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La Protezione nelle Reti di Telecomunicazione

A Priority-Aware Protection Technique for QoS Enabled WDM Networks

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Sommario

- Introduzione
- Strategie di Protezione classiche
- Priority-Aware Shared-Protection
- Modelli Matematici e risultati numerici
- Interpretazione dei risultati

Resilience in WDM Networks

- The maturing of WDM technology:
  - A single fiber carries huge amount of data (Terabit/s)
- The failure of a network component:
  - Can lead to huge loss in data and **<u>revenue</u>**
- Solution:
  - **Protection**, a proactive procedure to recover traffic when a failure occurs:
    - One path is referred to as primary path used to carry traffic during normal operation.
    - Extra backup resources are pre-reserved and activated when the primary path fails.

Challenges

- The operator is faced by several challenges:
  - Satisfy the QoS requirements of the client defined through an SLA (Service Level Agreement):
    - An SLA Violation may cause a certain amount of penalty to be paid by the operator.

	Premium	Gold	Silver	Bronze
Out of service criterion	Degraded BER=10^{-4}	Degraded BER=10^{-3}	Fault (LOS)	Fault (LOS)
Recovery time with degraded SLA	Not spec.	50 ms	500 ms	5 sec
Full recovery time	50 ms	300 ms	5 sec	5 min
Service unavailability	10^{-5}	10^{-4}	10^{-3}	10^{-2}

  - At the same time, select a cost effective protection scheme to achieve this goal

Why do we protect?

- Protection is normally done for the purpose of increasing the availability of the end-to-end connection.
- Availability:
  - Availability = fraction of time the connection is up during entire service time (unit: mins/year)
    - Availability = (available Time)/(available Time+ down time).
  - Protection does help to increase availability:
    - Traffic on failed primary path will be switched to the backup path
    - The more backup resources we have, the greater will be the availability

Availability (1)

- Each network component is characterized by its availability which depends upon:
  - Failure rate:
    - Mean Time To Failure (MTTF) = 1/Lambda
  - Failure recovery rate:
    - Mean Time To Repair (MTTR) = 1/Mu

FAILURE RATES AND REPAIR TIMES (BELLCORE) [11].

Metric	Bellcore Statistics
Equipment MTTR	2 hrs
Cable Cut MTTR	12 hrs
Cable Cut Rate	4.39/yr/1000 sheath miles
Tx failure rate in FIT	10867
Rx failure rate in FIT	4311

501142 FIT/1000 miles

FIT=Failure In Time (how many failures the componenet experiences in 10^9 hours)

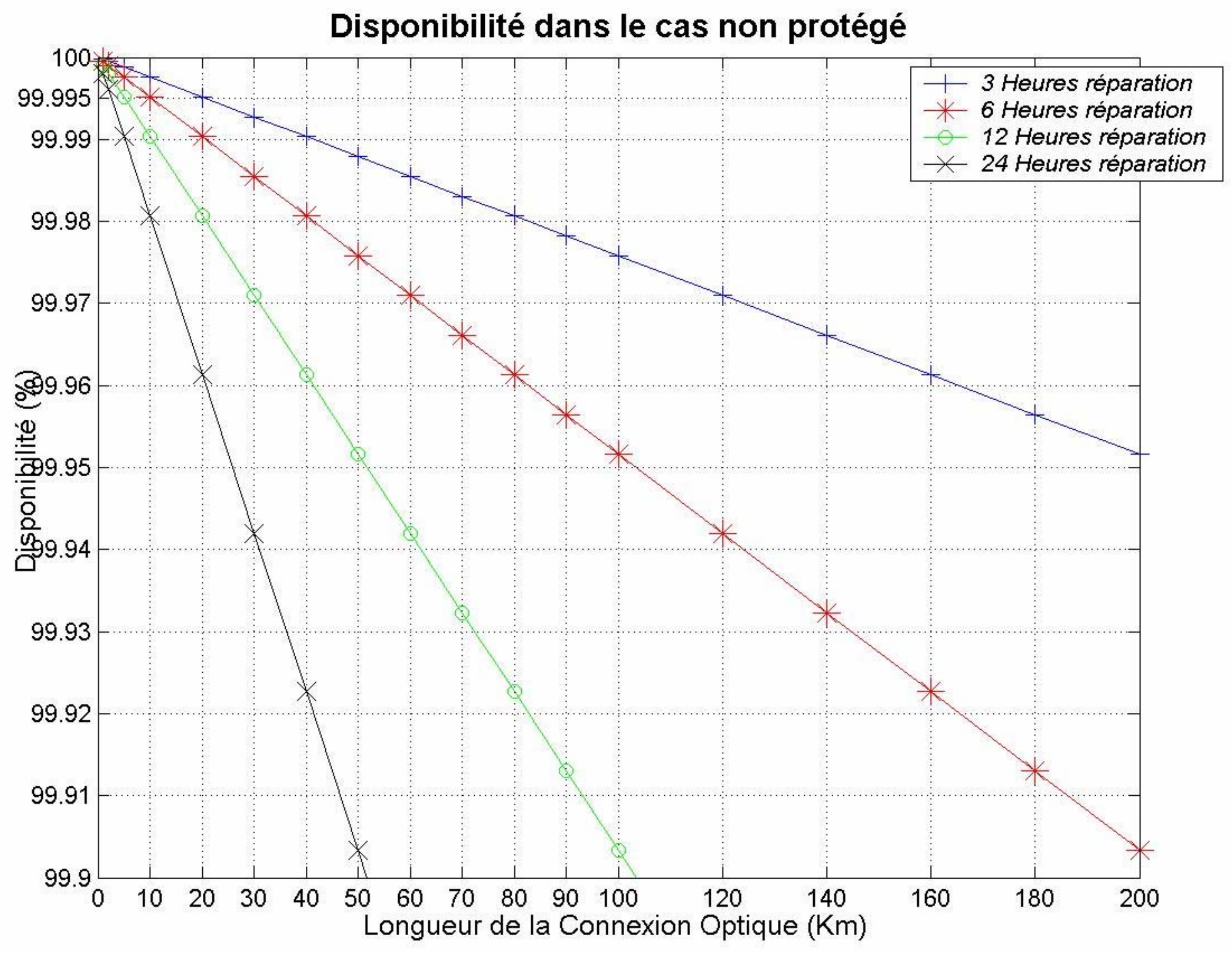
Availability (2)

- Path availability:
  - Product of in between N components availability

$$A_t = \prod_{i}^{N} A_i$$

  - Where:
    - A_i = MTTF/(MTTR + MTTF)
    - Main reason for failure is related to fiber links

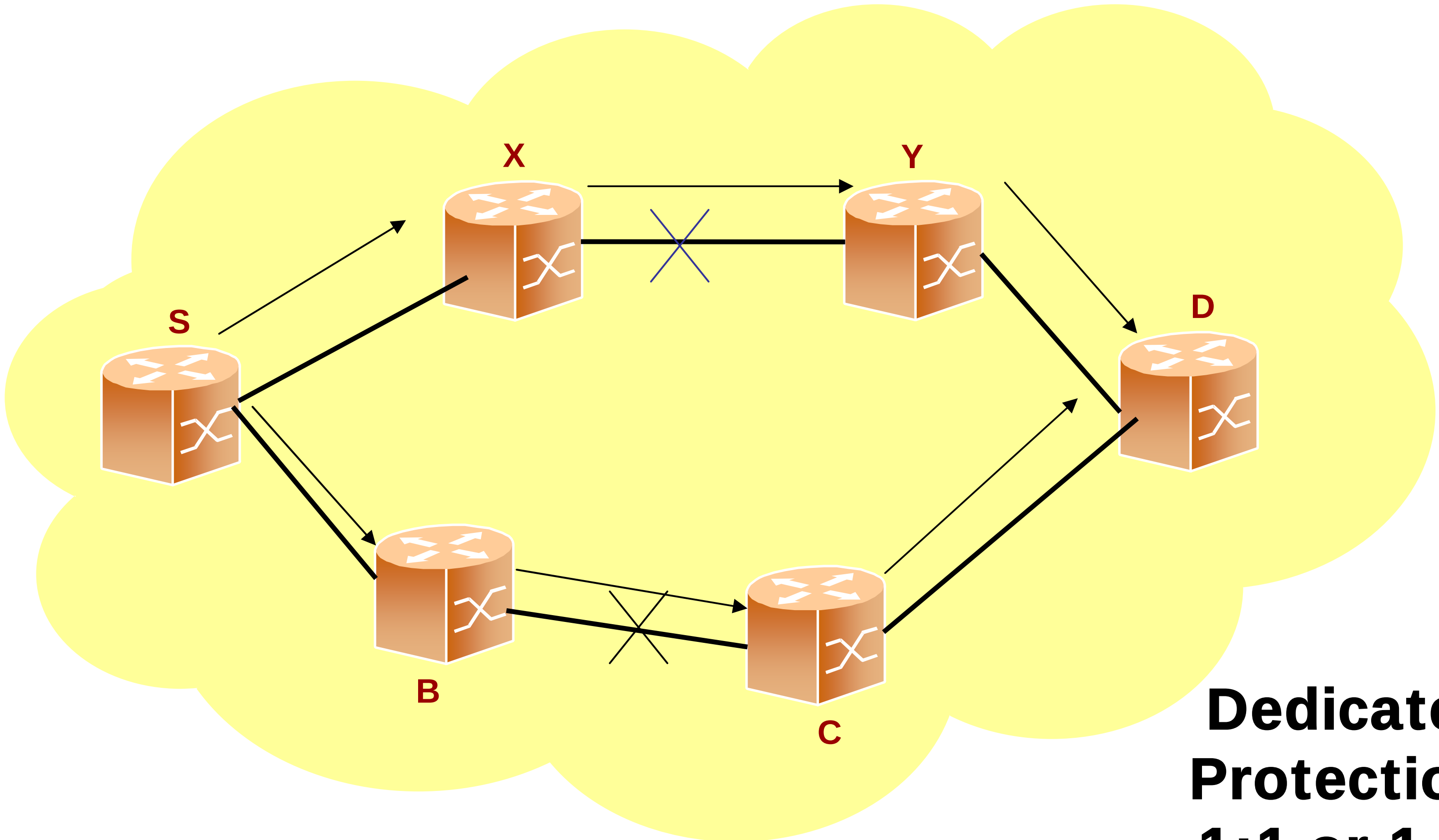
Availability (3)



First Conclusion

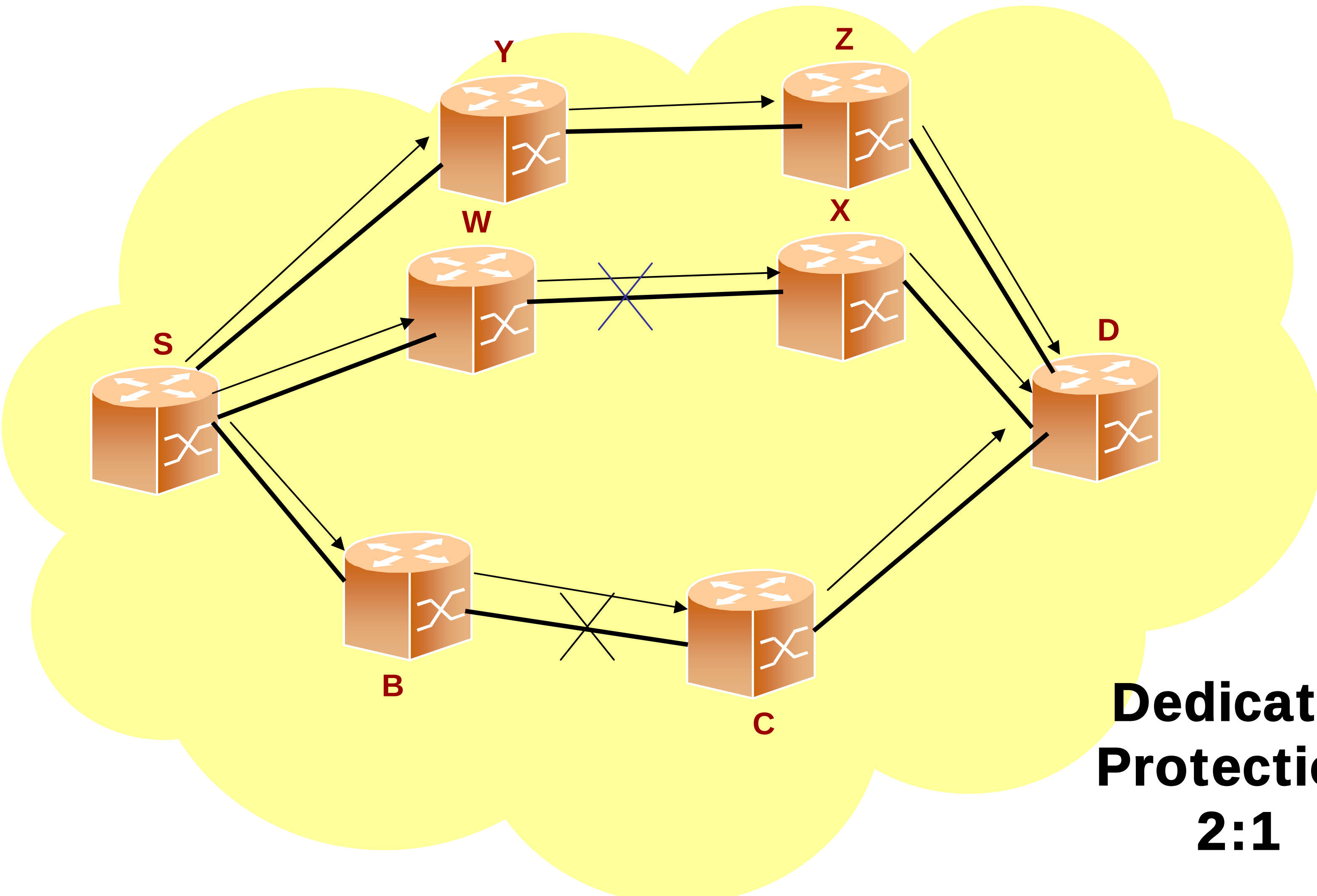
- To reach the 5 9's objective for long distance connections we need to protect the signal
- Several protection schemes exist in the literature:
  - Each one has its own advantage and disadvantage.
  - The most common:
    - Dedicated Protection
    - Shared Protection
- Still we don't know with each protection scheme what is the resulting availability:
    - We tend to combine the advantages from both approaches to use resources efficiently while meeting user's requirement

Dedicated Protection



Dedicated Protection: 1:1 or 1+1

Dedicated Protection

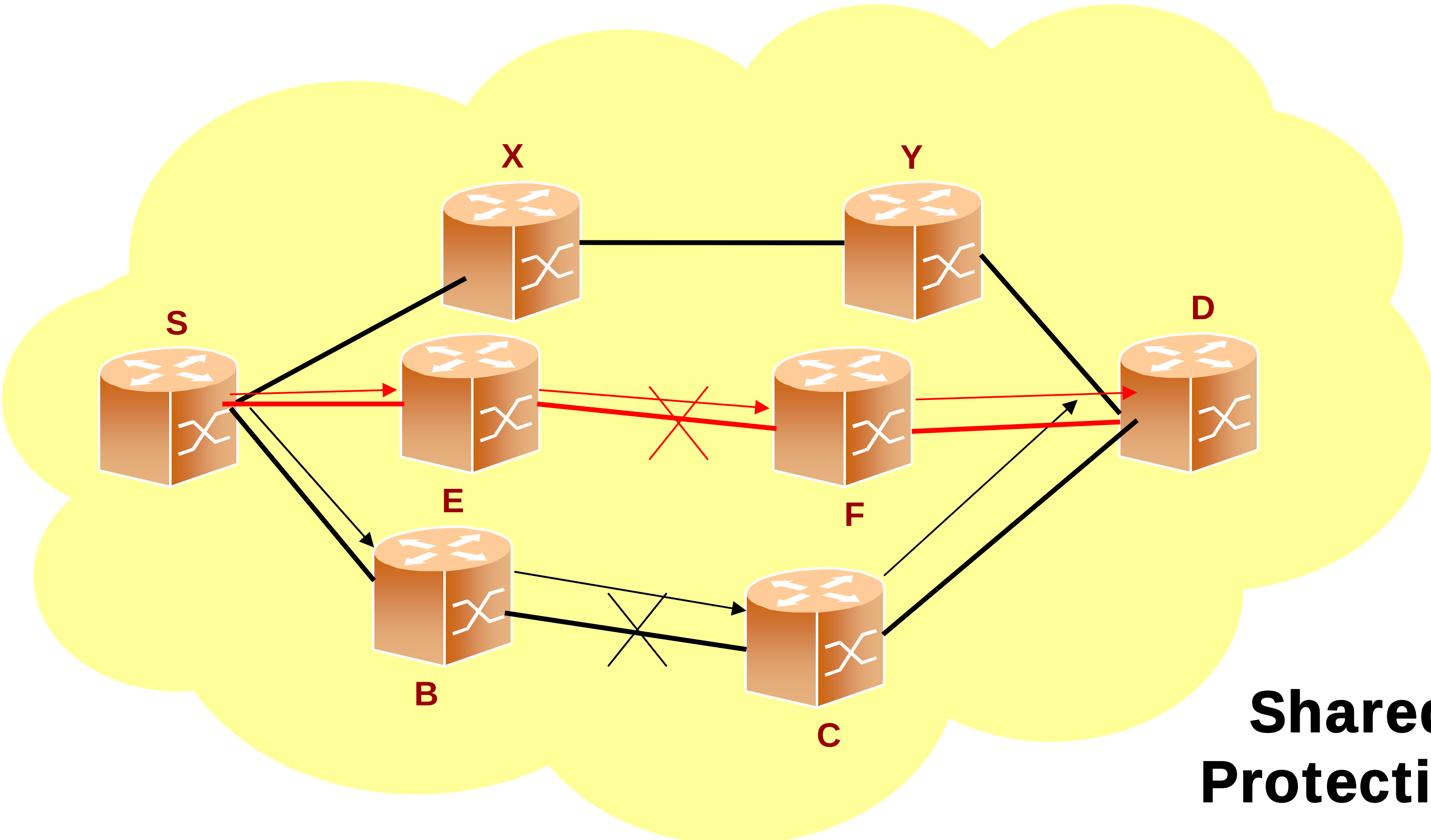


Dedicated Protection: 2:1

Dedicated Protection Analysis

- Advantages
  - Availability is increased by several orders of magnitude
  - Excluding the multiple concurrent failure scenario, Availability = 100%
- Drawbacks:
  - Resource redundancy = 100%

Shared Protection



Shared Protection

Shared Protection Analysis

- Advantages
  - Less resources are needed for protection compared to dedicated protection case
- Drawbacks:
  - Less Availability is obtained in case of multiple failures

Our Proposition

- Priority-Aware Shared Protection Scheme

Priority-Aware Shared Protection

- A new scheme exploiting the advantage of dedicated and shared protection may be realized

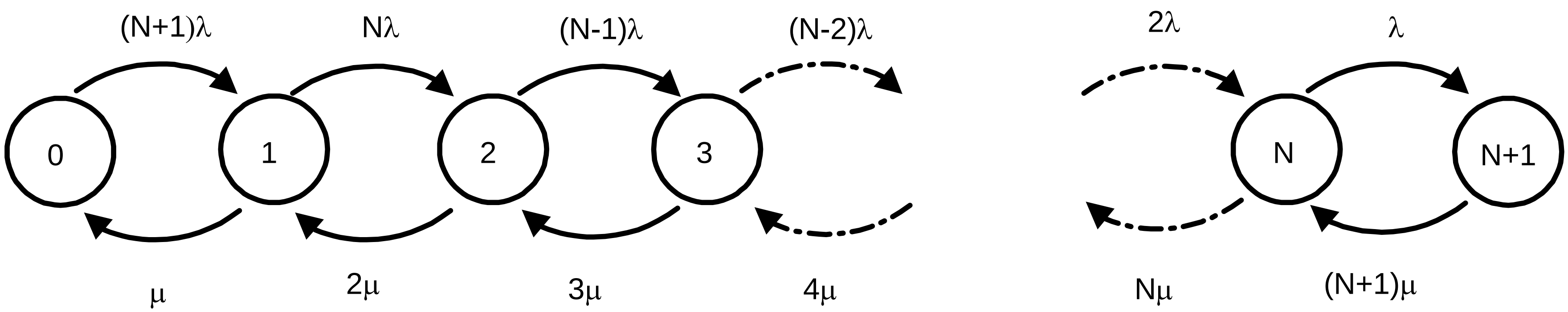
- Instead of equally treating the N connections sharing the protection channel:
  - A notion of service differentiation may be introduced
- So, N_G Gold connections and N_S Silver connections may share the same backup path.
- Gold connections can preempt Silver ones in the utilization of backup resources.

Mathematical Models

- For both Classical and Priority Aware protection Schemes
- We compute the Availability for every connection

Analysis of 1:N protection without Service Differentiation

- We have *N* working paths protected by a single protection path
- The system can be modeled with a Markov Chain having N+1 states
- State *i* = *i* paths (including Working and Protection paths) are down



- Steady State Probability:

$$p(n) = \binom{N+1}{n} \overline{A}^n A^{N+1-n} = \binom{N+1}{n} \left(\frac{\rho}{1+\rho}\right)^n \left(\frac{1}{1+\rho}\right)^{N+1-n} = \binom{N+1}{n} \frac{\rho^n}{(1+\rho)^{N+1}}$$

$$\binom{N+1}{n} = \frac{(N+1)!}{n!(N+1-n)!}$$

$$\begin{cases} \lambda = \text{Mean Failure Rate} \\ \mu = \text{Mean Repair Rate} \\ \rho = \dfrac{\lambda}{\mu} \end{cases}$$

Analysis of 1:N protection without Service Differentiation

- Performance of the 1:N Protection Scheme:
  - Mean Unavailability:

$$U(N,\lambda,\mu)=\sum_{n=2}^{N+1}\frac{(n-1)}{N}\,p(n)$$

- Nello stato n, per $n>=2$, ci sono infatti (n-1) connessioni non protette sul totale delle N connessioni
- La probabilità che, nello stato n, una connessione scelta a caso fra le N sia proprio tra le (n-1) non protette è data dal rapporto (n-1)/N

Analysis of 1:N protection with Service Differentiation

- We have N_G Gold connections, N_S Silver connections

- Mean Unavailability for the Gold and Silver Connections:

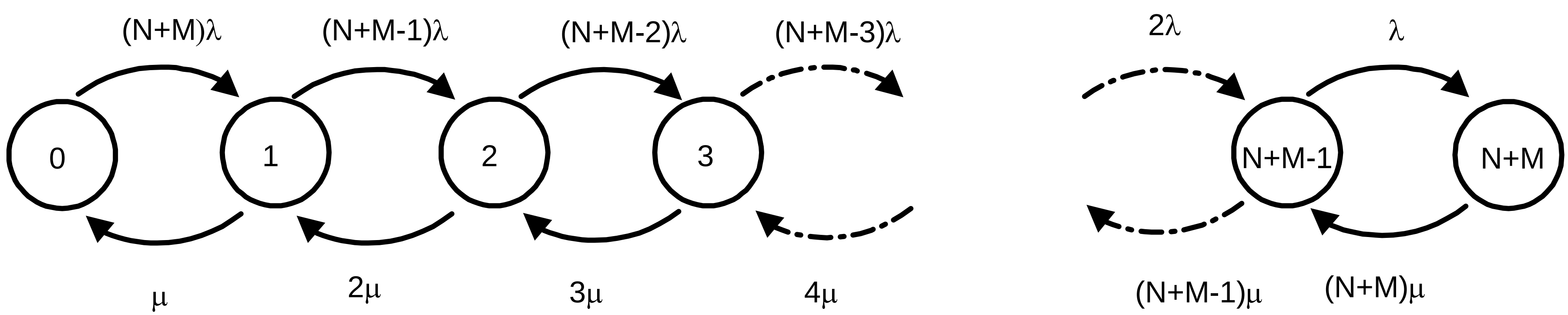
$$U_G(N_G,\lambda,\mu)=\sum_{n=2}^{N_G+1}\frac{(n-1)}{N_G}\,p(n)$$

$$U_S(N,N_G,\lambda,\mu)=\frac{U(N,\lambda,\mu)\cdot N-U_G(N_G,\lambda,\mu)\cdot N_G}{N_S}$$

- Le connessioni Gold è come se “non vedessero” neanche quelle Silver, viste che possono “preemptarle” nell’occupare il cammino di backup. Quindi l’unavailability U_G di una connessione Gold è pari a quella di una connessione in un sistema con protezione 1:N_G
- L’unavailability totale U si conserva.

Analysis of M:N protection without Service Differentiation

- We have *M* Protection paths protecting *N* Working paths
- We model the system with a Markov Chain with N+M states
- State *i* = *i* paths (including Working and Protection paths) are down



- Steady State Probability:

$$p(n) = \binom{N+M}{n} \overline{A}^n A^{N+M-n} = \binom{N+M}{n} \left(\frac{\rho}{1+\rho}\right)^n \left(\frac{1}{1+\rho}\right)^{N+M-n} = \binom{N+M}{n} \frac{\rho^n}{(1+\rho)^{N+M}}$$

Analysis of M:N protection without Service Differentiation

- Performance of the M:N Protection Scheme:
  - Mean Unavailability:

$$U(N,M,\lambda,\mu)=\sum_{n=M+1}^{N+M}\frac{(n-M)}{N}p(n)$$

- Nello stato n, per $n>=M+1$, ci sono infatti $(n-M)$ connessioni non protette sul totale delle N connessioni
- La probabilità che, nello stato n, una connessione scelta a caso fra le N sia proprio tra le $(n-M)$ non protette è data dal rapporto $(n-M)/N$

Analysis of M:N protection with Service Differentiation

- We have N_G Gold connections, N_S Silver connections
- Mean Unavailability for the Gold and Silver Connections:

$$U_G(N_G, M, \lambda, \mu) = \sum_{n=M+1}^{N_G+M} \frac{(n-M)}{N_G} p(n)$$

$$U_S(N, N_G, M, \lambda, \mu) = \frac{U(N, M, \lambda, \mu) \cdot N - U_G(N_G, M, \lambda, \mu) \cdot N_G}{N_S}$$

- Mean Frequency of Failure for the Gold and Silver Connections:

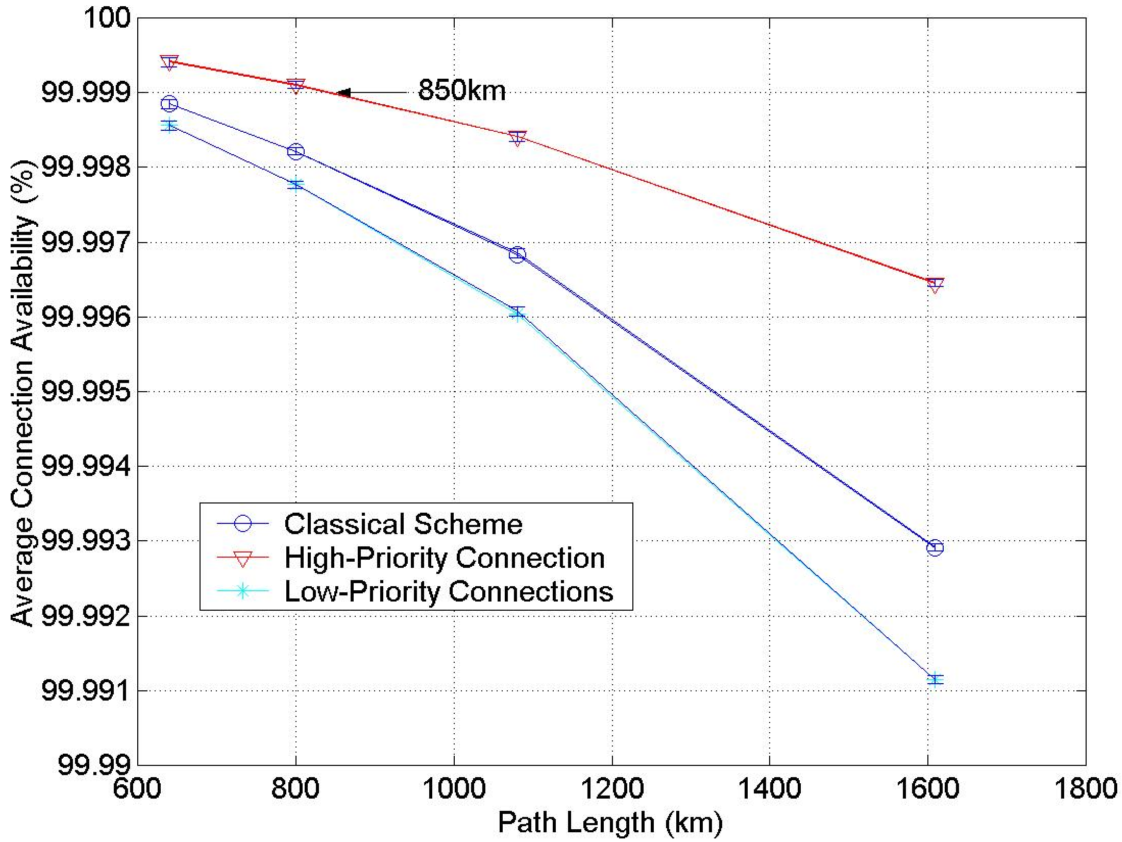
$$F_G(N_G, M, \lambda, \mu) = \lambda \sum_{n=M}^{N_G+M-1} (1 - \frac{n-M}{N_G}) \cdot p(n)$$

$$F_S(N, N_G, M, \lambda, \mu) = \frac{F(N, M, \lambda, \mu) \cdot N - F_G(N_G, M, \lambda, \mu) \cdot N_G}{N_S}$$

Numeric Results

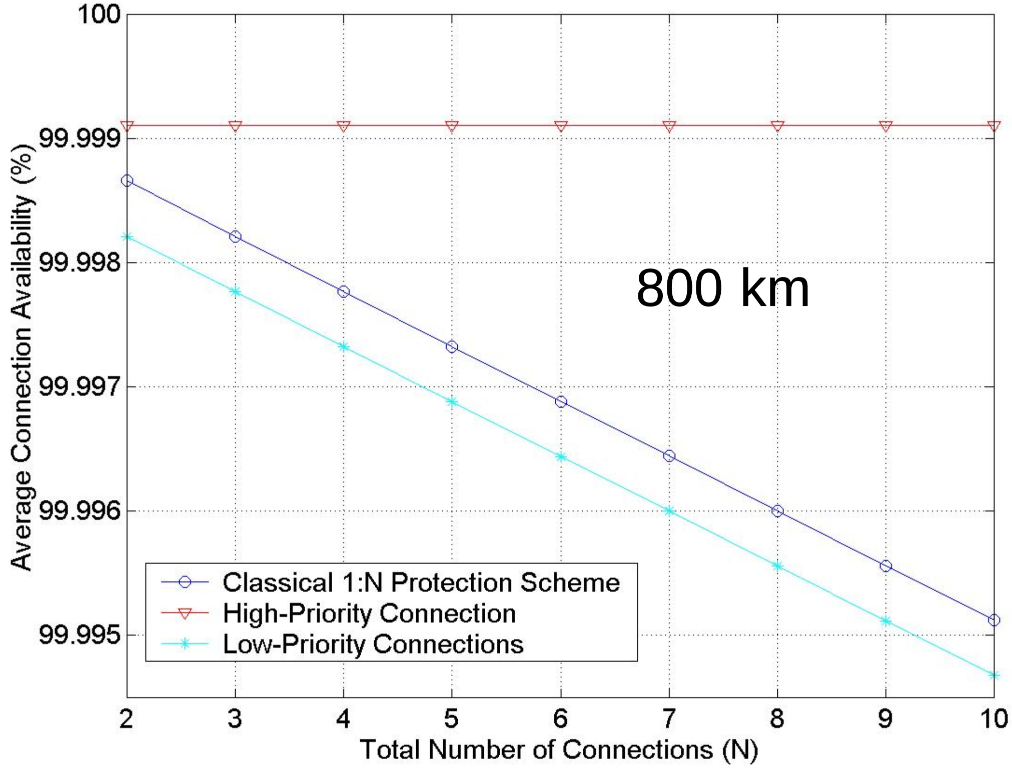
- Based on the mathematical we defined for each protection scheme the resulting availability

Numeric Results: 1:3 Protection



- The Priority-Aware scheme allows the provisioning of one Platinum connection (99.999%), which was impossible with the classical scheme.
- Two Gold connections can be provisioned (Availabilty > 99.99%)

Numeric Results: 1:N Protection



- The Priority-Aware scheme allows the deployment of one Platinum connection (99.999%) for every value of N
- N-1 Gold connections can be provisioned (Availability > 99.99%)

Conclusions

- We proposed an improvement of the classical shared protection based on relative priorities
- We developed a detailed mathematical model to gauge the impact of our proposition
- We showed that service differentiation is better achieved through the use of our proposed protection scheme
- We developed a simulation study, showing that the proposed scheme achieves high Availability Satisfaction Rates while realizing cost-effectiveness in terms of resource usage in the network.