Service-driven Offline Inter-provider Traffic Engineering for End-to-end QoS Provisioning

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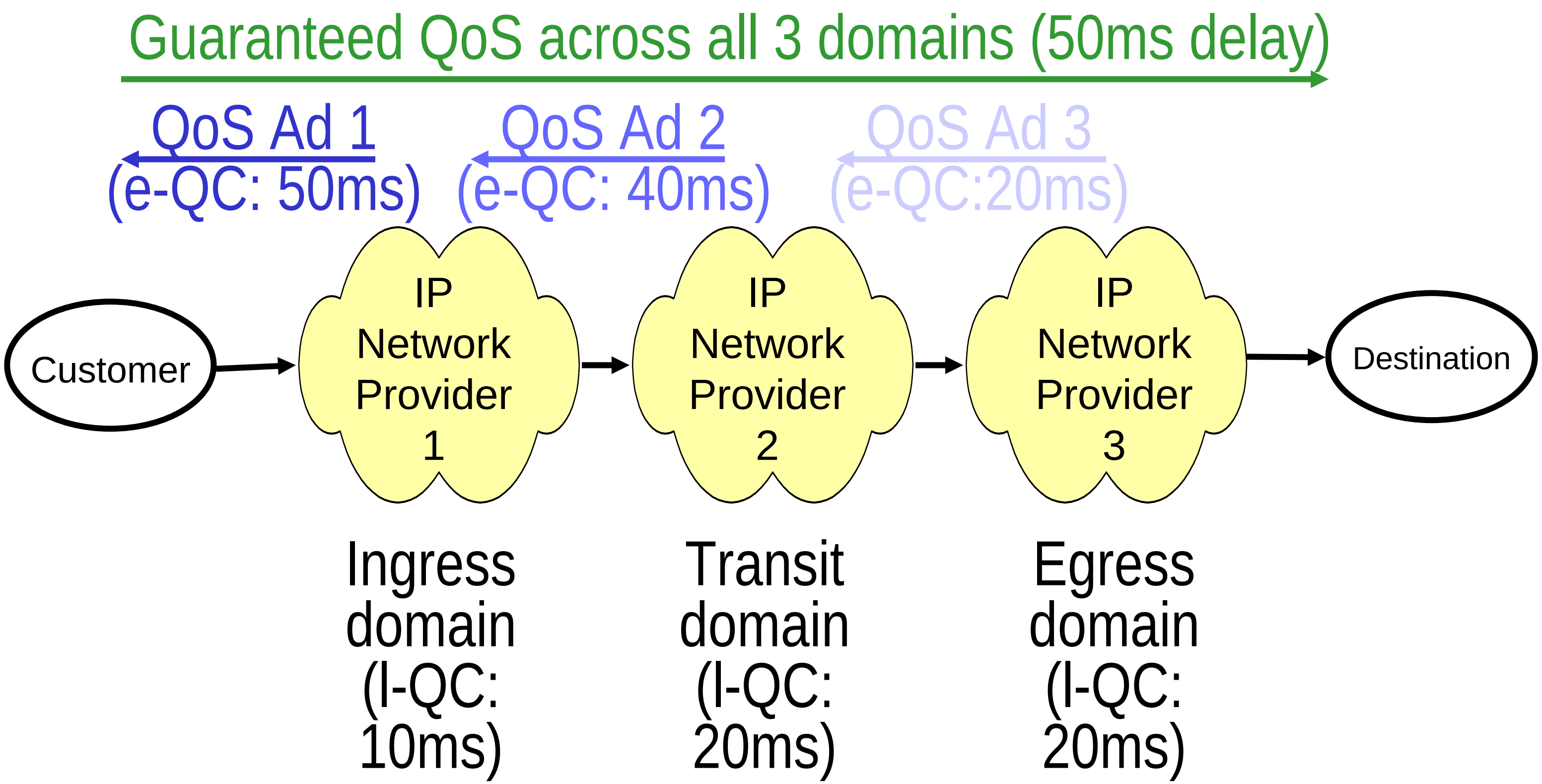
Overview

- Review cascaded model
- Offline Inter-domain TE architecture
  - Offline TE functions
  - Objectives in apportioning QoS values between domains
  - Genetic Algorithm (“Evolutionary Approach”) as an example heuristic
- Illustrative results

Cascaded QoS Model (review)

- Each domain can typically provide several l-QCs and e-QCs
- A domain has in general a choice of several downstream domains



Offline Inter-domain TE functions

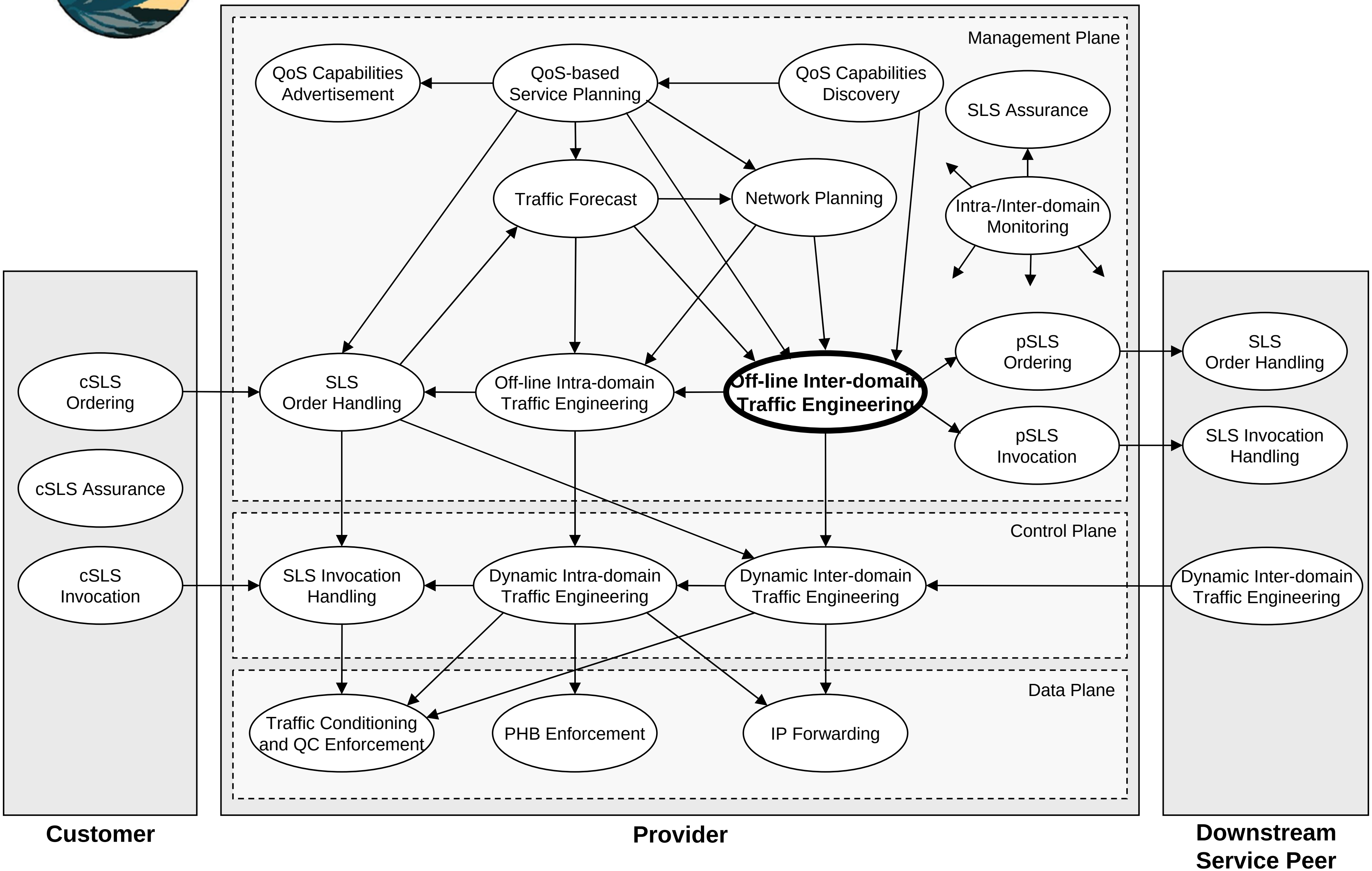
Given:

- Traffic Matrix (TM): predicted set of QoS-aware traffic aggregates
- QoS capabilities of this domain
- QoS advertisements from neighbouring domains
- Existing set of pSLSs (peer Service Level Specifications) with neighbouring domains

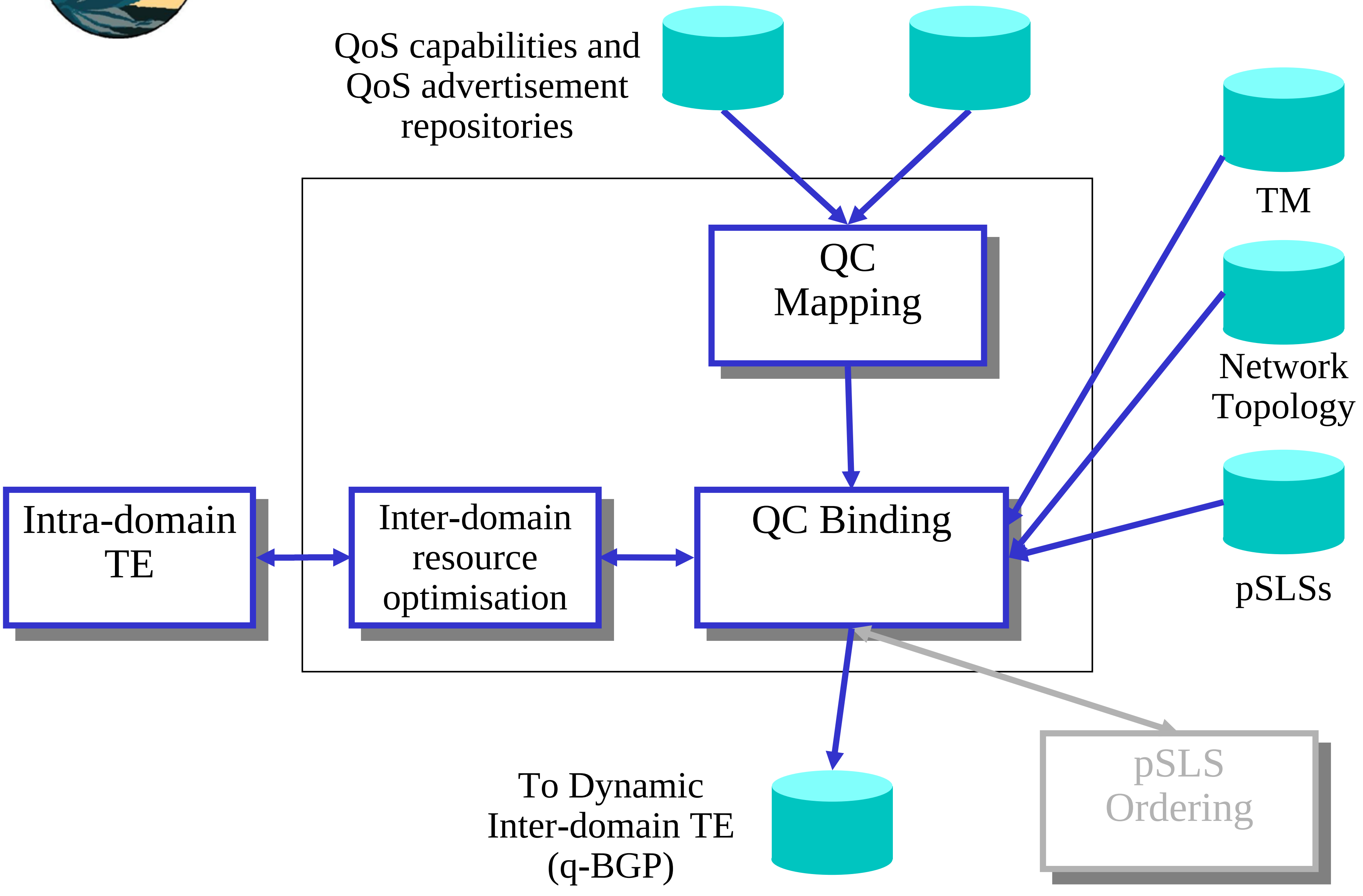
Calculate:

- For each aggregate: select an downstream domain and assign aggregate to l-QCs (within the domain) and e-QCs (in downstream domains)
- Determine optimum set of pSLSs:
  - New pSLSs to be ordered
  - Old pSLS to be ceased

MESCAL functional architecture (reminder)



Offline Inter-domain TE: functional overview



QC Mapping - example

- Assume delay to be the QoS metric
- Given QoS Classes:

$$\left\{ \begin{array}{l} e\text{-}QC_1 : 100\text{ ms} \\ e\text{-}QC_2 : 175\text{ ms} \end{array} \right\} = \left\{ \begin{array}{l} l\text{-}QC_1 : 25\text{ ms} \\ l\text{-}QC_2 : 50\text{ ms} \end{array} \right\} \oplus \left\{ \begin{array}{l} e\text{-}QC_{x,1} : 50\text{ ms} \\ e\text{-}QC_{x,2} : 75\text{ ms} \\ e\text{-}QC_{x,3} : 125\text{ ms} \end{array} \right\}$$

- Binding candidates are as follows:

$e\text{-}QC_1$ (100ms):

$l\text{-}QC_1$ (25) $\oplus$ $e\text{-}QC_{x,1}$ (50)
$l\text{-}QC_2$ (50) $\oplus$ $e\text{-}QC_{x,1}$ (50)
$l\text{-}QC_1$ (25) $\oplus$ $e\text{-}QC_{x,2}$ (75)

$e\text{-}QC_2$ (175ms): as for $e\text{-}QC_1$, plus:

$l\text{-}QC_2$ (50) $\oplus$ $e\text{-}QC_{x,2}$ (75)
$l\text{-}QC_1$ (25) $\oplus$ $e\text{-}QC_{x,3}$ (125)
$l\text{-}QC_2$ (50) $\oplus$ $e\text{-}QC_{x,3}$ (125)

Apportioning QoS constraints between domains

Three illustrative policies: *

- ***Least effort***: domain selects the lowest QoS Class, and downstream domains therefore employ higher QoS Class
- ***Most effort***: domain selects the highest QoS Class, and downstream domains can therefore use lower QoS Class
- ***Equal distribution***: responsibility split evenly between domains

Pricing mechanisms reflect the QoS burden incurred by domains

We assign traffic so as to minimise the overall cost of carrying the predicted traffic

  - Select a downstream domain
  - Select I-QC / downstream e-QC combination (i.e. least effort / most effort / equal distribution)

* Pongpaibool & Kim, Computer Networks 46 2004

IDRO: Genetic Algorithm – survival of the fittest

- ***Gene***: the assignment of a single eTM flow to a l-QC and a pSLS
  - Note that by specifying the pSLS we have therefore specified the inter-domain egress link and the o-QC
- ***Chromosome***: set of genes
  - A single chromosome is a potential solution for the entire eTM
- ***Population***: set of chromosomes
- ***Fitness function***: how well the chromosome is suited to the environment
  - Is the solution valid (link utilisation constraint & pSLS bw constraint)?
  - Fittest chromosome has lowest cost (Inter-domain and Intra-domain)

Genetic Algorithm (3): reproduction

A "best" chromosome

Dest A	BW4	l-QC2	pSLSb
Dest B	BW2	l-QC1	pSLSe
Dest C	BW7	l-QC1	pSLSf
Dest D	BW2	l-QC2	pSLSa
Dest E	BW3	l-QC3	pSLSa
Dest F	BW1	l-QC1	pSLSd
Dest G	BW4	l-QC1	pSLSe
Dest H	BW8	l-QC2	pSLSc

A "middle" chromosome

Dest A	BW4	l-QC1	pSLSc
Dest B	BW2	l-QC3	pSLSf
Dest C	BW7	l-QC2	pSLSe
Dest D	BW2	l-QC1	pSLSa
Dest E	BW3	l-QC1	pSLSd
Dest F	BW1	l-QC3	pSLSe
Dest G	BW4	l-QC2	pSLSd
Dest H	BW8	l-QC1	pSLSf

New chromosome

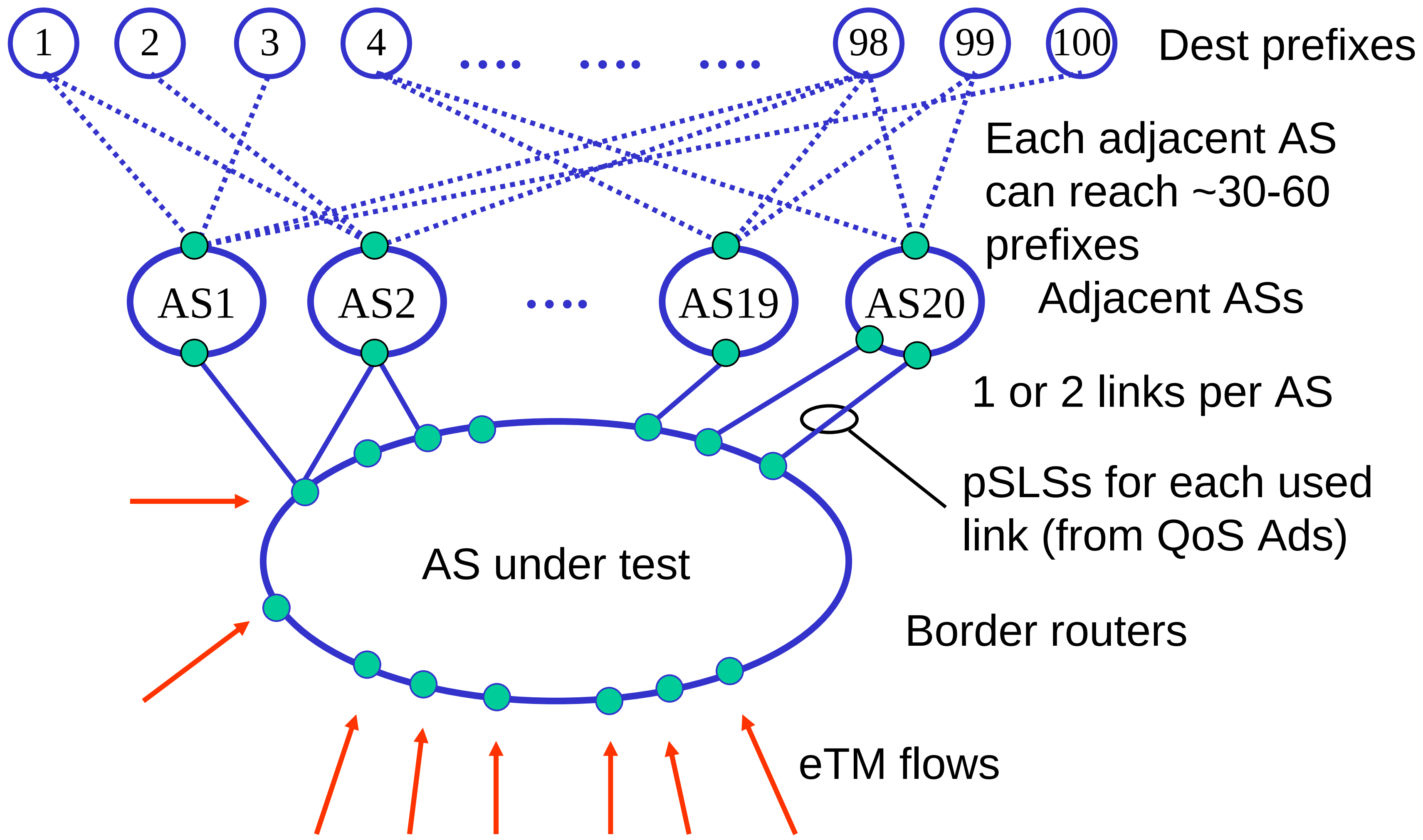
Dest A	BW4	l-QC2	pSLSb
Dest B	BW2	l-QC1	pSLSe
Dest C	BW7	l-QC2	pSLSe
Dest D	BW2	l-QC2	pSLSa
Dest E	BW3	l-QC2	pSLSc
Dest F	BW1	l-QC3	pSLSe
Dest G	BW4	l-QC1	pSLSe
Dest H	BW8	l-QC2	pSLSc

Mutation

eTM contains 8 flows

The best and middle chromosome have been randomly selected; each contains a possible solution (i.e. an assignment of each flow to a l-QC and pSLS)

Simulation scenario

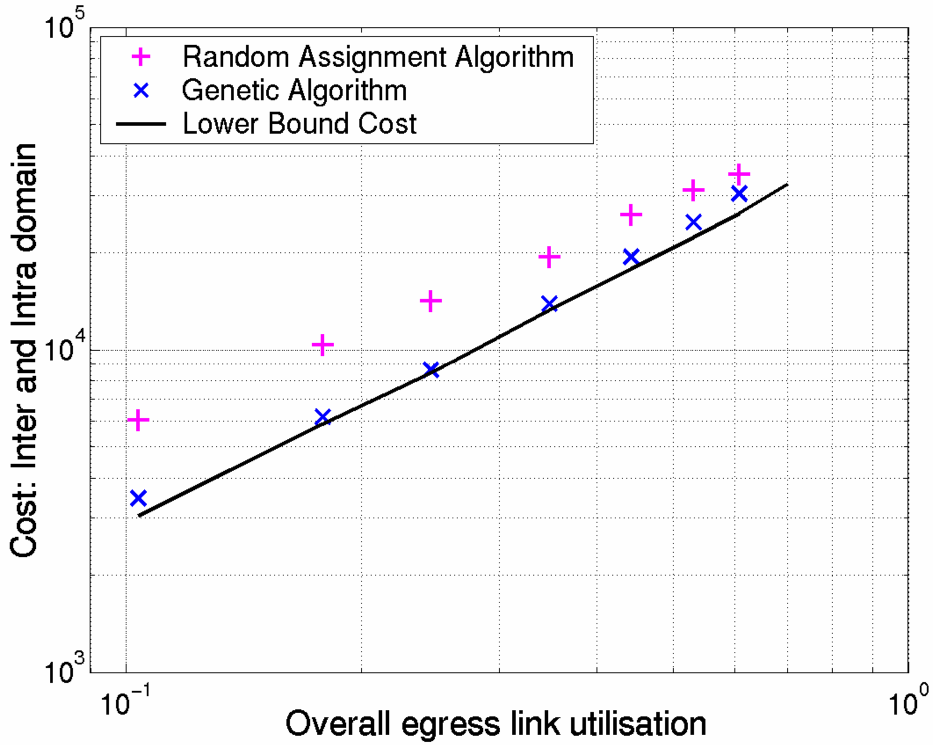


Genetic Algorithm applied to a test scenario

QoS parameters: delay, bandwidth

Costs:

- Inter-domain: pSLS cost (proportional to bandwidth assigned to each pSLS, cost different for each pSLS)
- Intra-domain cost (inversely proportional to I-QC delay)



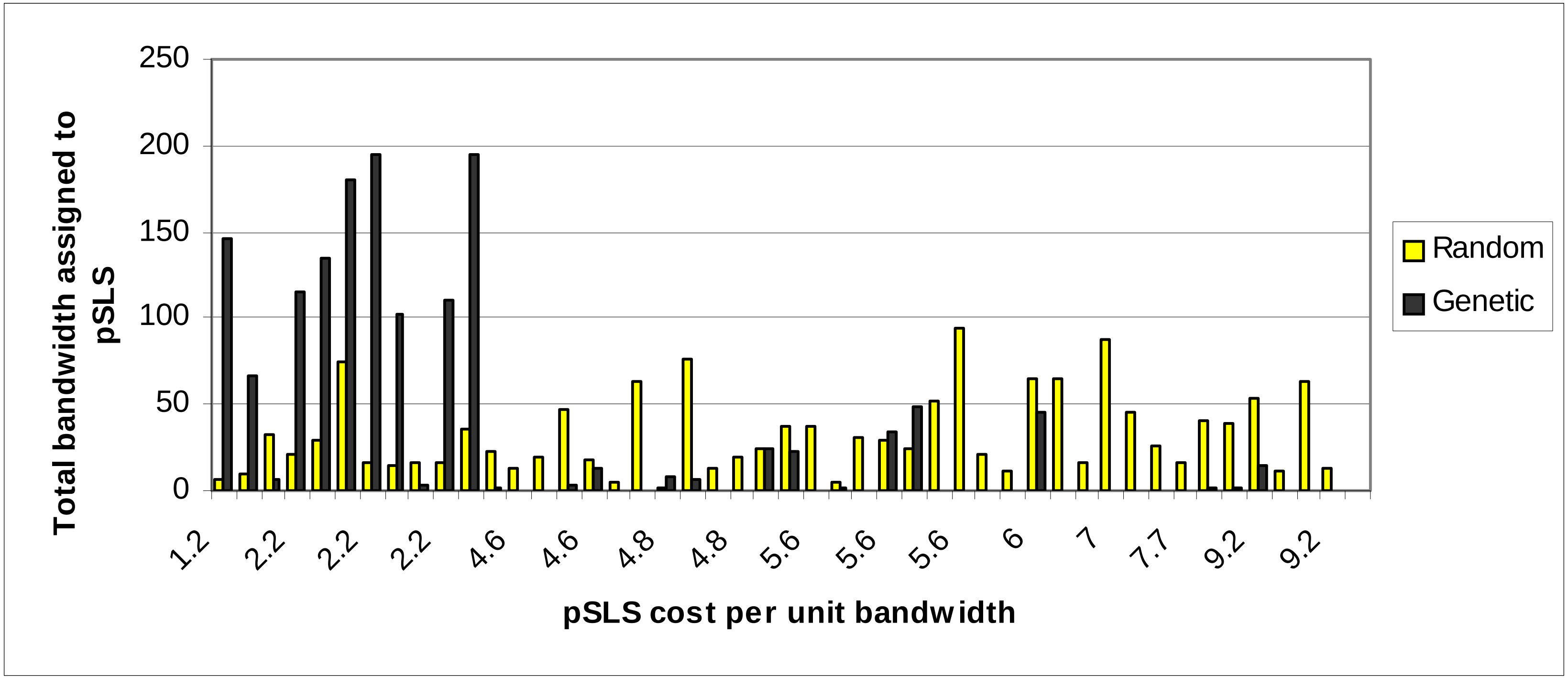
Genetic Algorithm optimally assigns flows of different QoS to downstream domains

Random Assignment algorithm for comparison

Lower Bound only calculable for relaxed problem with single e-QCs

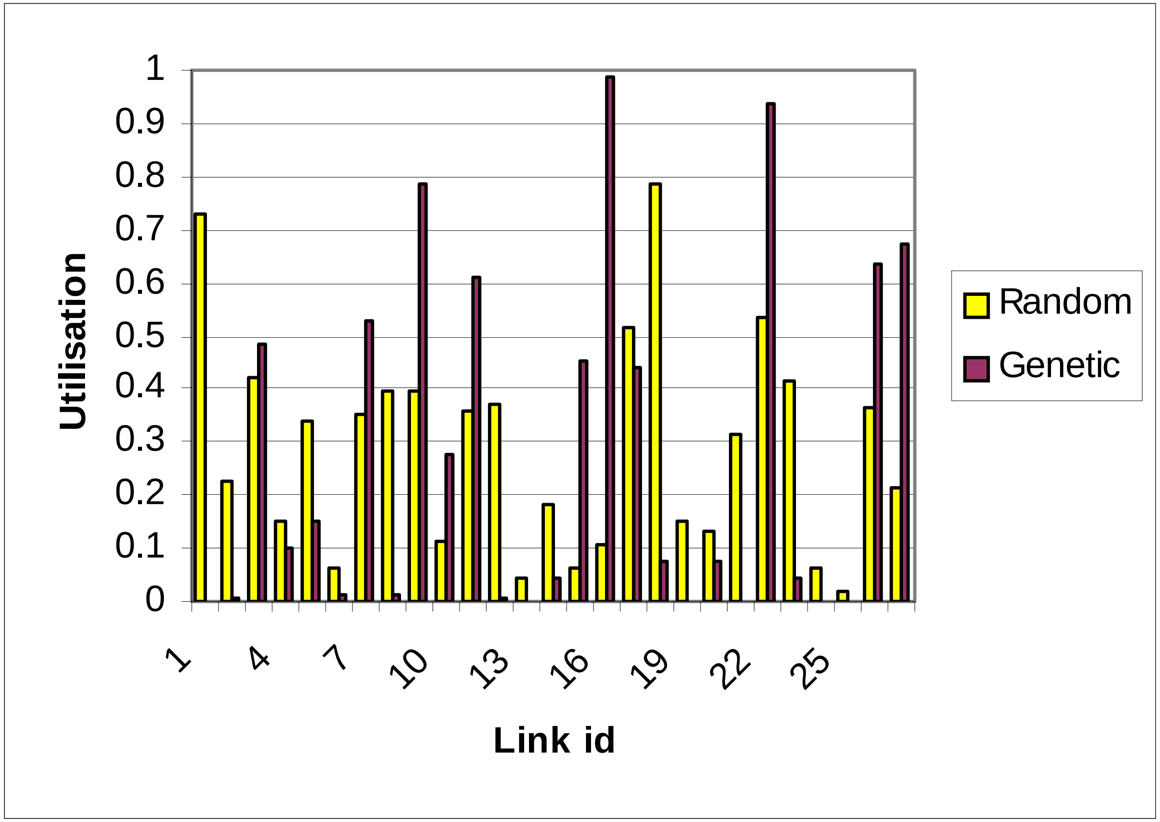
pSLS utilisation

- The Genetic Algorithm has successfully assigned most flows to the lowest cost pSLSs
- The Random Assignment algorithm spreads the flows out amongst the various pSLSs, resulting in higher costs



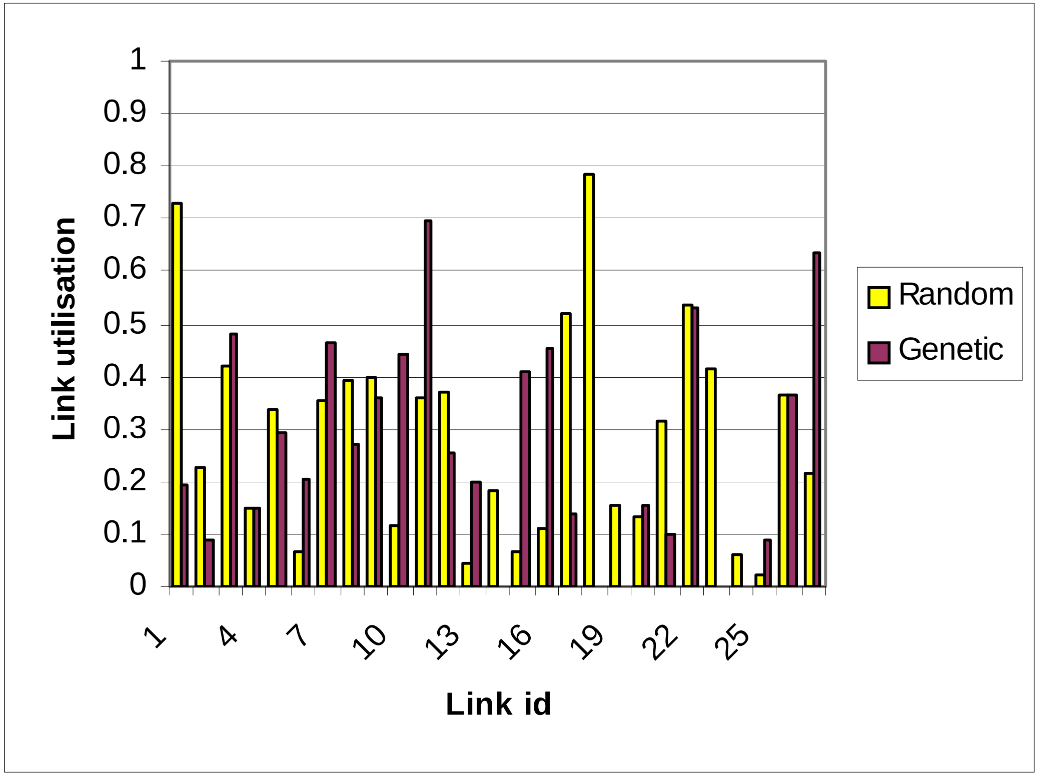
Inter-domain link utilisation (1)

- Although the Genetic Algorithm has found the cheapest pSLSs, it has resulted in very high utilisations on some Inter-domain links



Inter-domain link utilisation (2)

- Introducing link cost as a third component of the cost function reduces the worst case link utilisation
- Costs:
  - Inter-domain: pSLS cost (as before)
  - Intra-domain cost (as before)
  - Inter-domain link utilisation (based on Fortz & Thorup model)



Summary

- Offline Inter-domain TE can be used to assign predicted traffic aggregates to an optimal set of intra-domain l-QCs and downstream e-QCs
- Genetic Algorithm is an appropriate tool, reducing costs by ~30-50% compared to Random Assignment
- A pricing mechanism ensures effective apportionment of QoS values between domains
- The right mix of cost functions is required to optimise the solution