# DESIGN AND PLANNING OF RELIABLE COMMUNICATION NETWORKS

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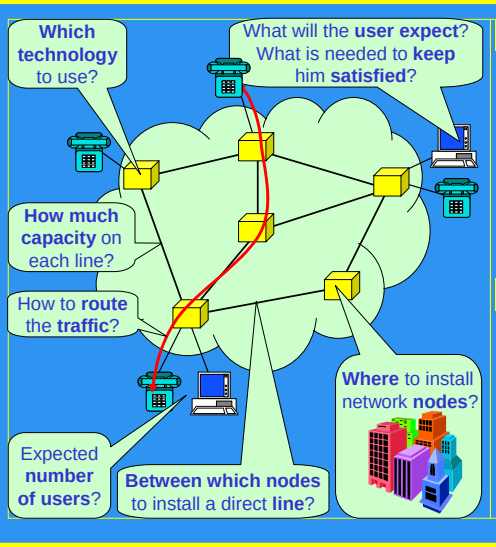



## What is network planning

The science of **network planning** has as goal to come up with a **time-schedule for the network deployment**. **Technical and other aspects**, which are not directly related to networking, have to be considered: e.g., prediction of the real-estate market, population density, etc.

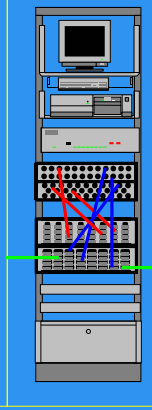
As the figure (left) illustrates, network planning relies on a **prediction of future situation**. Predictions far away in the future become **inaccurate and uncertain**.

## Planning for different time horizons

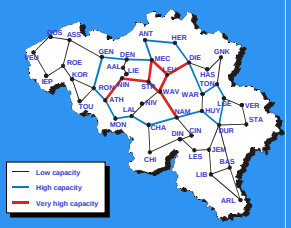
**Network planning** should be a **continuous** process, taking decisions for **several time horizons** (figure right):

- **Short-term** planning = **configuration**: which fibre to plug into which socket, which connection to route using which time-slot, etc.?
- **Mid-term** planning = **tactical** decisions: e.g., which line has to be upgraded/installed with how much capacity.
- **Long-term** planning = **strategic** decisions: e.g., which technology to use, what topology to build, etc?

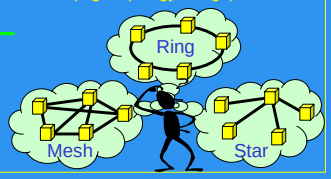
1) **Short-term** planning = Network **configuration**



2) **Mid-term** planning = **tactical** decision (e.g., capacity dimensioning)




3) **Long-term** planning = **strategic** decision (e.g., topology design)

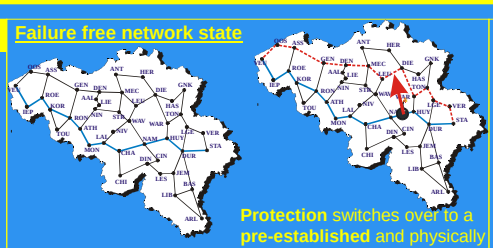



## Network reliability

An important issue in network design (or planning) is network reliability. For example, a single optical fiber cut (e.g., due to digging) can affect huge amounts of traffic.

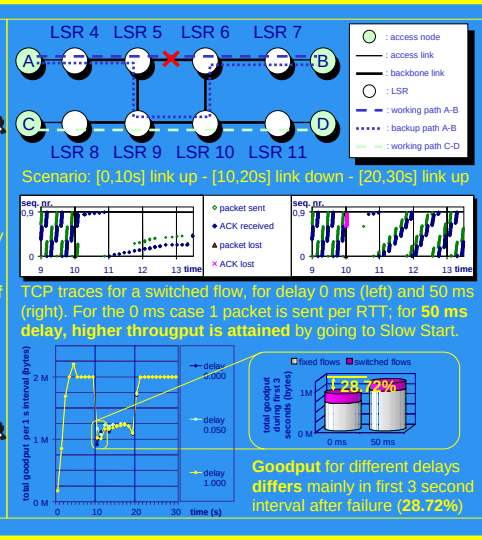
Therefore, **preventive actions** are necessary to avoid network failures as much as possible. However, not all failures can be avoided, thus requiring a **recovery mechanism** (**protection or restoration**: see figure (right)), to **reroute the affected traffic** in the case of a failure.

**Failure free network state**



**Protection** switches over to a **pre-established** and physically **disjoint backup path**.

**Restoration** searches for an alternative path **at the time of a failure**, on a **link** (left) or **end-to-end** (right) basis



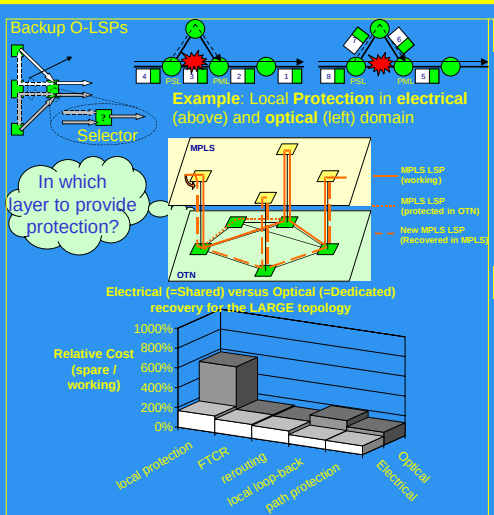

TCP traces for a switched flow, for delay 0 ms (left) and 50 ms (right). For the 0 ms case 1 packet is sent per RTT; for **50 ms delay, higher througput is attained** by going to Slow Start.

**Goodput** for different delays **differs** mainly in first 3 second interval after failure (**28.72%**)

## Example 1: MPLS protection and TCP

MPLS opens opportunities for **fast protection switching**, in addition to the inherent (slow) IP restoration. The figure (left) investigates the **impact**, of the fast protection switching, on the **TCP behaviour**, immediately after the occurrence of the failure. The sample **packet trace** is an illustration of the **detailed simulations**.

The main conclusion is that fast protection is beneficial, but that making it as fast as possible may perform worse, from a goodput viewpoint.




**Example**: Local **Protection** in **electrical** (above) and **optical** (left) domain

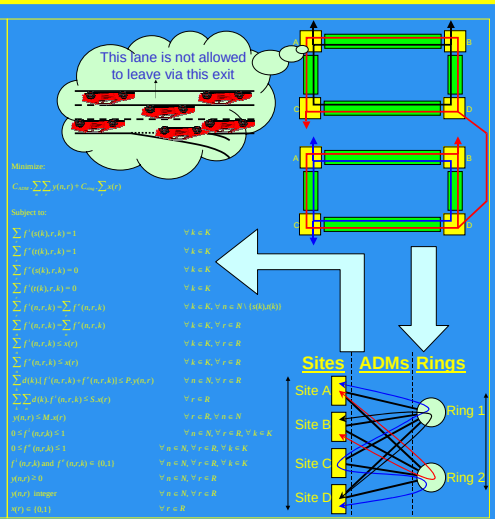
## Example 2: network dimensioning

Optical Transport Networks (OTNs) are able to fulfill the need for high transmission speeds in future IP networks (resulting in an **IP-over-OTN multilayer network**).

The study, (see figure (left)), helps to decide in **which layer** to provide reliability, by means of **which technique**. The principle of Protection for an **MPLS**-capable network is also illustrated, for both the IP and the OTN layers. Of course, more than just the relative capacity need (as being studied) is important.

## Example 3: equipment limitation

The figure (right) shows a typical **configuration problem**. An Add/Drop Multiplexer (**ADM**) on a Self-Healing Ring (**SHR**), is similar to a exit/entrance on a motor high-way. So-called **Compact-ADMs** have a limited add/drop capacity (lower than the ring capacity). The goal of this problem was to **optimize the routing** of the connections, in order to **minimize the installation cost**. This was solved by an integer linear program (**ILP**), based on a **dual network representation**.

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