Engineering the Multi-Service Internet: MPLS and IP-based Techniques

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Presentation Outline

- Introduction
- TE Functional Model
- MPLS-based TE
- IP-based TE
- Summary and Further Work

Introduction

- **The Internet is the global multi-service network**
- **Need for scalable QoS solutions**
- **Differentiated Services (Diffserv)**
  - **Classify, mark and police at the edges**
  - **Specified 'per-hop behaviours' (PHBs), to traffic aggregates**
- **Traffic Engineering**
  - **Control the manner traffic is mapped onto and handled by network to achieve specific performance objectives**

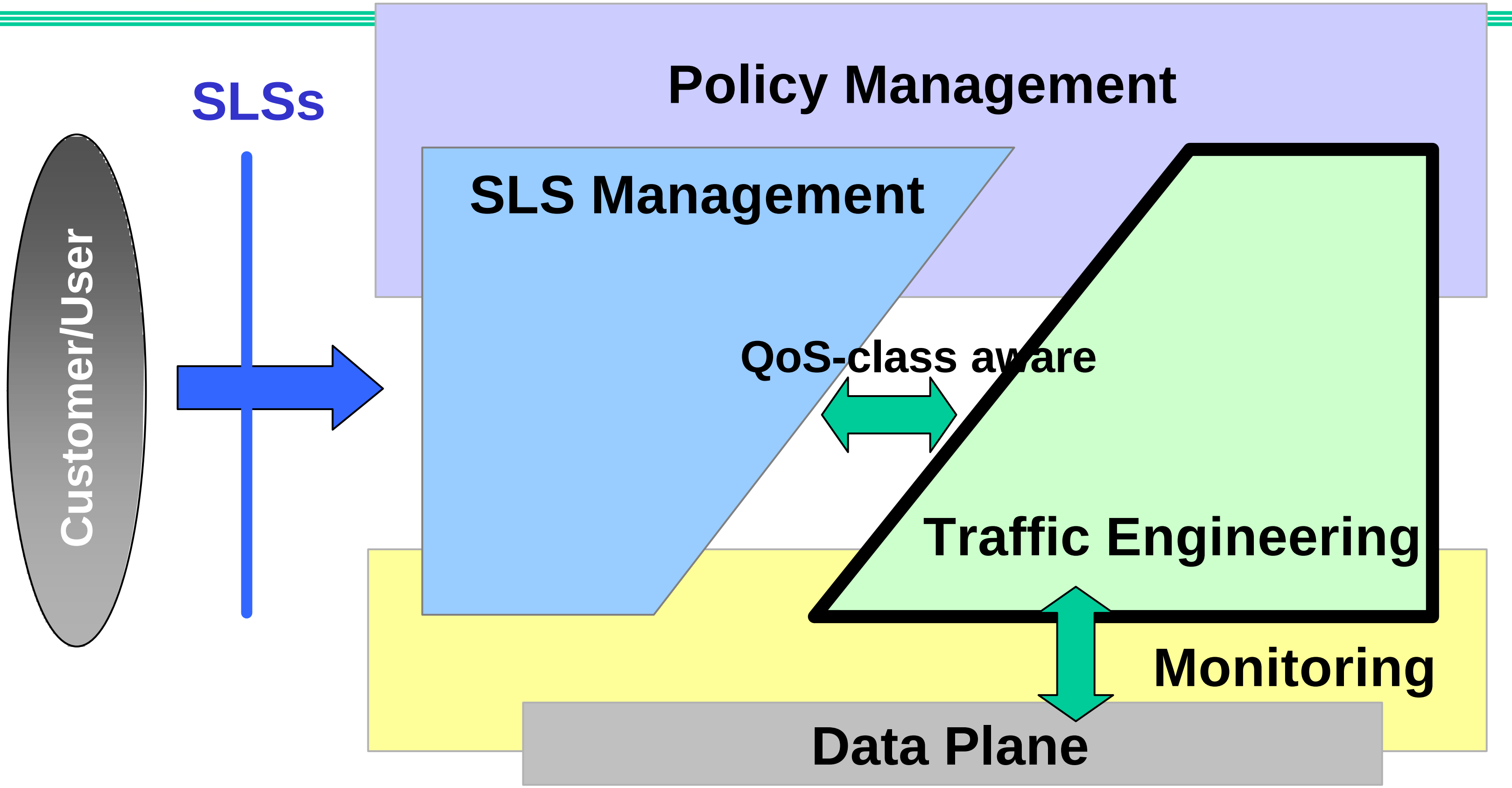
Problem:

How to 'traffic engineer' a DiffServ domain, to meet edge-to-edge QoS requirements

Tequila Consortium

- **Industrial Partners**
  - **Alcatel, Antwerp, Belgium**
  - **Algosystems S.A., Athens, Greece**
  - **France Telecom-R&D, Paris, France**
  - **Global Crossing, UK**
- **Universities**
  - **UCL - University College London, UK**
  - **NTUA - National Technical University Athens, Greece**
  - **UniS - The University of Surrey, Guildford, UK**
- **Research Institutes**
  - **IMEC, Ghent, Belgium**
  - **TERENA, Amsterdam, Netherlands**

A Functional Model for QoS

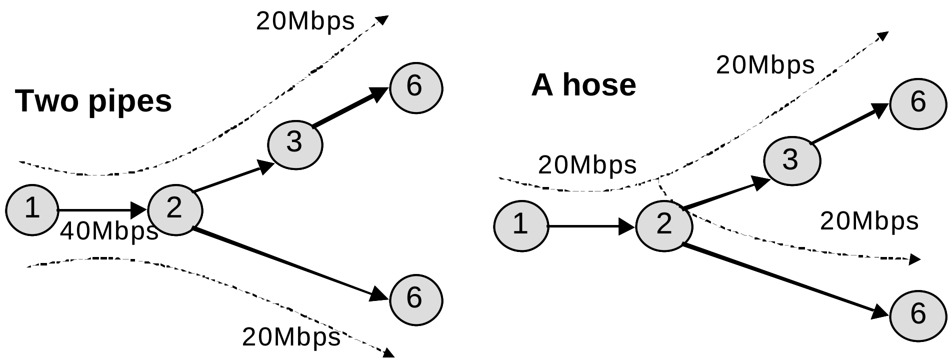


Service description and negotiation through SLSs (per-)Customer awareness

service provisioning through Traffic Engineering (QoS-)Class awareness

Traffic Model

- **Traffic Trunk (TT)**
  - **Ingress, set of egresses**
    - **pipe or hose**
  - **QoS class**
    - **blocking probability, loss probability, delay bounds**
    - **mapped into an OA (ordered aggregate)**
  - **Bandwidth demands**
    - **derived from service contracts and/or 'ad-hoc' estimates**



Traffic Engineering Model

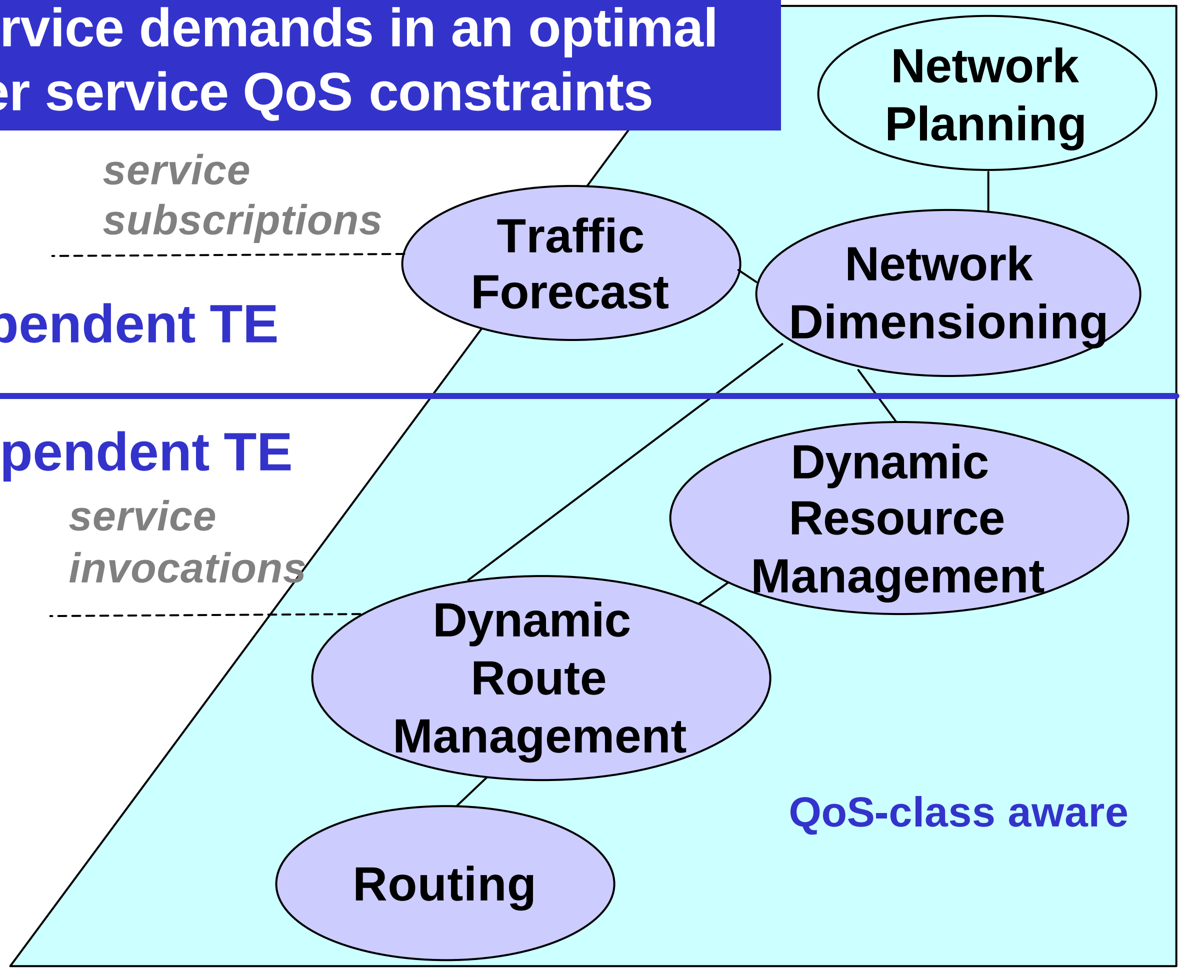
Objectives:
Satisfy service demands in an optimal way, under service QoS constraints

service subscriptions

time-dependent TE

state-dependent TE

service invocations



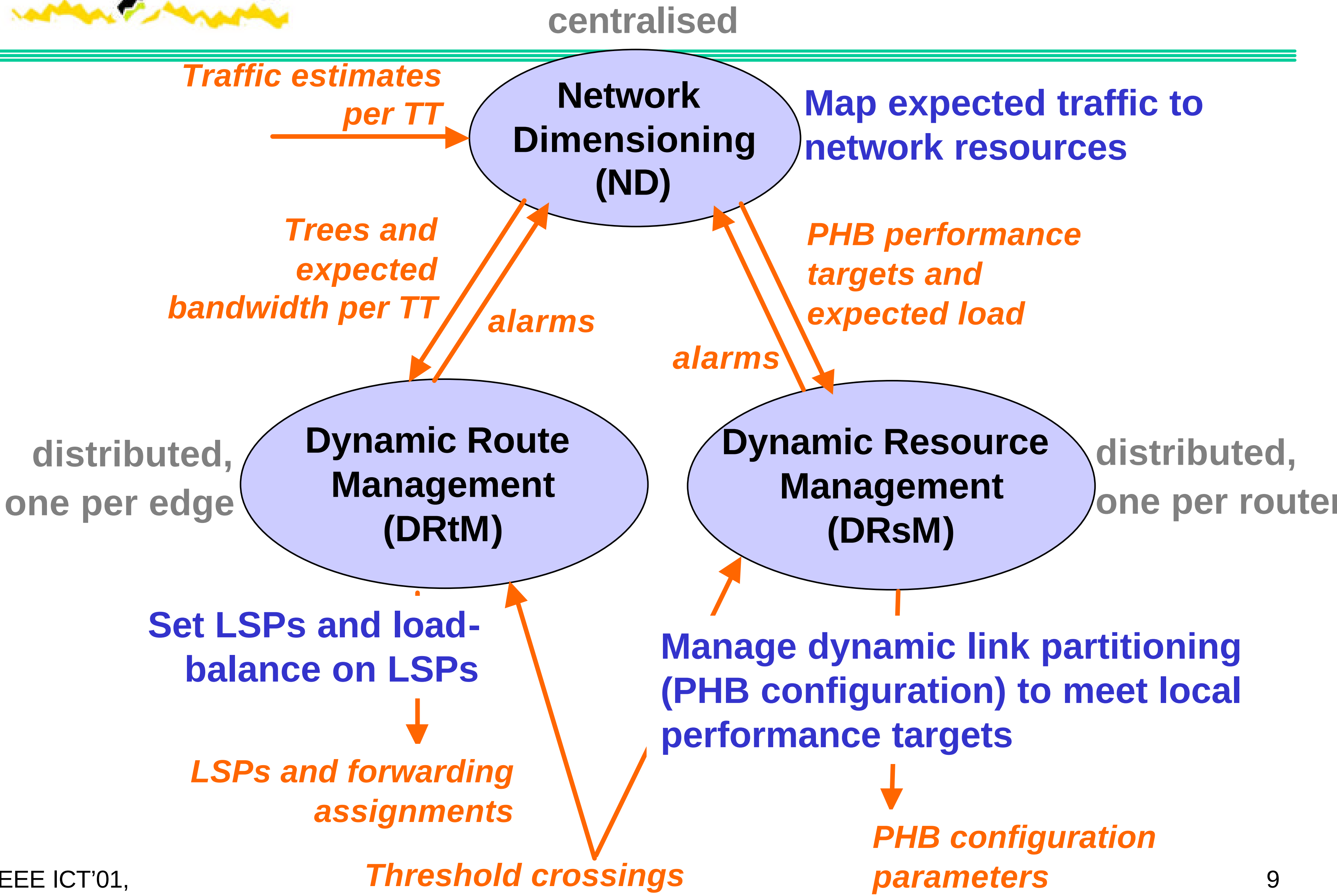
Routing and resource (PHB requirements

Dynamic routir and resource (PHB) management

TE Approaches

- MPLS-based
  - Explicit routing through LSPs
  - LSPs are not explicitly associated with bandwidth
- IP-based
  - Hop-by-hop routing, OSPF-based
  - Assignment of link-weights
- Bandwidth reservations in the network per PHB per network interface
- Loss and delay constraints are translated into route hop-count constraints (PHBs are associated with delay and loss bounds)

MPLS-based TE Overview



MPLS-based TE
Time-dependent

centralised

Network Dimensioning (ND)

Map expected traffic to network resources

INPUT

- **physical network topology**
- **traffic load estimates per TT**
- **policy constraints**
- **network (over)(under)-utilised alarms**

OUTPUT

- **sets of routes (paths or trees) per TT (to DRtM)**
- **expected bandwidth per tree per TT (to DRtM)**
- **expected load per PHB (to DRsM)**

MPLS Network Dimensioning

- Minimise network cost
  - Network cost is the minimum maximum of, or the sum of links' cost per PHB
  - Link cost per PHB is a function of the anticipated load
- With respect to anticipated load of each PHB
- Subject to
  - Service demand constraint
  - QoS-class performance (hop-count) constraint
  - Link capacity constraint
- Solution on an iterative procedure
  - Based on gradient projection method
  - Involving calculations of Steiner trees (for hose TTs)

MPLS-based TE State-dependent (I)

distributed, one per edge

Dynamic Route Management (DRtM)

Set LSPs and load-balance on LSPs

INPUT

- set of trees and expected bandwidth per TT from the edge node
- commodities (IP addresses) per TT
- threshold crossings on PHB performance, LSP bandwidth/performance

OUTPUT

- LSPs from the edge to all egresses (based on defined trees) and their expected bandwidth (to router)
- (re)mappings of commodities to LSPs (to router)
- network over-utilised alarms (to ND)

MPLS-based TE State-dependent (II)

distributed, one per router

Dynamic Resource Management (DRsM)

Manage dynamic link partitioning (PHB configuration) according to actual load to meet local performance targets

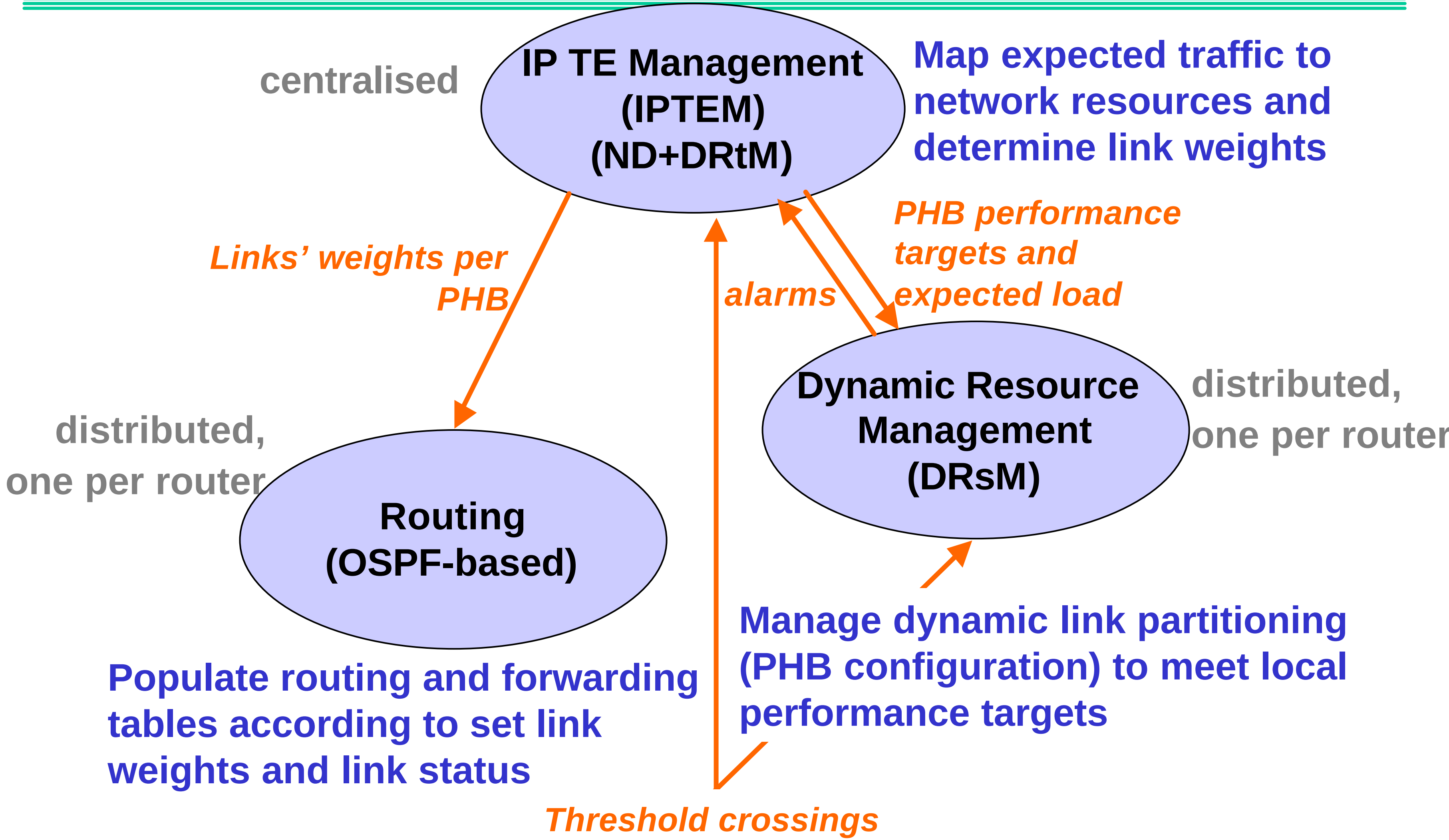
INPUT

- supported PHB (types of queues, scheduling mechanisms and their parameters) and their performance targets
- expected load per local PHB
- threshold crossings on local PHB performance

OUTPUT

- PHB configuration parameters (scheduling and buffer parameters) (to router)
- network under-utilised alarms (to ND)

IP-based TE Overview



IP-based TE
Time-dependent

centralised

IP TE Management (IPTEM) (ND+DRtM)

Map expected traffic to network resources and determine link weights

INPUT

- physical network topology
- traffic load estimates per TT
- policy constraints
- link utilisation alarms

OUTPUT

- link weights per PHB (to routers)
- expected load per PHB (to DRsM)

Link Weight Assignment

- **Minimise network cost**
  - **Network cost is the minimum maximum of, or the sum of links' cost per PHB**
  - **Link cost per PHB is a function of the anticipated load**
- **With respect to links' weights per PHB**
- **Subject to**
  - **Service demand constraint**
  - **QoS-class performance (hop-count) constraint**
  - **Link capacity constraint**
- **Solution on an iterative procedure**
  - **modify links' weights to reduce network cost**

IP-based TE
State-dependent

distributed,
one per router

Dynamic Resource Management (DRsM)

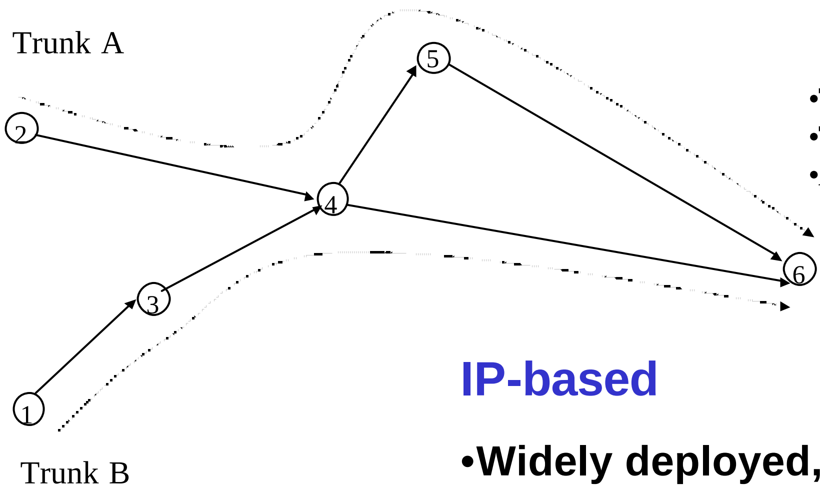
Manage dynamic link partitioning (PHB configuration) according to actual load to meet local performance targets

distributed,
one per router

Routing (OSPF-based)

Populate routing and forwarding tables according to set link weights and link status

MPLS- and IP-based TE



- Trunk A: max hop-count 3, bandwidth 1
- Trunk B: max hop-count 3, bandwidth 1
- All link capacities are equal to 1

IP-based

- **Widely deployed, scalable**
- **Multi-path routing (ECMP, OMP) improves performance; overhead and scalability are of concern**
- **Hard to meet QoS constraints (e.g. hop count); needs explicit information on routing look-up's**
- **Dynamic (load sensitive) weights, Widest Path routing may be helpful, but needs careful evaluation**

MPLS-based

- **Useful features for QoS-routing (explicit routing, utilisation of rich information in routing)**
- **Scalability and overhead are concerns**

Summary

- **TE architecture and algorithms**
  - **Interworking between service management and traffic engineering**
  - **TE is based on a pre-provisioned model and follows the paradigm of ‘initially plan and then take care’**
  - **Two approaches: MPLS- and IP-based**
- **Architecture and algorithms currently being realised**
- **Validation through simulation and testbed experimentation**
- **Work done in the European project TEQUILA**

http://www.ist-tequila.org