NORTEL
NORTHERN TELECOM

Frame Relay Network Engineering

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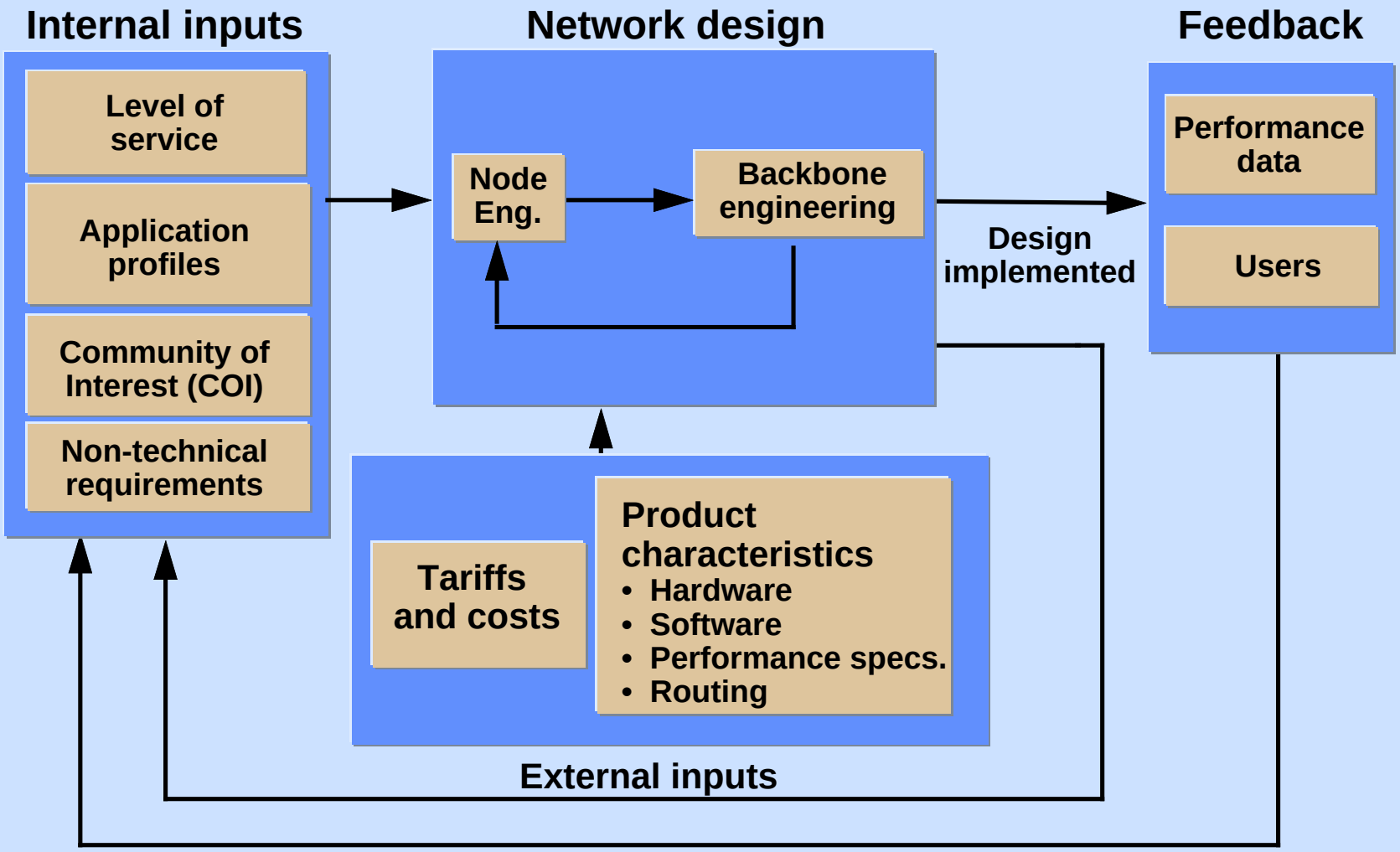
Agenda

- **The Frame Relay Explosion**
- The Network Design Process
- Frame Relay Network Design Parameters
- Frame Relay Access Design Parameters
- Magellan Congestion Management
- Frame Relay NNI
- Case Study
- Summary

The Frame Relay Explosion

- **Increased peer-to-peer LAN traffic over the WAN**
- **Multiplexed mesh topologies cost effective**
- **Multiple transport options and bandwidth accounting options**
- **Frame relay is widely available and accepted**
- **Frame relay is a necessary step for multimedia, transition to ATM**

The Network Design Process



Frame Relay Network Design Parameters

- Design perspective
- Number of sites and DLCI's per site
- Applications riding the network
  - Delay and throughput requirements
  - CIR and EIR values
- Financial resources
- Oversubscription strategy

Oversubscription

- **Objective to minimize backbone bandwidth required to carry user data**
- **Requirements have statistical distribution**
- **Congestion and traffic management impacts**
- **Typically use values of 3.5 to 8**

Frame Relay Access Design Parameters

- **Study applications**
  - **identify the required traffic classes**
    - **delay and throughput requirements**
    - **frame loss tolerance**
  - **determine the line speed**
  - **frame size is dependent on application**
- **Assign traffic profiles for each DLCI**
  - **decide on CIR and EIR**
  - **verify trunks have sufficient bandwidth for the frame size**

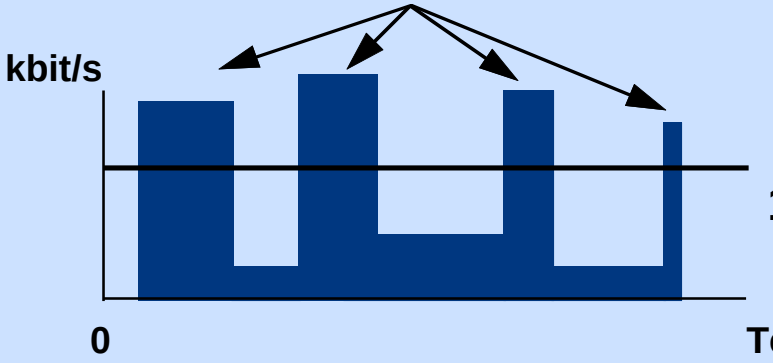
Assign Traffic Profiles per DLCI

- **Mission critical traffic: CIR = peak**
- **Interactive traffic: CIR = averaged burst**
- **Background traffic:**
  - **CIR = 0**
  - **EIR = average bandwidth required**
- **File transfers:**
  - **CIR = Avg. file length (kbytes)/acceptable transfer time**
  - **EIR = (Peak - CIR)**

Engineering CIR and EIR

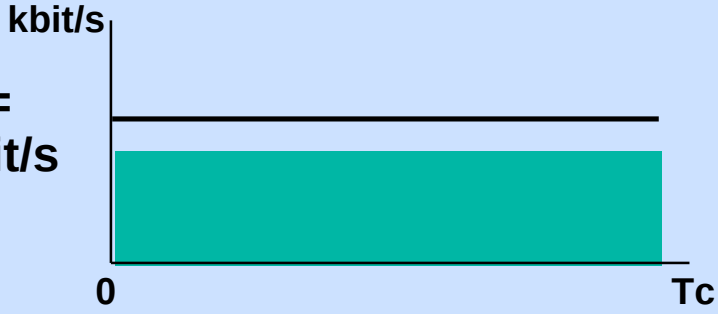
- **Bursts can be absorbed by the network**
- **Fast forward technique minimizes delay**

Bursts of data exceeding CIR allowed as long as <u>average</u> traffic does not exceed 128 kbit/s over a time interval of Tc



CIR = 128 kbit/s

Average traffic does not exceed CIR

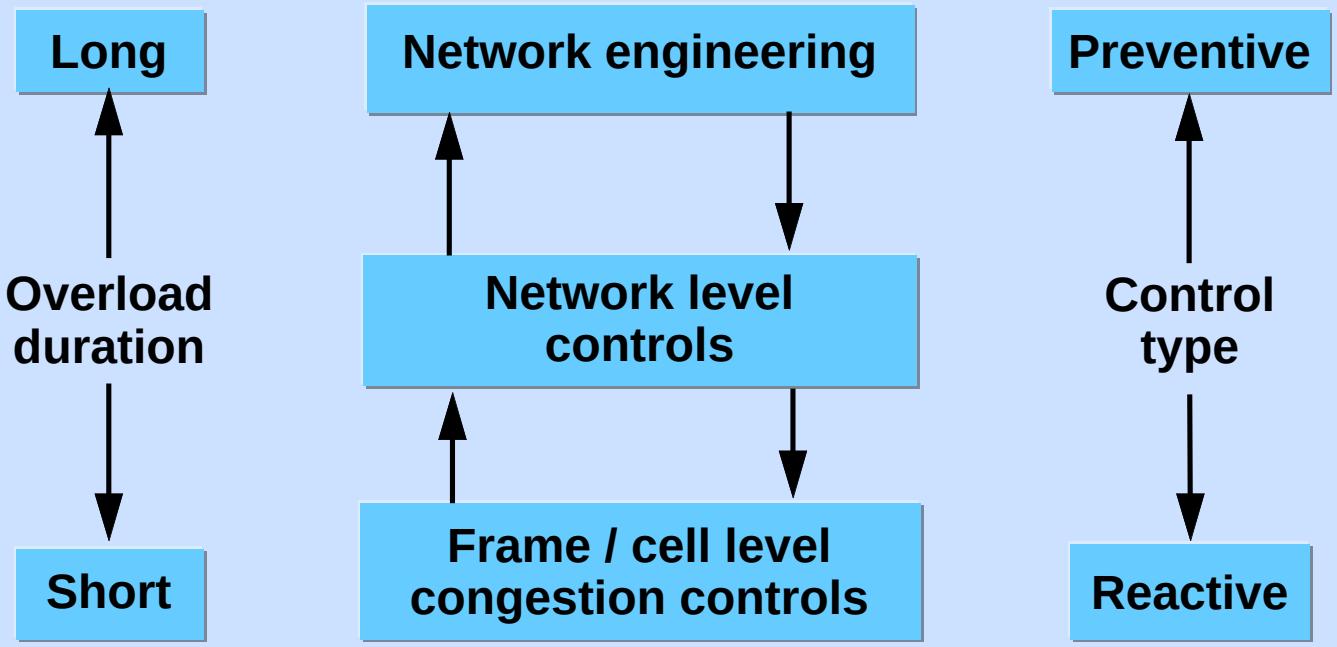


Magellan Congestion Management

- **Overall strategy**
- **Traffic slasses and quality of service**
- **Magellan dynamic routing**
- **Loadsharing and loadspreading**
- **Failure recovery**
- **Impacts of oversubscription**

Congestion management simplifies engineering

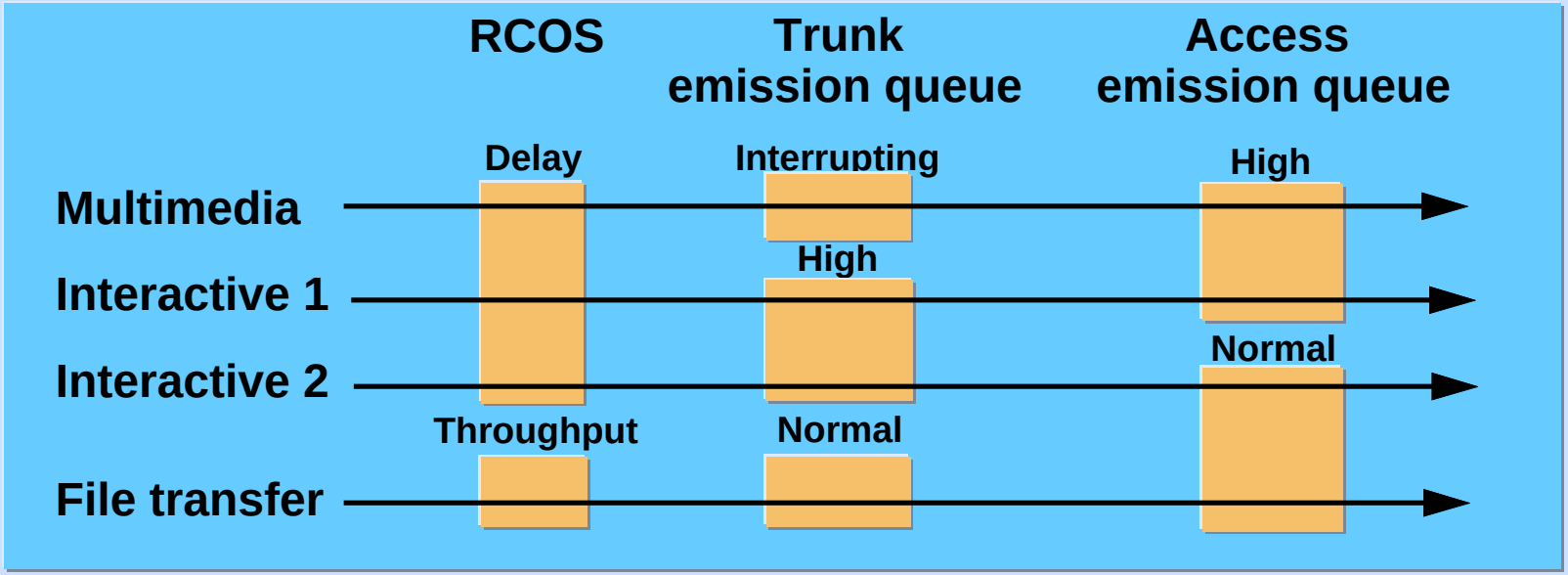
Overall Strategy



Proper network engineering is critical

Traffic Classes

- **Select traffic handling preferences**
  - **urgency → emission priority**
  - **importance → discard priority**
  - **reliability → overflow routing**
- **Traffic classes**



Traffic Classes (notes)

- **Notes continued**

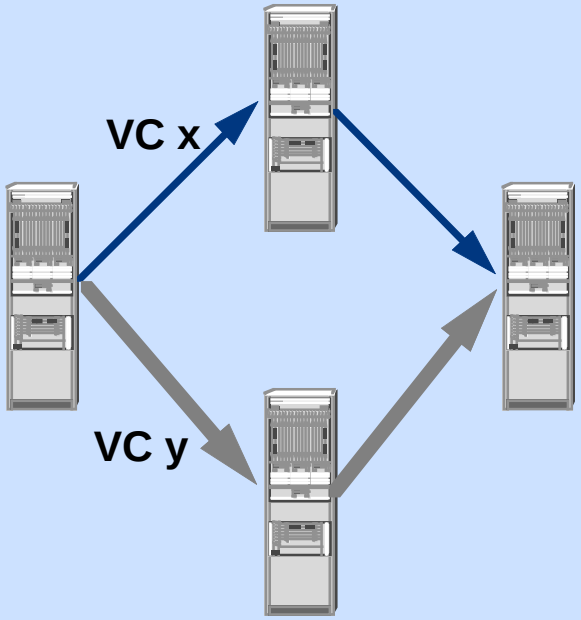
Magellan Dynamic Routing

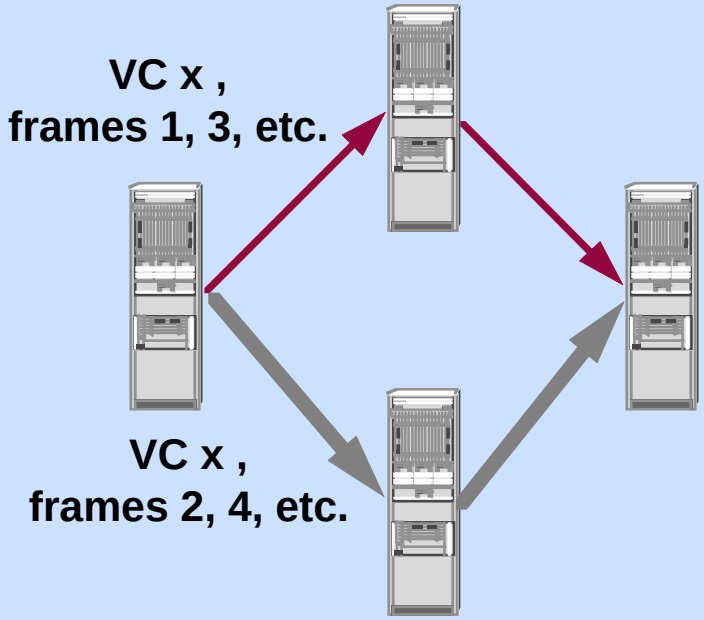
- **Offered traffic handled as an aggregate load simplifying network design**
  - **each packet contains routing information**
  - **each node makes independent decision**
  - **responds quickly to congestion or failure**
  - **alternate routing**
- **Trunk can be used as soon as available**
  - **no delay for discovery of new node**

Simplified deployment of the network

Loadsharing and Loadspreading

- **Loadspreading**
  - **spreads VC's over links**
- **Loadsharing**
  - **distributes frames in a VC over links**
  - **sharing helps prevent congestion**



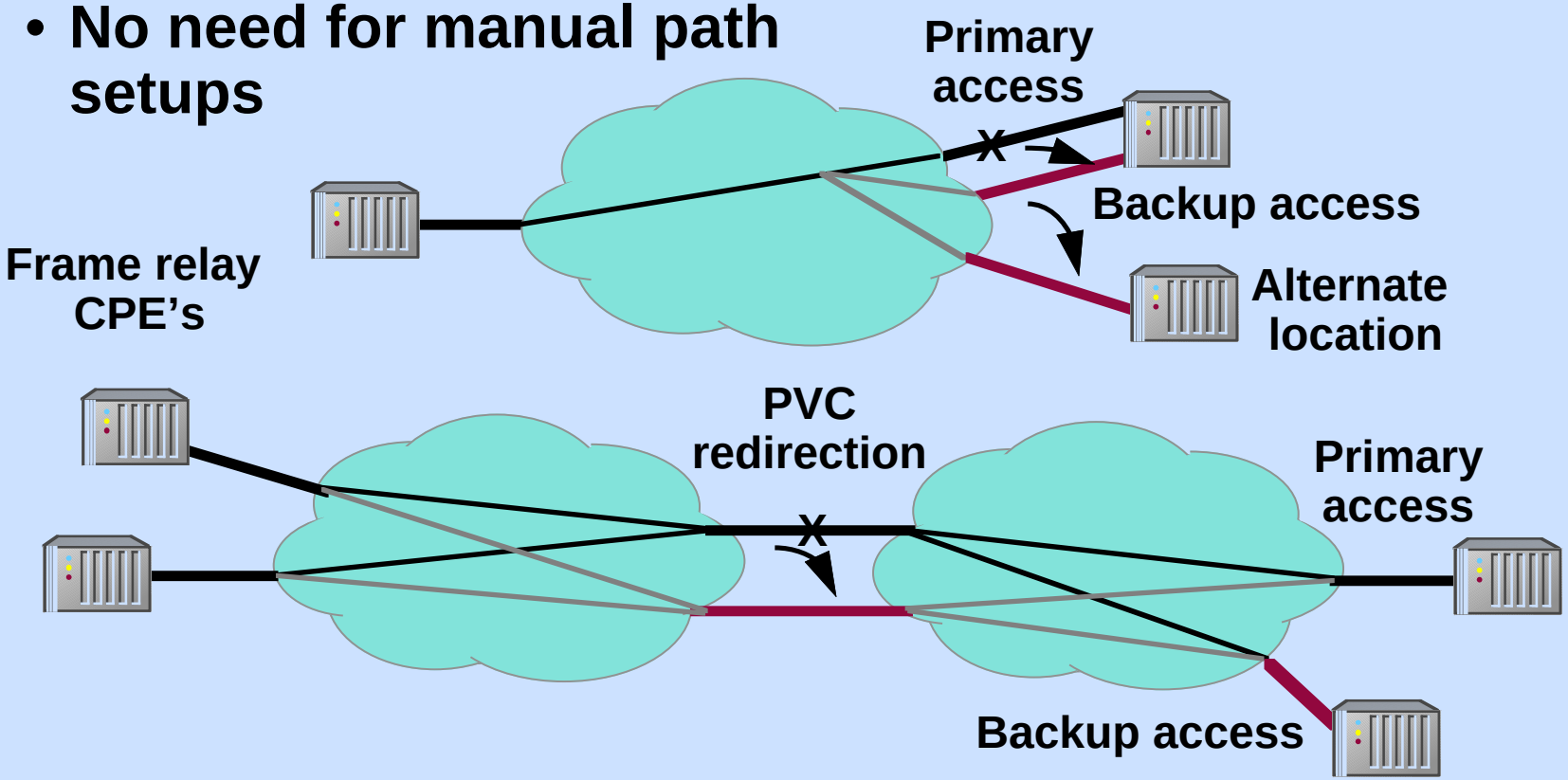


Failure Recovery

- **Circuit re-establishment**
  - **dynamic packet routing system**
  - **no need to provision alternate facilities**
  - **engineer trunk capacity to carry overflow in event of failure**
- **UNI/NNI resiliency**

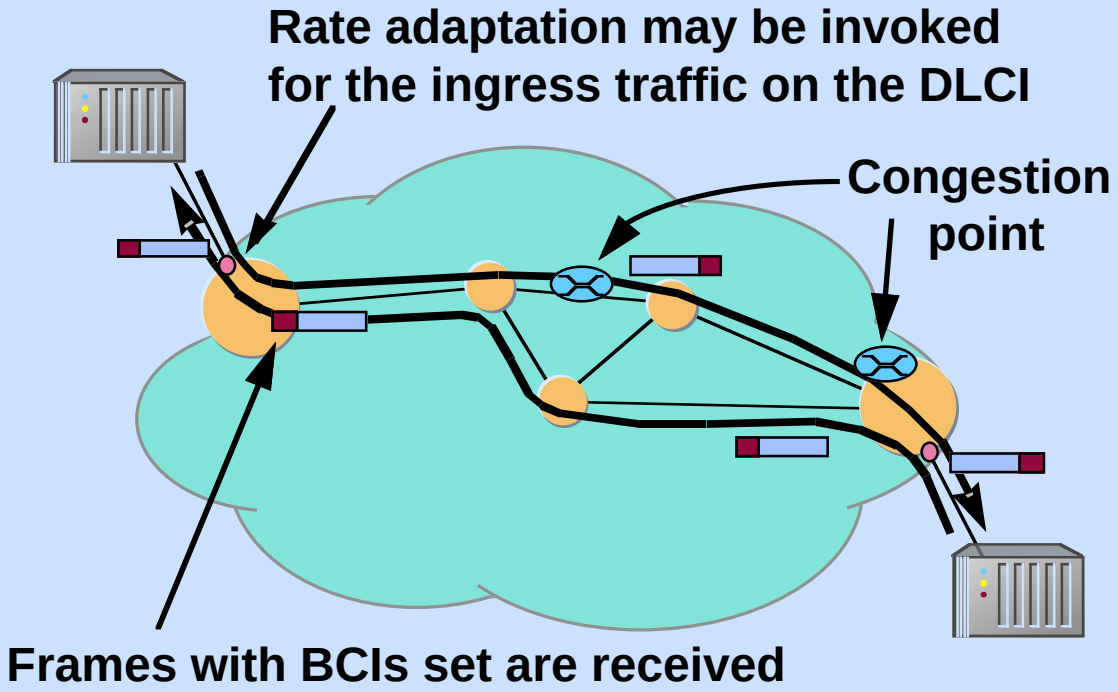
FR UNI/NNI Resiliency

- Automatic routing to alternate site
- Allows fair delivery of all offered traffic
- No need for manual path setups

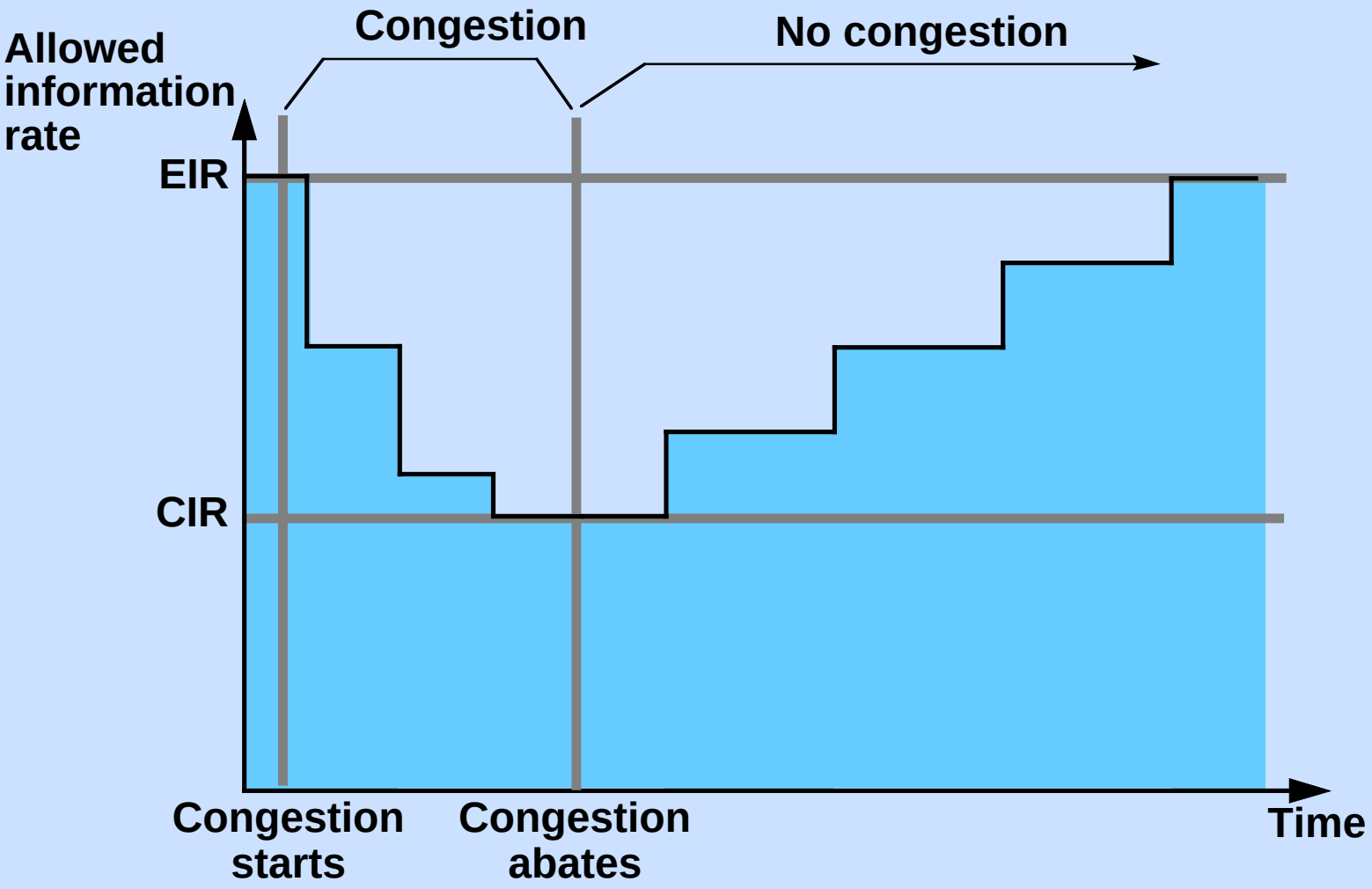


The Impacts of Oversubscription

- Network cannot rely on user to respond to congestion notifications
- Use allowed information rate mechanism

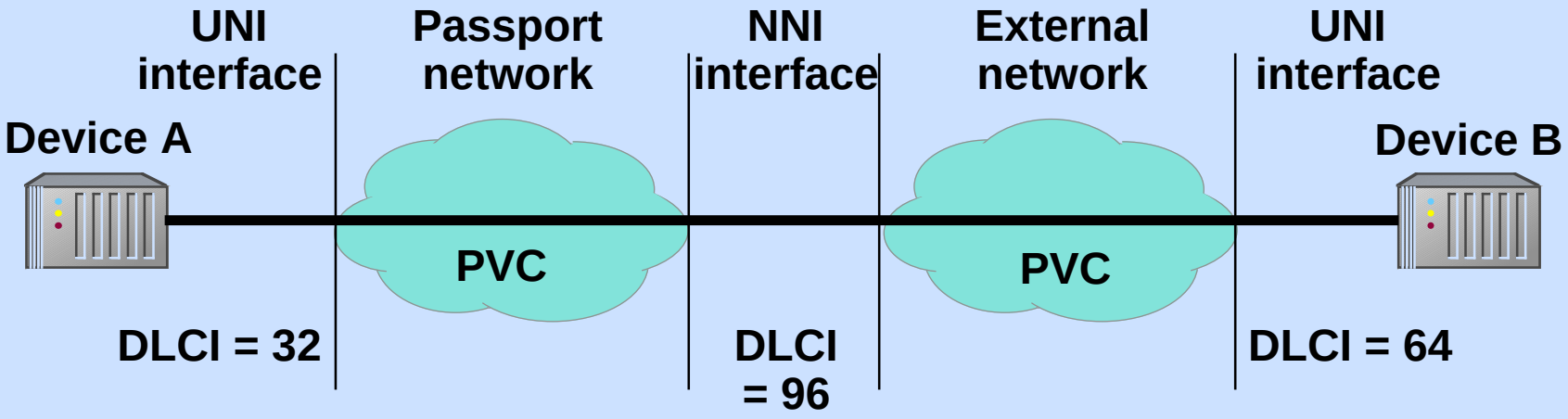


AIR Procedure



Frame Relay NNI

- Multi-carrier, or private NNI
- Engineering guidelines



NNI works well today!

Frame Relay NNI (notes only)

- NNI is operational today
- Standards compliance
  - Nortel editorship of X.76
  - Annex D of T1.617 (ANSI)
  - Annex A of Q.933 (ITU-T)
- Other activity
  - regular contributor to frame relay Forum Technical Committee
  - chair of Frame Relay Forum Market Development and Education committee

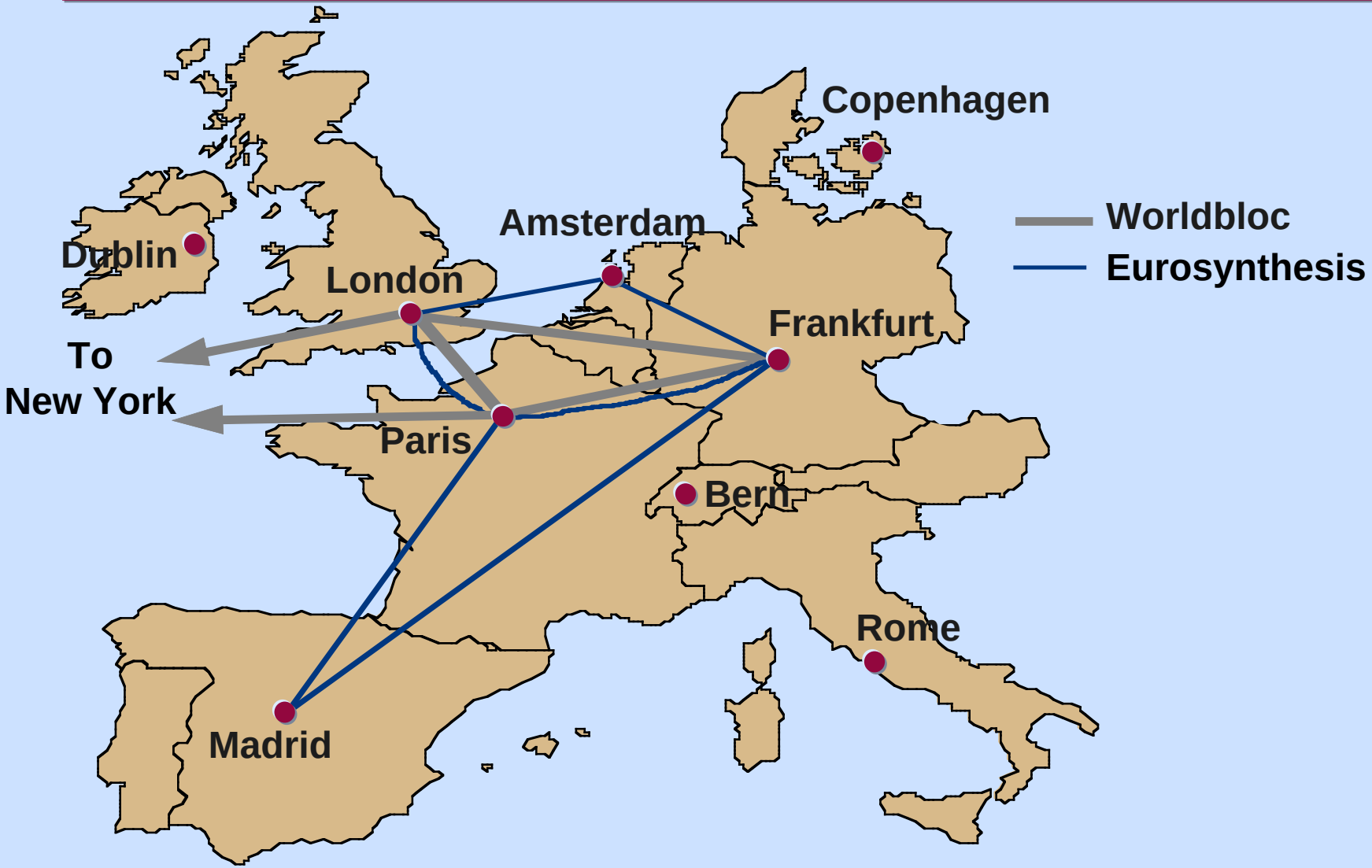
NNI Engineering Guidelines

- **Coordination with UNIs**
- **Where available, use co-located platforms to minimize facilities costs and maximize availability**
- **Use natural interconnection points at high speed**
- **Initially engineer sum of CIRs < NNI access rate, then develop oversubscription strategy for each NNI**
- **Where possible, provision alternate NNI**

NNI Engineering Guidelines

- **Rate enforcement**
  - **traffic shape may have been altered**
- **Rate adaptation**
  - **faster reaction to potential congestion**

Case Study


Copenhagen
Amsterdam
Dublin
London
Frankfurt
To
New York
Paris
Bern
Rome
Madrid
Worldbloc
Eurosynthesis

Customer Information

- **Generated traffic proportional to country population**
- **Worldbloc uses Passport**
- **Eurosynthesis uses another vendor**

Design Requirements

- **Optimize design for cost of leased facilities**
- **Design should survive single link failures**
- **Average frame delay < 90 ms**
- **Average trunk utilization < 80%**
- **Ease of NNI implementation**

Design Assumptions

- Average frame size is 256 bytes
- Standard deviation is 128 bytes
- Backbone trunking is terrestrial
- Bandwidth is available in N*128 kbit/s increments
- Nodal delay is 0.18 ms
- Prices are based on simulated tariffs

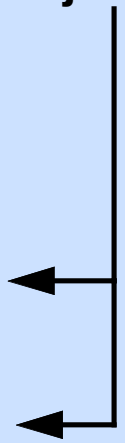
Eurosynthesis Current Network

Network Summary	Normal	Failure
Average Frame Relay Data Field (bytes)	256	256
Standard Deviation of Data Field (bytes)	128	128
Average Mesh Path Delay Per Frame (ms)	5.6	7.5
Average Frame Relay Access Speed (kbps)	256	256
Average Access + CIR Delay Per Frame (ms)	16.6	16.6
Average Total Delay Per Frame (ms)	22.2	24.2
Trunk Cost (Pounds/Month)	45,480	45,480
Data Traffic Carried (Mbit/s)	3.969	3.969
Average Trunk Utilization (Total)	24.1%	30.6%

Bandwidth Summary

				Normal		Failure	
Source	Dest	km	Available BW (kbps)	Used Tot BW	% Tot Util	Used Tot BW	% Tot Util
Amsterdam	Frankfurt	361	1920	518	26.1	1053	54.8
Amsterdam	London	311	1920	565	28.5	962	50.1
Frankfurt	Amsterdam	361	1920	609	30.7	1144	59.6
Frankfurt	Madrid	1158	1920	353	17.8	546	28.4
Frankfurt	Paris	482	1920	450	22.7	792	41.3
London	Amsterdam	311	1920	539	27.1	935	48.7
London	Paris	362	1920	535	27.0	0	0.0
Madrid	Frankfurt	1158	1920	299	15.1	476	24.8
Madrid	Paris	925	1920	359	18.1	181	9.5
Paris	Frankfurt	482	1920	398	20.0	755	39.3
Paris	London	362	1920	535	26.9	0	0.0
Paris	Madrid	925	1920	390	19.7	198	10.3

Failed major link

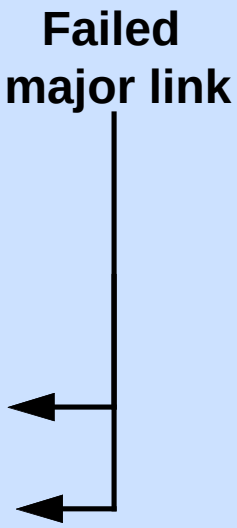


Worldbloc Current Network

Network Summary	Normal	Failure
Average Frame Relay Data Field (bytes)	256	256
Standard Deviation of Data Field (bytes)	128	128
Average Mesh Path Delay Per Frame (ms)	30.2	34.2
Average Frame Relay Access Speed (kbps)	256	256
Average Access + CIR Delay Per Frame (ms)	16.6	16.6
Average Total Delay Per Frame (ms)	46.9	50.8
Trunk Cost (Pounds/Month)	149,364	149,364
Data Traffic Carried (Mbit/s)	3.072	3.072
Average Trunk Utilization (Total)	23.5%	28.4%

Bandwidth Summary

				Normal		Failure	
Source	Dest	km	Available BW (kbps)	Used Tot BW	% Tot Util	Used Tot BW	% Tot Util
Frankfurt	London	601	1920	0	0.0	657	34.2
Frankfurt	Paris	482	1920	657	34.2	0	0.0
London	Frankfurt	601	1920	0	0.0	657	34.2
London	New York NY	5569	1920	465	24.2	1595	83.1
London	Paris	362	1920	0	0.0	473	24.6
New York NY	London	5569	1920	465	24.2	1595	83.1
New York NY	Paris	5539	1920	1130	58.9	0	0.0
Paris	Frankfurt	482	1920	657	34.2	0	0.0
Paris	London	362	1920	0	0.0	473	24.6
Paris	New York NY	5539	1920	1130	58.9	0	0.0



Where Locate NNI Interface

- **How will additional traffic affect Worldbloc network**
- **How will NNI point affect flows in Eurosynthesis network**
- **Access closest to traffic source, or gateway**
- **Impact of link failure**

NNI in London - Impact on Eurosynthesis

Network Summary	Normal	Failure
Average Frame Relay Data Field (bytes)	256	256
Standard Deviation of Data Field (bytes)	128	128
Average Mesh Path Delay Per Frame (ms)	6.1	162.3
Average Frame Relay Access Speed (kbps)	256	256
Average Access + CIR Delay Per Frame (ms)	16.6	16.6
Average Total Delay Per Frame (ms)	22.8	178.9
Trunk Cost (Pounds/Month)	45,480	45,480
Data Traffic Carried (Mbit/s)	5.809	5.809
Average Trunk Utilization (Total)	37.5%	40.0%

Failed major link

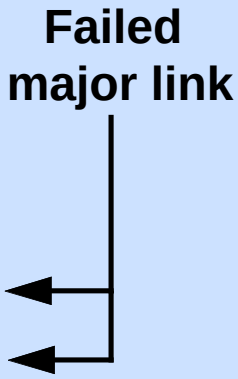
Bandwidth Summary				Normal		Failure	
			Available	Used	%	Used	%
Source	Dest	km	BW (kbps)	Tot BW	Tot Util	Tot BW	Tot Util
Amsterdam	Frankfurt	361	1920	914	47.6	329	17.1
Amsterdam	London	311	1920	1038	54.1	0	0.0
Frankfurt	Amsterdam	361	1920	1006	52.4	394	20.5
Frankfurt	Madrid	1158	1920	353	18.4	353	18.4
Frankfurt	Paris	482	1920	450	23.5	1488	77.5
London	Amsterdam	311	1920	1011	52.7	0	0.0
London	Paris	362	1920	1018	53.0	1890	98.5
Madrid	Frankfurt	1158	1920	299	15.6	299	15.6
Madrid	Paris	925	1920	556	28.9	556	28.9
Paris	Frankfurt	482	1920	398	20.7	1409	73.4
Paris	London	362	1920	1017	53.0	1917	99.8
Paris	Madrid	925	1920	587	30.6	587	30.6

NNI in London - Impact on Worldbloc

Network Summary	Normal	Failure
Average Frame Relay Data Field (bytes)	256	256
Standard Deviation of Data Field (bytes)	128	128
Average Mesh Path Delay Per Frame (ms)	32.4	Fail
Average Frame Relay Access Speed (kbps)	256	256
Average Access + CIR Delay Per Frame (ms)	16.6	16.6
Average Total Delay Per Frame (ms)	49.1	Fail
Trunk Cost (Pounds/Month)	149,364	149,364
Data Traffic Carried (Mbit/s)	5.453	5.453
Average Trunk Utilization (Total)	36.3%	54.0%

Bandwidth Summary

				Normal		Failure	
Source	Dest	km	Available BW (kbps)	Used Tot BW	% Tot Util	Used Tot BW	% Tot Util
Frankfurt	London	601	1920	0	0.0	0	0.0
Frankfurt	Paris	482	1920	657	34.2	657	34.2
London	Frankfurt	601	1920	0	0.0	0	0.0
London	New York NY	5569	1920	1700	88.6	0	0.0
London	Paris	362	1920	0	0.0	1700	88.6
New York NY	London	5569	1920	1700	88.6	0	0.0
New York NY	Paris	5539	1920	1130	58.9	2830	147.4
Paris	Frankfurt	482	1920	657	34.2	657	34.2
Paris	London	362	1920	0	0.0	1700	88.6
Paris	New York NY	5539	1920	1130	58.9	2830	147.4

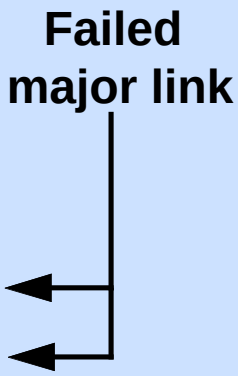


NNI in London - Impact on Worldbloc with New Capacity

Network Summary	Normal	Failure
Average Frame Relay Data Field (bytes)	256	256
Standard Deviation of Data Field (bytes)	128	128
Average Mesh Path Delay Per Frame (ms)	28.5	34.2
Average Frame Relay Access Speed (kbps)	256	256
Average Access + CIR Delay Per Frame (ms)	16.6	16.6
Average Total Delay Per Frame (ms)	45.1	50.8
Trunk Cost (Pounds/Month)	214,743	214,743
Data Traffic Carried (Mbit/s)	5.453	5.453
Average Trunk Utilization (Total)	21.6%	39.3%

Bandwidth Summary

				Normal		Failure	
Source	Dest	km	Available BW (kbps)	Used Tot BW	% Tot Util	Used Tot BW	% Tot Util
Frankfurt	London	601	1920	0	0.0	0	0.0
Frankfurt	Paris	482	1920	657	34.2	657	34.2
London	Frankfurt	601	1920	0	0.0	0	0.0
London	New York NY	5569	1920	1700	44.3	0	0.0
London	Paris	362	1920	0	0.0	1700	88.6
New York NY	London	5569	1920	1700	44.3	0	0.0
New York NY	Paris	5539	1920	1130	29.4	2830	73.7
Paris	Frankfurt	482	1920	657	34.2	657	34.2
Paris	London	362	1920	0	0.0	1700	88.6
Paris	New York NY	5539	1920	1130	29.4	2830	73.7



NNI in Paris - Impact on Eurosynthesis

Network Summary	Normal	Failure
Average Frame Relay Data Field (bytes)	256	256
Standard Deviation of Data Field (bytes)	128	128
Average Mesh Path Delay Per Frame (ms)	5.4	9.3
Average Frame Relay Access Speed (kbps)	256	256
Average Access + CIR Delay Per Frame (ms)	16.6	16.6
Average Total Delay Per Frame (ms)	22.0	26.0
Trunk Cost (Pounds/Month)	45,480	45,480
Data Traffic Carried (Mbit/s)	5.799	5.799
Average Trunk Utilization (Total)	33.0%	44.3%

Failed major link

Bandwidth Summary				Normal		Failure	
			Available	Used	%	Used	%
Source	Dest	km	BW (kbps)	Tot BW	Tot Util	Tot BW	Tot Util
Amsterdam	Frankfurt	361	1920	518	27.0	1409	73.4
Amsterdam	London	311	1920	641	33.4	1242	64.7
Frankfurt	Amsterdam	361	1920	609	31.7	1501	78.2
Frankfurt	Madrid	1158	1920	353	18.4	546	28.4
Frankfurt	Paris	482	1920	847	44.1	1545	80.5
London	Amsterdam	311	1920	614	32.0	1216	63.3
London	Paris	362	1920	891	46.4	0	0.0
Madrid	Frankfurt	1158	1920	299	15.6	476	24.8
Madrid	Paris	925	1920	556	28.9	379	19.7
Paris	Frankfurt	482	1920	794	41.4	1508	78.5
Paris	London	362	1920	891	46.4	0	0.0
Paris	Madrid	925	1920	587	30.6	395	20.5

NNI in Paris - Impact on Worldbloc

Network Summary	Normal	Failure
Average Frame Relay Data Field (bytes)	256	256
Standard Deviation of Data Field (bytes)	128	128
Average Mesh Path Delay Per Frame (ms)	28.6	34.6
Average Frame Relay Access Speed (kbps)	256	256
Average Access + CIR Delay Per Frame (ms)	16.6	16.6
Average Total Delay Per Frame (ms)	45.3	51.3
Trunk Cost (Pounds/Month)	214,743	214,743
Data Traffic Carried (Mbit/s)	5.453	5.453
Average Trunk Utilization (Total)	21.6%	39.4%

Failed major link

Bandwidth Summary				Normal		Failure	
			Available	Used	%	Used	%
Source	Dest	km	BW (kbps)	Tot BW	Tot Util	Tot BW	Tot Util
Frankfurt	London	601	1920	0	0.0	657	34.2
Frankfurt	Paris	482	1920	657	34.2	0	0.0
London	Frankfurt	601	1920	0	0.0	657	34.2
London	New York NY	5569	3840	465	12.1	2830	73.7
London	Paris	362	1920	0	0.0	1709	89.0
New York NY	London	5569	3840	465	12.1	2830	73.7
New York NY	Paris	5539	3840	2366	61.6	0	0.0
Paris	Frankfurt	482	1920	657	34.2	0	0.0
Paris	London	362	1920	0	0.0	1709	89.0
Paris	New York NY	5539	3840	2366	61.6	0	0.0

NNI in Frankfurt - Impact on Eurosynthesis

Network Summary	Normal	Failure
Average Frame Relay Data Field (bytes)	256	256
Standard Deviation of Data Field (bytes)	128	128
Average Mesh Path Delay Per Frame (ms)	5.8	8.9
Average Frame Relay Access Speed (kbps)	256	256
Average Access + CIR Delay Per Frame (ms)	16.6	16.6
Average Total Delay Per Frame (ms)	22.4	25.5
Trunk Cost (Pounds/Month)	45,480	45,480
Data Traffic Carried (Mbit/s)	5.585	5.585
Average Trunk Utilization (Total)	33.8%	37.3%

Failed major link

Bandwidth Summary				Normal		Failure	
			Available	Used	%	Used	%
Source	Dest	km	BW (kbps)	Tot BW	Tot Util	Tot BW	Tot Util
Amsterdam	Frankfurt	361	1920	874	45.5	0	0.0
Amsterdam	London	311	1920	846	44.1	329	17.1
Frankfurt	Amsterdam	361	1920	966	50.3	0	0.0
Frankfurt	Madrid	1158	1920	550	28.7	507	26.4
Frankfurt	Paris	482	1920	736	38.3	1654	86.1
London	Amsterdam	311	1920	819	42.7	394	20.5
London	Paris	362	1920	535	27.9	1409	73.4
Madrid	Frankfurt	1158	1920	496	25.8	448	23.3
Madrid	Paris	925	1920	359	18.7	407	21.2
Paris	Frankfurt	482	1920	683	35.6	1515	78.9
Paris	London	362	1920	535	27.8	1501	78.2
Paris	Madrid	925	1920	390	20.3	433	22.6

NNI in Frankfurt - Impact on Worldbloc

Network Summary	Normal	Failure
Average Frame Relay Data Field (bytes)	256	256
Standard Deviation of Data Field (bytes)	128	128
Average Mesh Path Delay Per Frame (ms)	62.2	63.8
Average Frame Relay Access Speed (kbps)	256	256
Average Access + CIR Delay Per Frame (ms)	16.6	16.6
Average Total Delay Per Frame (ms)	78.9	80.4
Trunk Cost (Pounds/Month)	214,743	214,743
Data Traffic Carried (Mbit/s)	5.453	5.453
Average Trunk Utilization (Total)	34.5%	39.4%

Failed major link

Bandwidth Summary				Normal		Failure	
			Available	Used	%	Used	%
Source	Dest	km	BW (kbps)	Tot BW	Tot Util	Tot BW	Tot Util
Frankfurt	London	601	1920	0	0.0	1893	98.6
Frankfurt	Paris	482	1920	1893	98.6	0	0.0
London	Frankfurt	601	1920	0	0.0	1893	98.6
London	New York NY	5569	1920	465	12.1	2830	73.7
London	Paris	362	1920	0	0.0	473	24.6
New York NY	London	5569	1920	465	12.1	2830	73.7
New York NY	Paris	5539	1920	2366	61.6	0	0.0
Paris	Frankfurt	482	1920	1893	98.6	0	0.0
Paris	London	362	1920	0	0.0	473	24.6
Paris	New York NY	5539	1920	2366	61.6	0	0.0

Location Summary

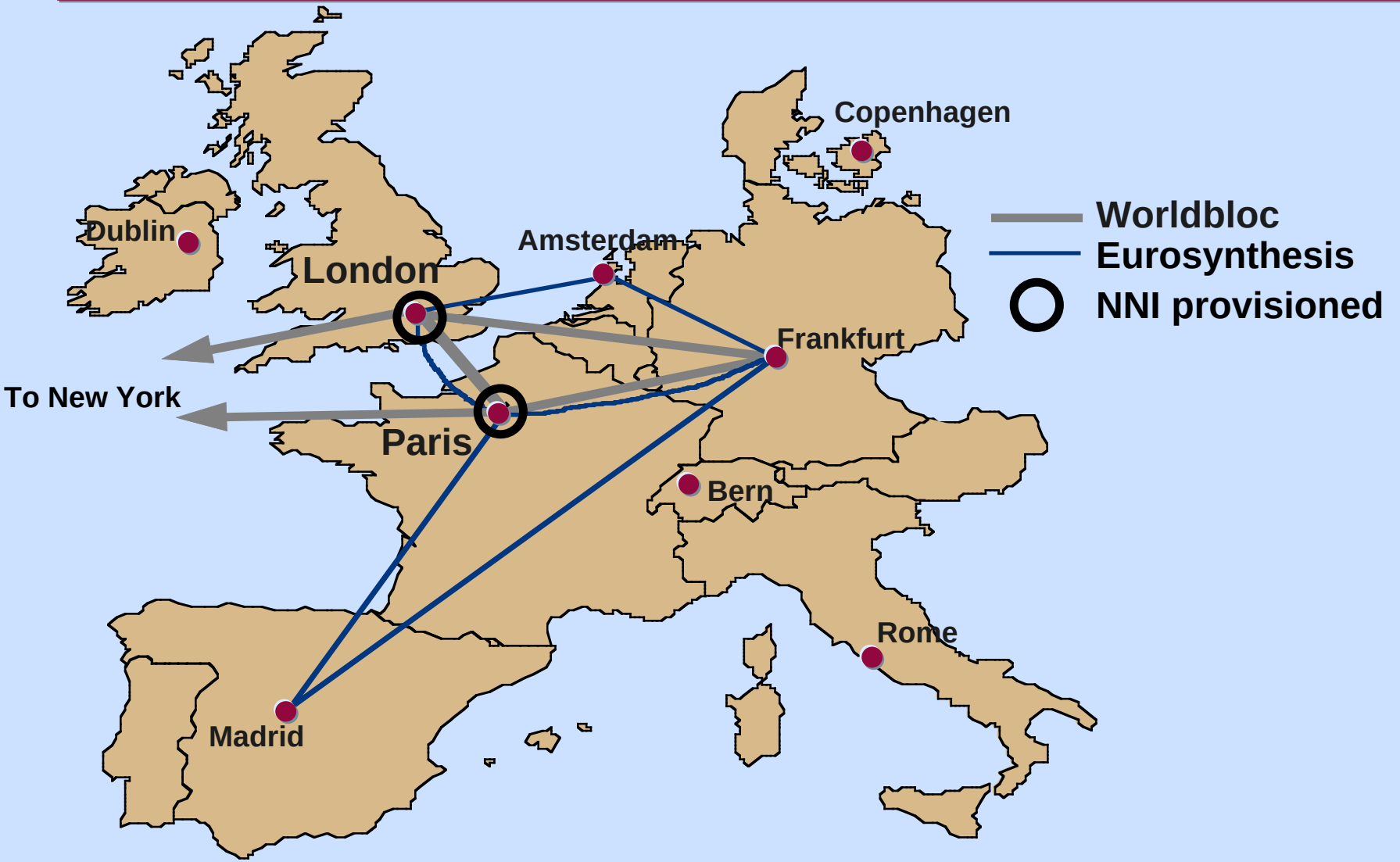
- **Compromise between the providers**

	London		Paris		Frankfurt	
	Eurosyn.	Worldbloc	Eurosyn.	Worldbloc	Eurosyn.	Worldbloc
Initial Capability	excellent	excellent	excellent	excellent	excellent	failure
Failure handling	failure	acceptable	good	adequate	acceptable	failure
Potential costs	one trunk	none	none	none	none	2 trunks

Multiple NNI interfaces

- **Provide enhanced reliability and survivability**
- **NNI resiliency at local node or distant node**
- **May provide more even distribution of offered traffic load on the networks**

Case Study Conclusion



Summary

- **Magellan products simplify task of network engineering**
  - **dynamic routing simplifies design**
  - **differentiate traffic with multiple classes**
  - **increase efficiency with loadspreading and loadsharing**
  - **exploit benefits of oversubscription**
- **NNI is operational today**
- **Frame relay engineering is evolving**
  - **focused on facilitating your growth and developing your business opportunities**