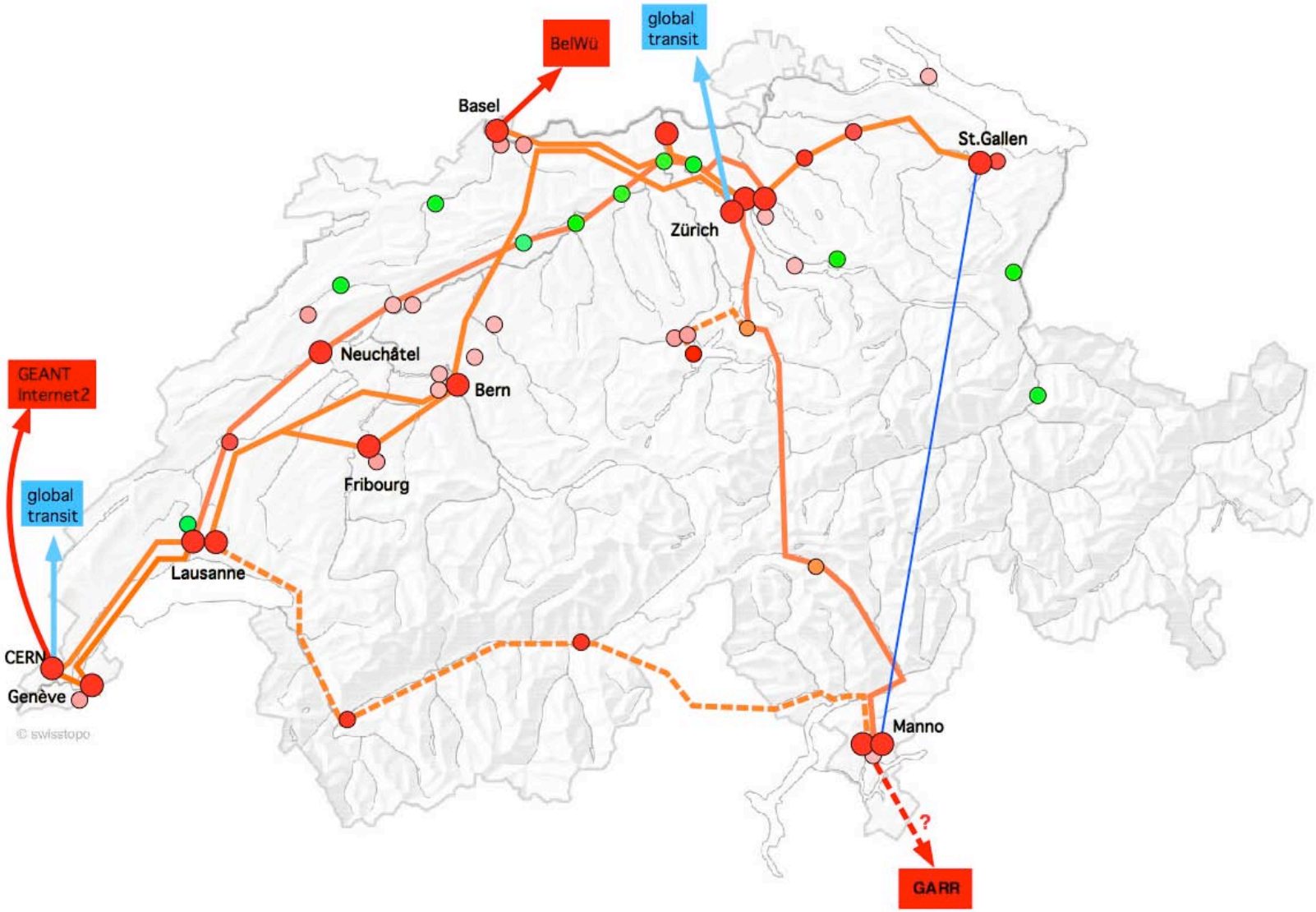

SWITCHlambda history & design

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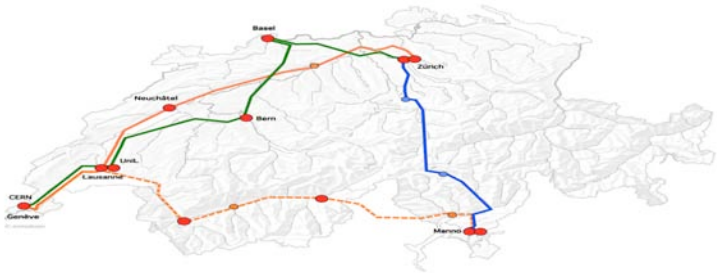
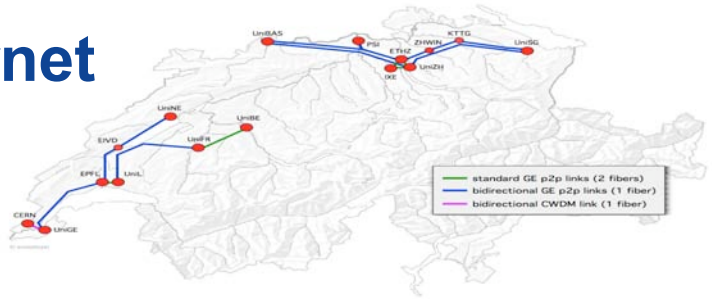
Phase 1, 2001-2003:

- build the backbone (except one "difficult" link)
- deploy DWDM technology:
  - considerable investment, but easy expansion
  - modular and scalable (but simple) design
  - range of interface options available



Phase 2, 2003 and beyond:

- emphasis on connecting smaller sites
- use second, "empty" fiber
- deploy cheapest possible GigabitEthernet technology



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SWITCHlambda technology (1)

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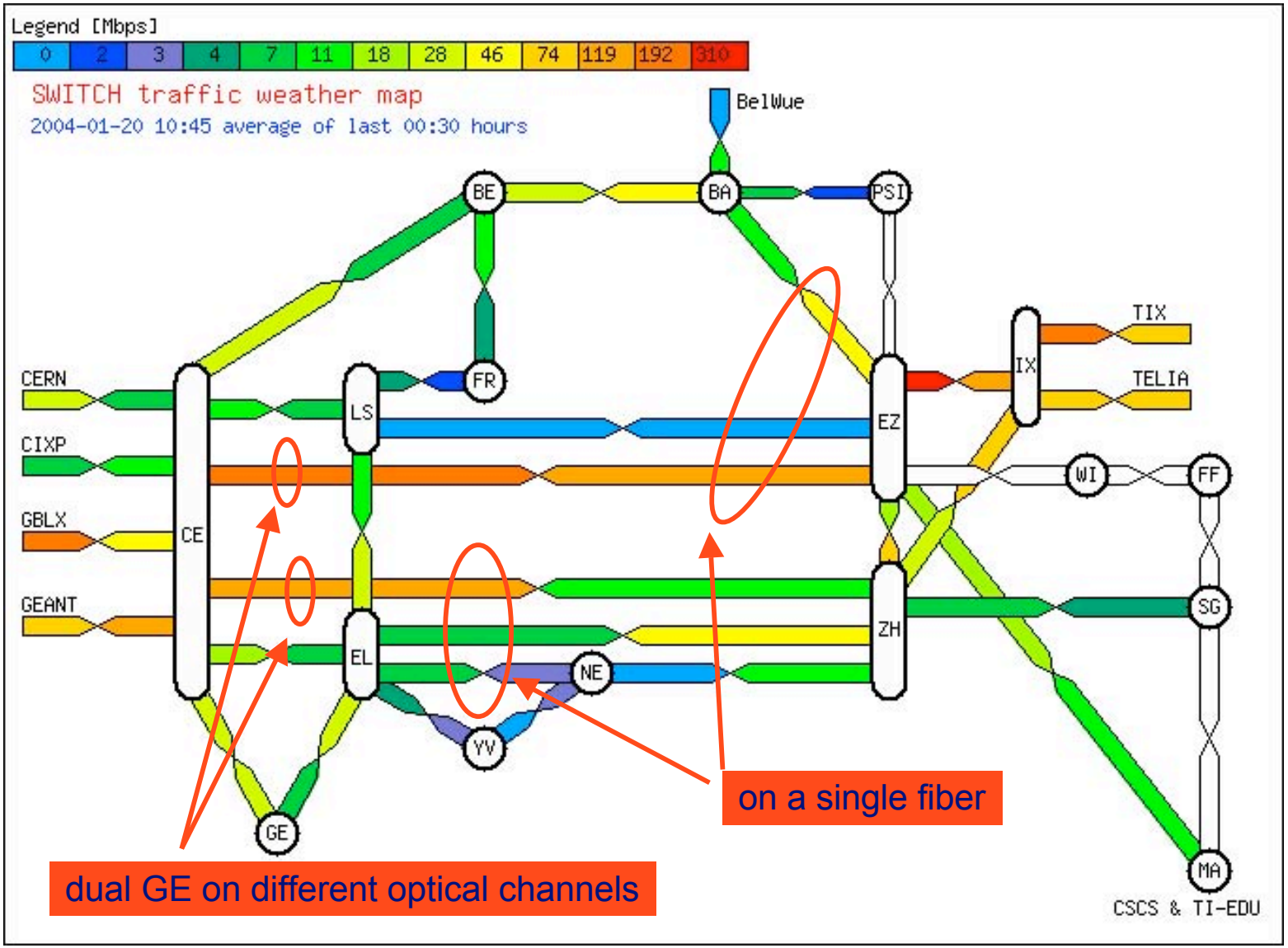
- DWDM: efficient use of bandwidth, easy expansion
- Ethernet on top: simplicity, cost efficiency
- Sorrento Gigamux DWDM systems deployed on SWITCH's three longest links
  - no regeneration or reclocking up to 600km
  - optical amplification every 80..100km
  - supports bidirectional transmission on a single fiber
  - typical channel speed is 2.5Gbps, split into two transparent GigabitEthernets
  - 10Gbps ready (chromatic dispersion compensated to <800ps/nm)
  - "non-intelligent" but simple!
- proving 10Gbps capability indispensable
  - to verify design and system performance
  - to test fiber quality (considerable PMD)

SWITCHlambda channel setup



DWDM Backbone Testing

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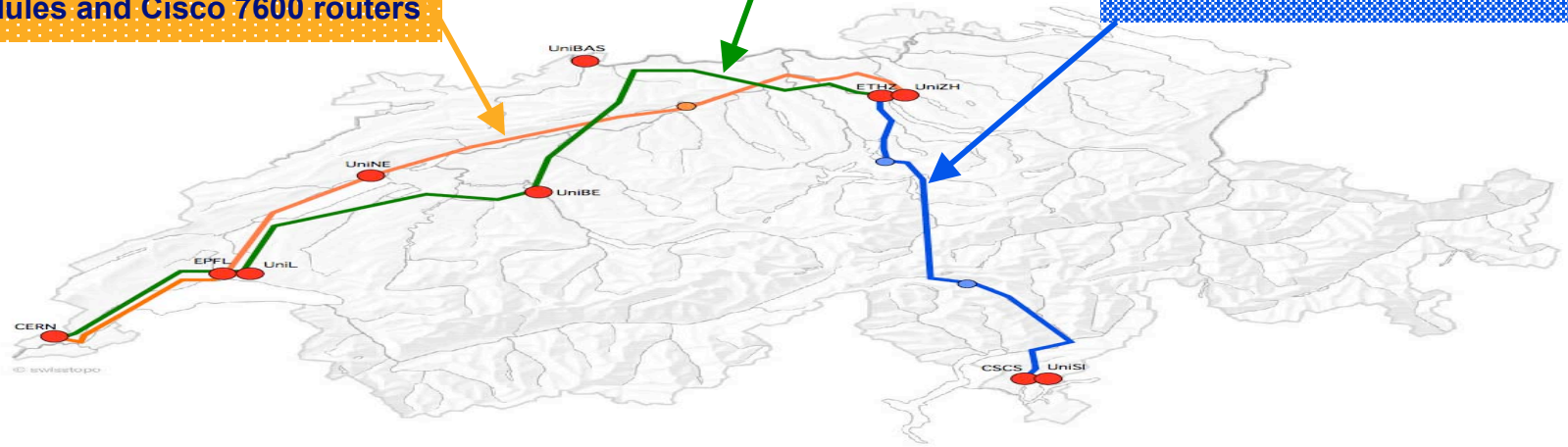
Geneva - Zürich along railway
- G.652 fibers
- running since Feb 2003
- bidirectional transmission
- 5 optical channels with dual/quad GE
- 1 optical channel with 10GE (new!)
- 320km
- 10 Gbps/ch tested Nov 2003 using 10GE modules and Cisco 7600 routers

Geneva - Zürich along motorway
- new G.652/G.655 fibers
- running since Sep 2001
- bidirectional transmission
- 5 optical channels with dual GE
- 360km
- 10 Gbps/ch tested Sep 2002 using STM-64 modules and Force10 routers

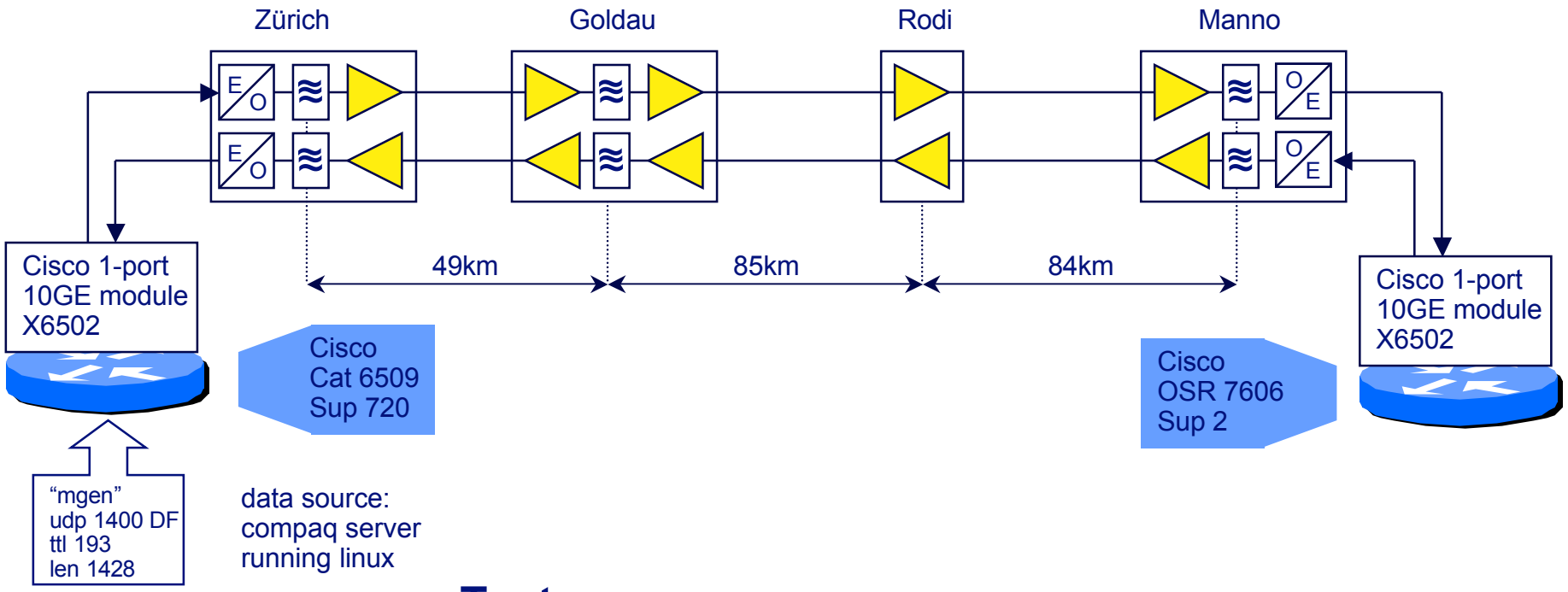
Zürich - Manno along railway
- G.652 fibers, up to 13 years old
- running since Dec 2002
- unidirectional transmission
- 3 optical channels with dual GE
- 220km
- 10 Gbps/ch tested Sep 2003 using 10GE modules and Cisco 7600 routers



- test interoperability
- verify link design
- test fiber quality (PMD!)

success!

10GE BER Test Setup



DCM+EDFA (+23dB)

OADMs

Sorrento Gigamux equip.

Test summary:

- **duration: ~36h**
- **avg. datarate: 7.8 Gbps**
- **avg packet rate: 673 kpps**
- **data transported: 125 TByte**
- **bits transported: 1*10E15 bit**
- **CRC errors & frame loss: 0**

BER >= 10E-15

Topics

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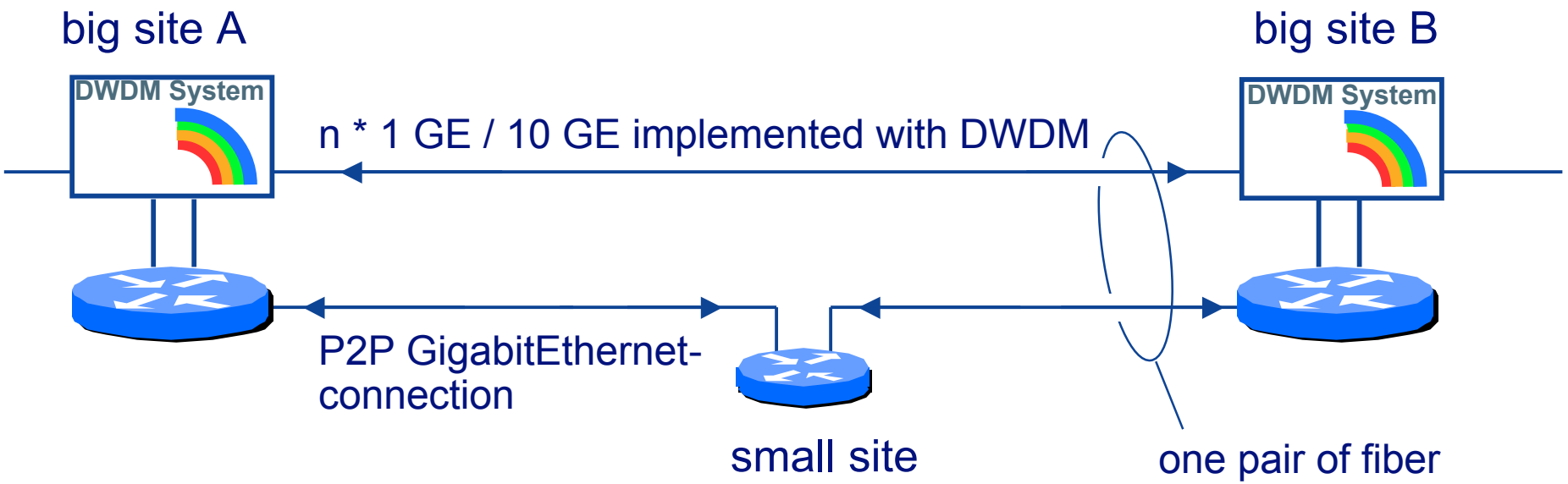
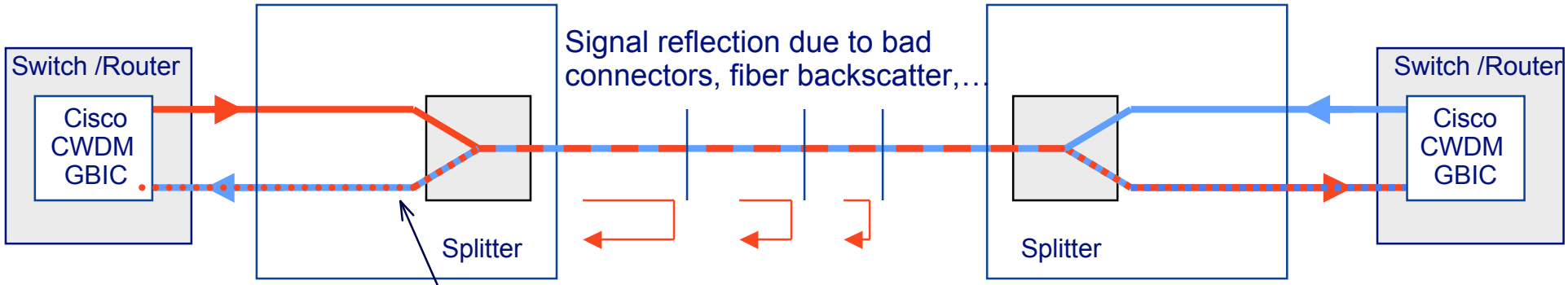
- Single Fiber Gigabit Ethernet

SWITCHlambda technology (2)

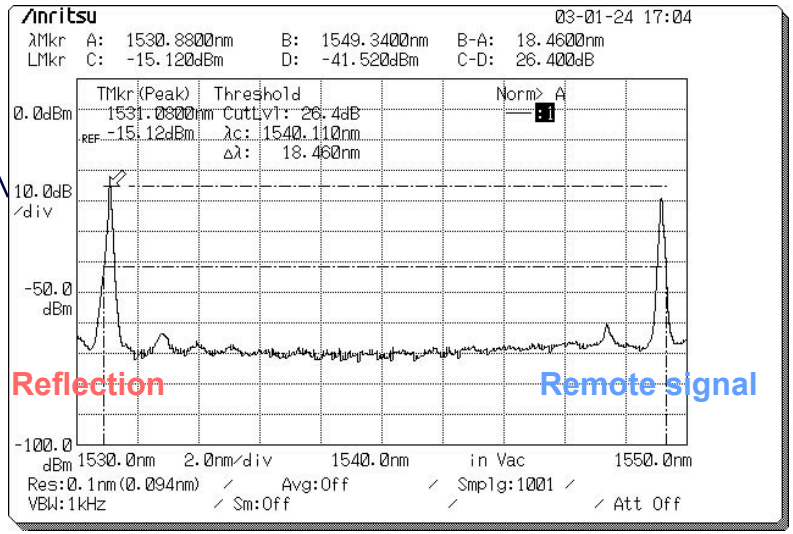
- **bidirectional Gigabit Ethernet over one fiber**
  - **little additional cost as one fiber was unused on most links**
  - **reach up to 100km without amplification**
  - **CWDM GBICs**
  - **POC (Passive Optical Coupler)**



Bidirectional GE - initial approach

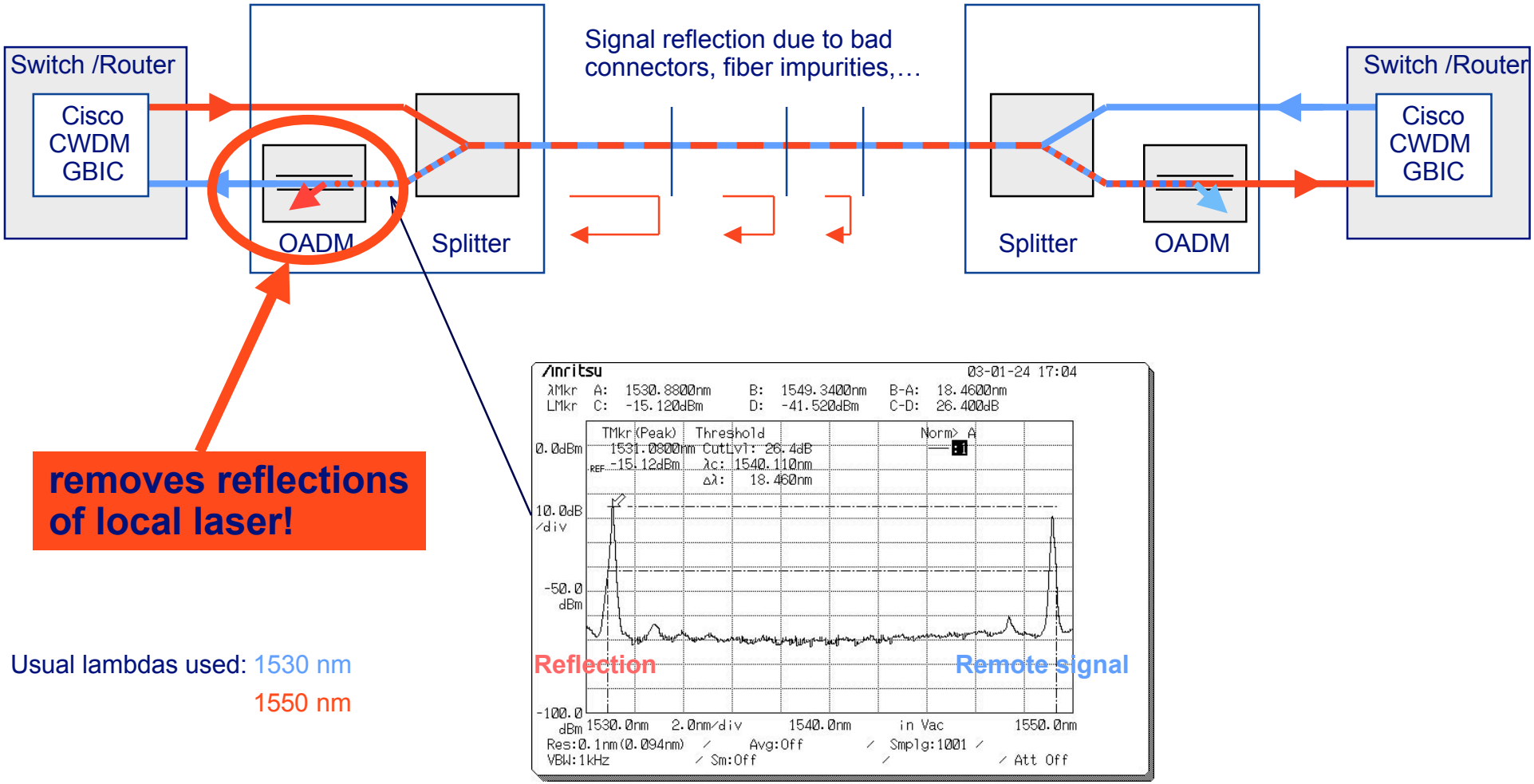


this setup does not work!



Usual lambdas used: 1530 nm
1550 nm

Bidirectional GE - cope with reflections



Usual lambdas used: 1530 nm
1550 nm

POC physical implementation

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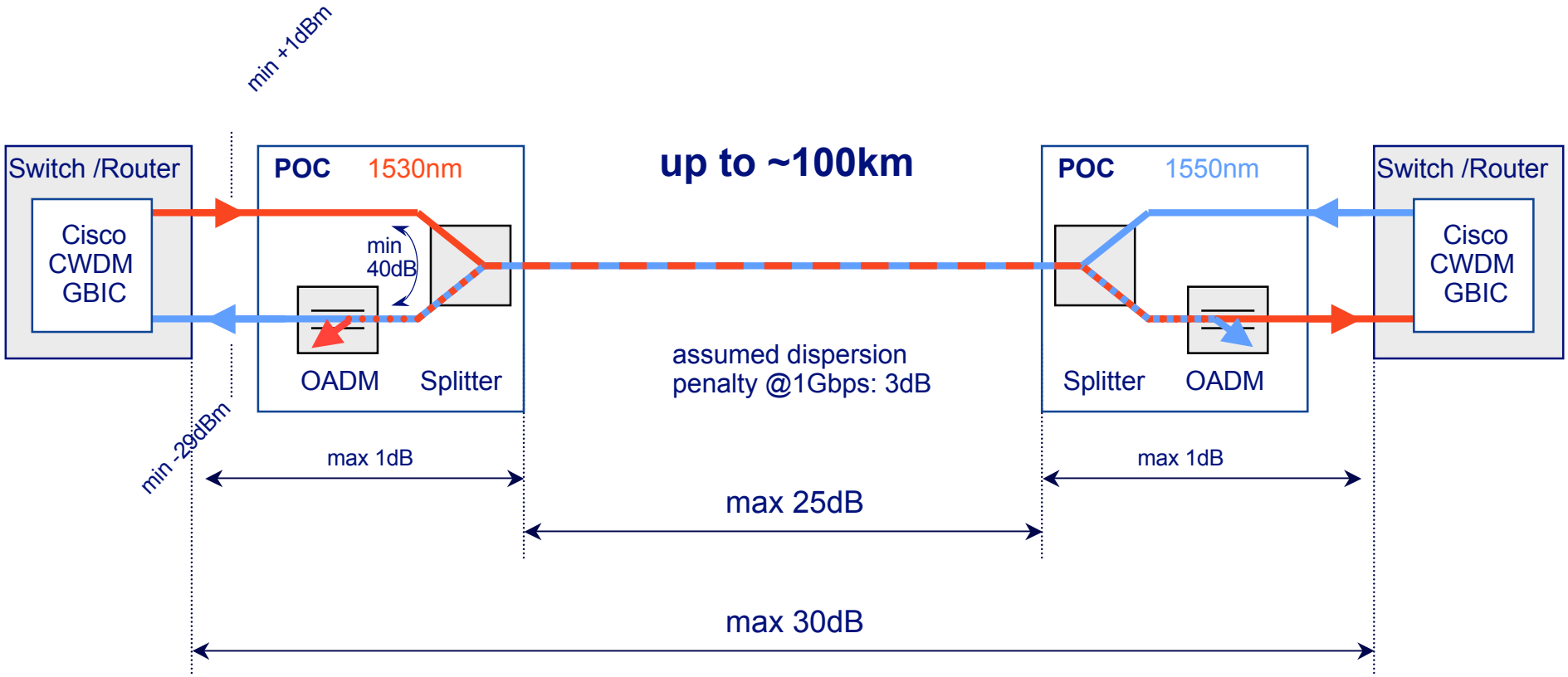
A POC in action in a SWITCHlan PoP:

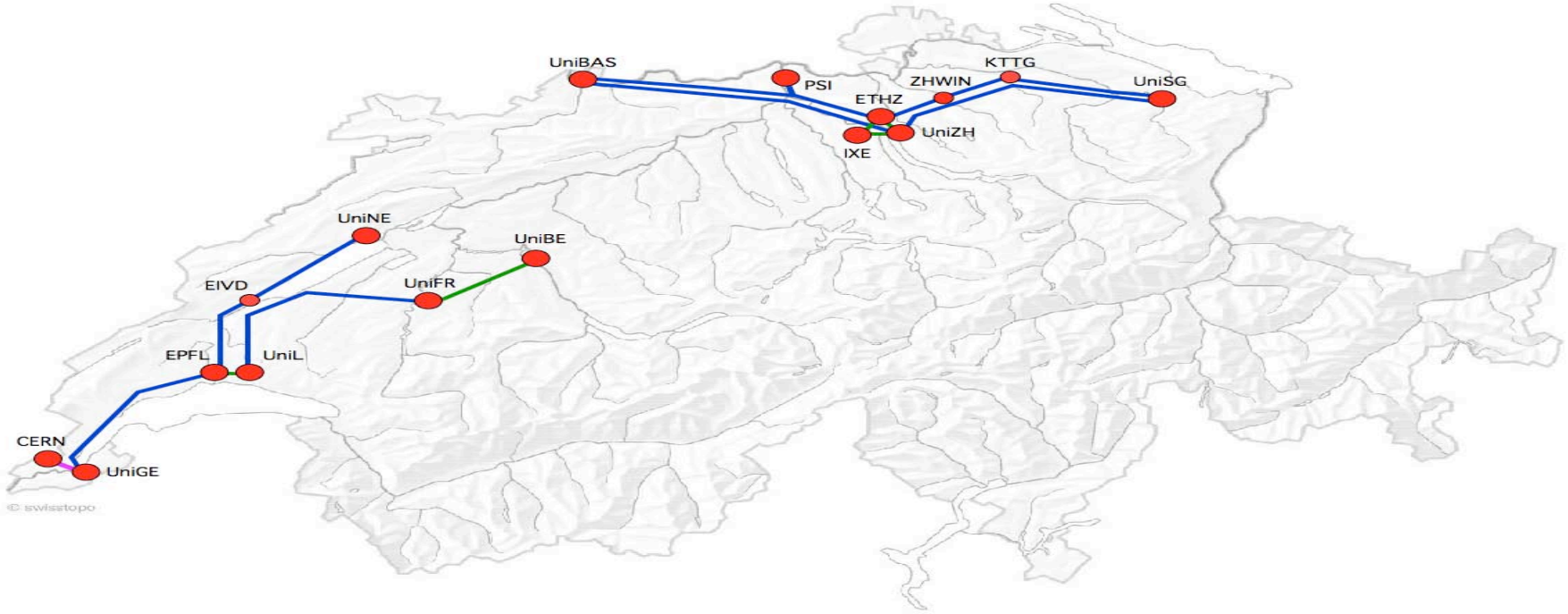
- **rack-mountable 19" box , 1 unit high**
- **E2000 connectors for optimal optical characteristics**
- **available in CWDM channel raster**
- **a purely passive device: protocol and data rate transparent, very small risk of component failure**

Bidirectional GE - today‘s setup



- inexpensive
- active parts directly pluggable into routers and switches
- external optical equipment is passive (POC = Passive Optical Coupler)

Non-DWDM Links



deployed by end of Feb 2004:

- **11 bidirectional GE links** ← **and many more by regional networks!**
- **5 standard GE links**
- **1 CWDM dual GE link**

The challenge…

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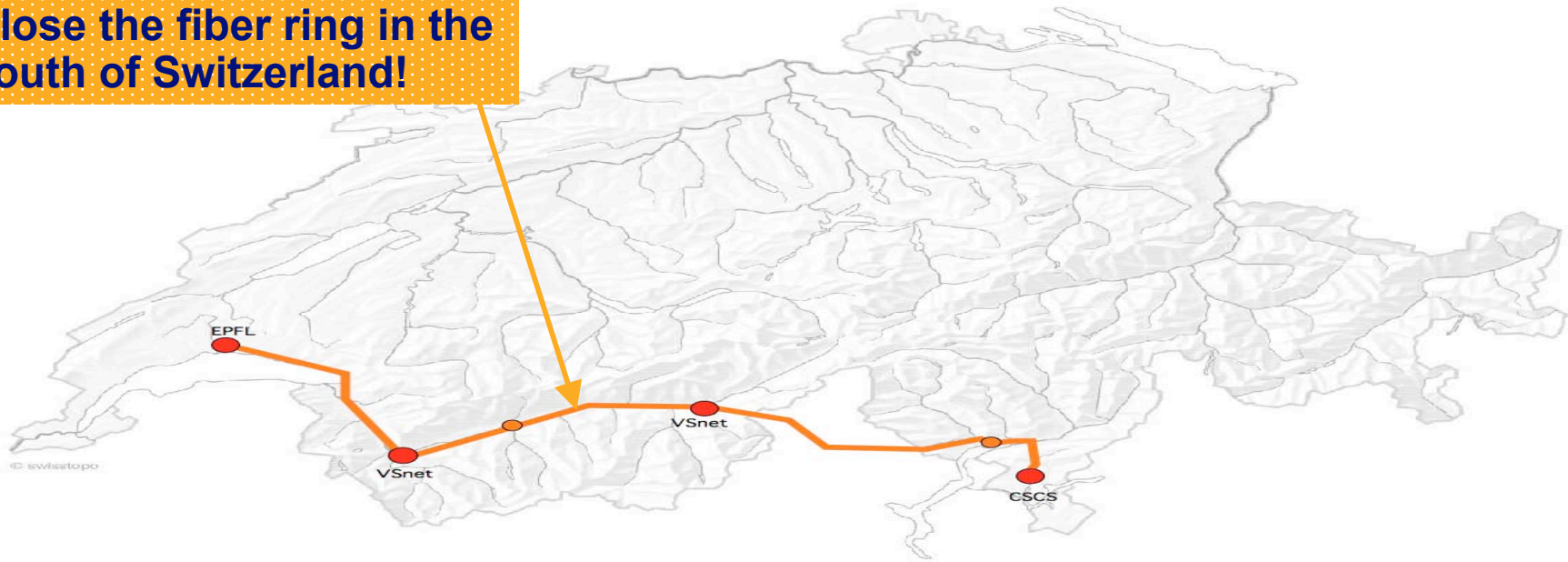
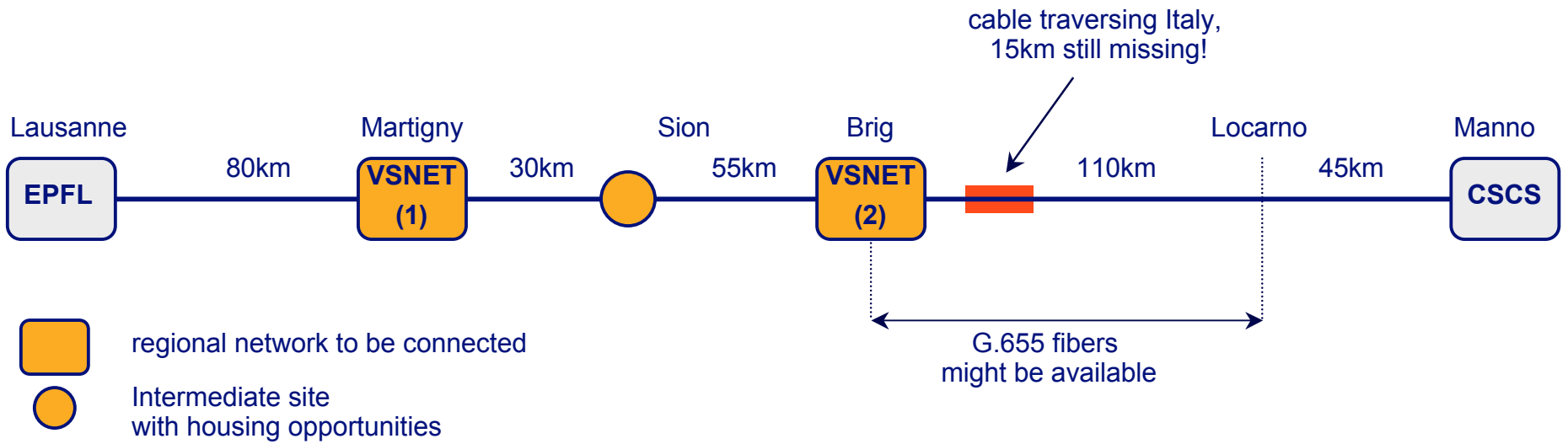
Close the fiber ring in the south of Switzerland!



- cover wider spans: 150km++
- go faster! 10Gigabit Ethernet
- do it on one fiber? “colored” laser modules

SWITCHlambda south leg



DWDM, with multiple channels up to 10Gbps, is scalable, but probably considered too expensive

More likely approach:

- **initial deployment of single channel Gigabit Ethernet**
- **single channel 10 GE without intermediate regeneration sites later**
- **low priced 10GE CWDM/DWDM solution when available and needed**

Long distance bidirectional GE (1)

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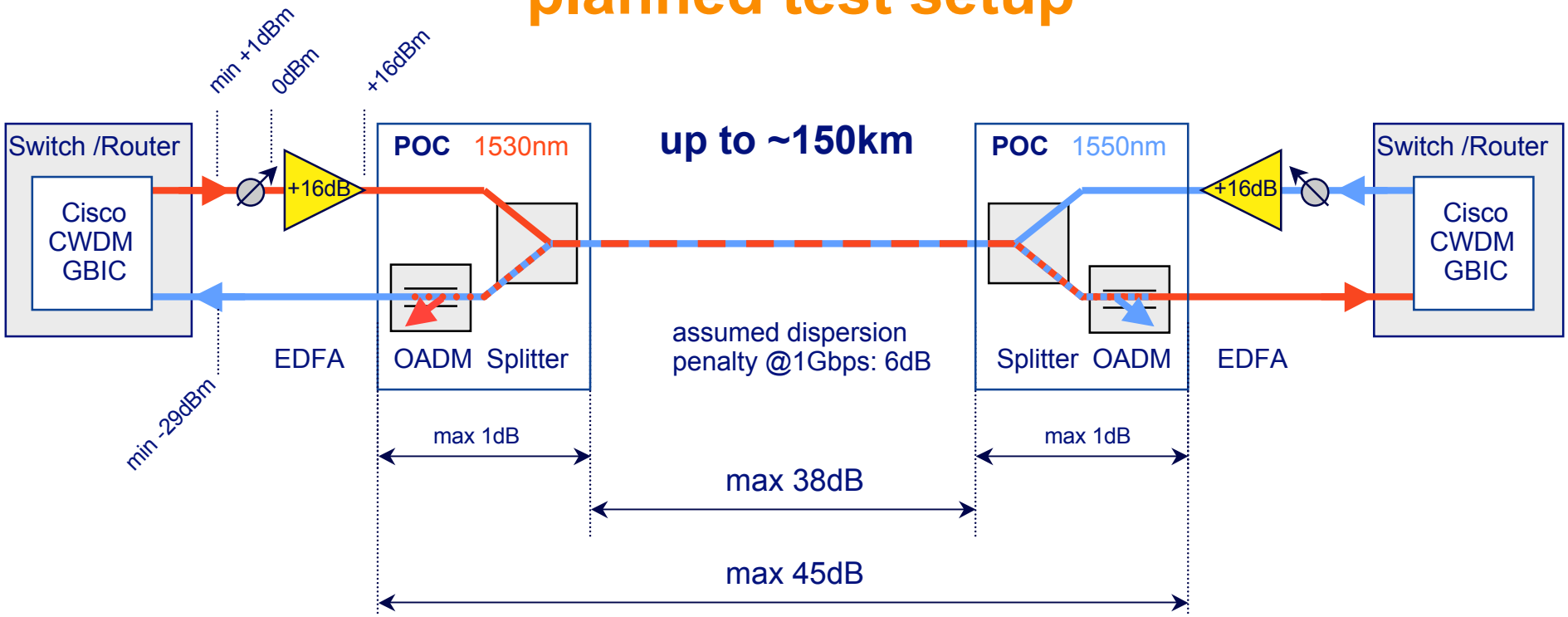
planned test setup



now requires external active parts: optical amplifiers

Long distance bidirectional GE (2)

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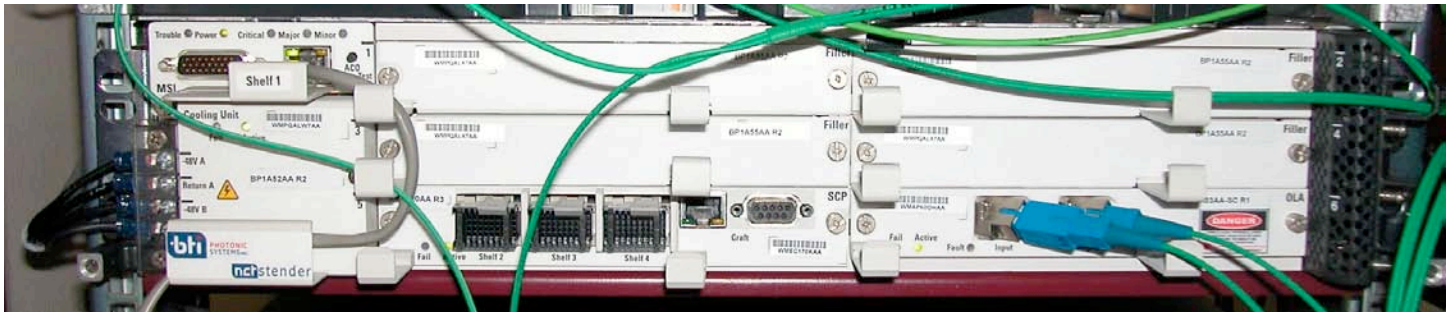
required hardware:

- CWDM GBIC
- POC coupler/filter
- optical amplifier

+



BTI Photonics optical amplifiers

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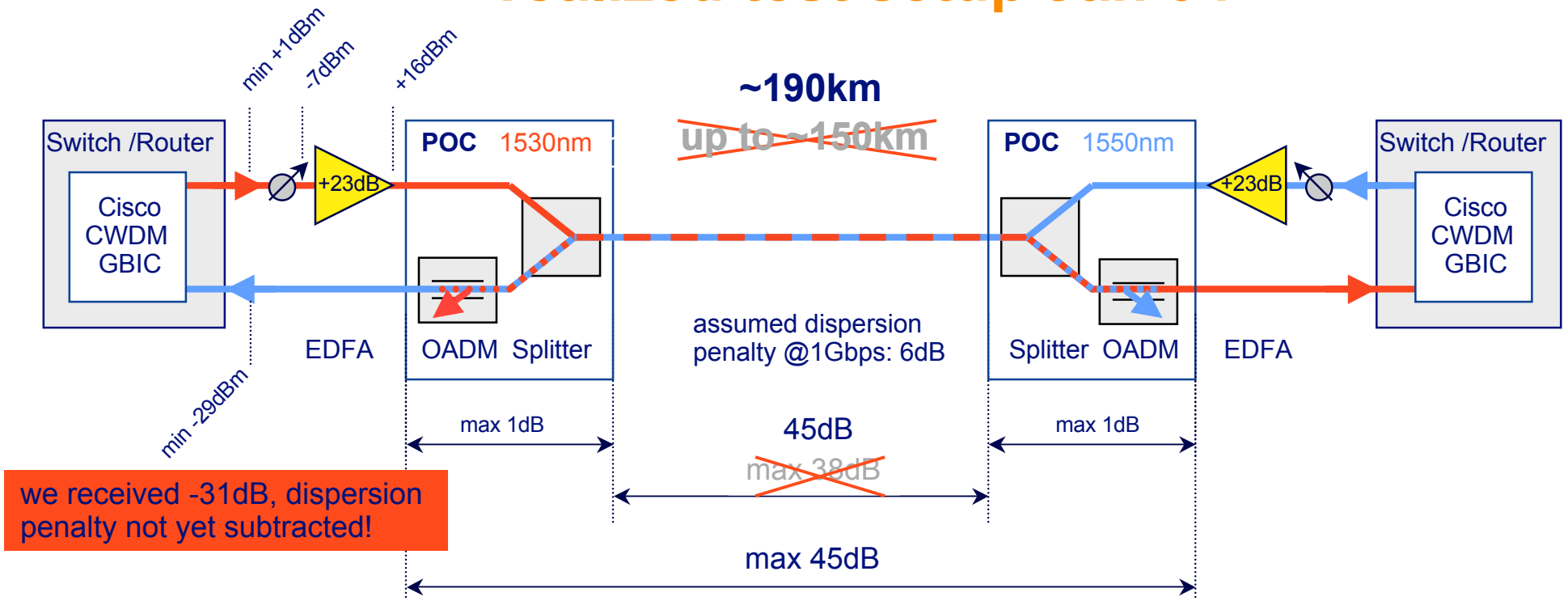
- expandable 19” chassis with 6 slots
- available amplifier modules:
  - preamp: 24dB gain, max +8dBm
  - line amp: 16..26dB gain, max +16dBm
  - booster: 10dB gain, max +18dBm
- management:
  - telnet/TL1 or GUI
  - access through RS232 or Ethernet interfaces
- SNMP support expected 2Q04
- other modules:
  - DCF dispersion compensators

Long distance bidirectional GE (3)

realized test setup Jan 04



- BTI Photonics optical line amplifiers (23dB max gain, +16dBm max out)
- the available fiber is longer than desired (too long!)
- the link is not yet working!

Long distance bidirectional GE (4)

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How to make it work:

- try to save a few dB on the link (46dB link loss for 190km is high!)
- use DWDM instead of CWDM GBICs:
  - smaller spectral width = less dispersion
  - but: slightly lower receiver sensitivity
- add chromatic (pre-)compensation elements in front of the booster amplifiers
- go for optical amplifiers with higher output power

A look back 5 years…

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Equipment

- costs/Mbps dropped dramatically
  - we got rid of the ATM Layer
  - we got rid of the SDH Layer
  - we could integrate colored optics into the routers & switches
- technological progress seems to go on

Dark Fibers

- most new cable projects concentrated on the axis Geneva - Zurich
- carriers are increasingly reluctant to sell dark fibers even if they have plenty
- organizations with good fiber density in the cities now have a de facto monopoly
- their idea is to sell only bandwidth, not dark fibers…