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

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# Presentation Outline

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- **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

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- **Industrial Partners**

- **Alcatel**, Antwerp, Belgium
- **Algosystems S.A.**, Athens, Greece
- **France Telecom-R&D**, Paris, France
- **Global Crossing**, UK

- **Universities**

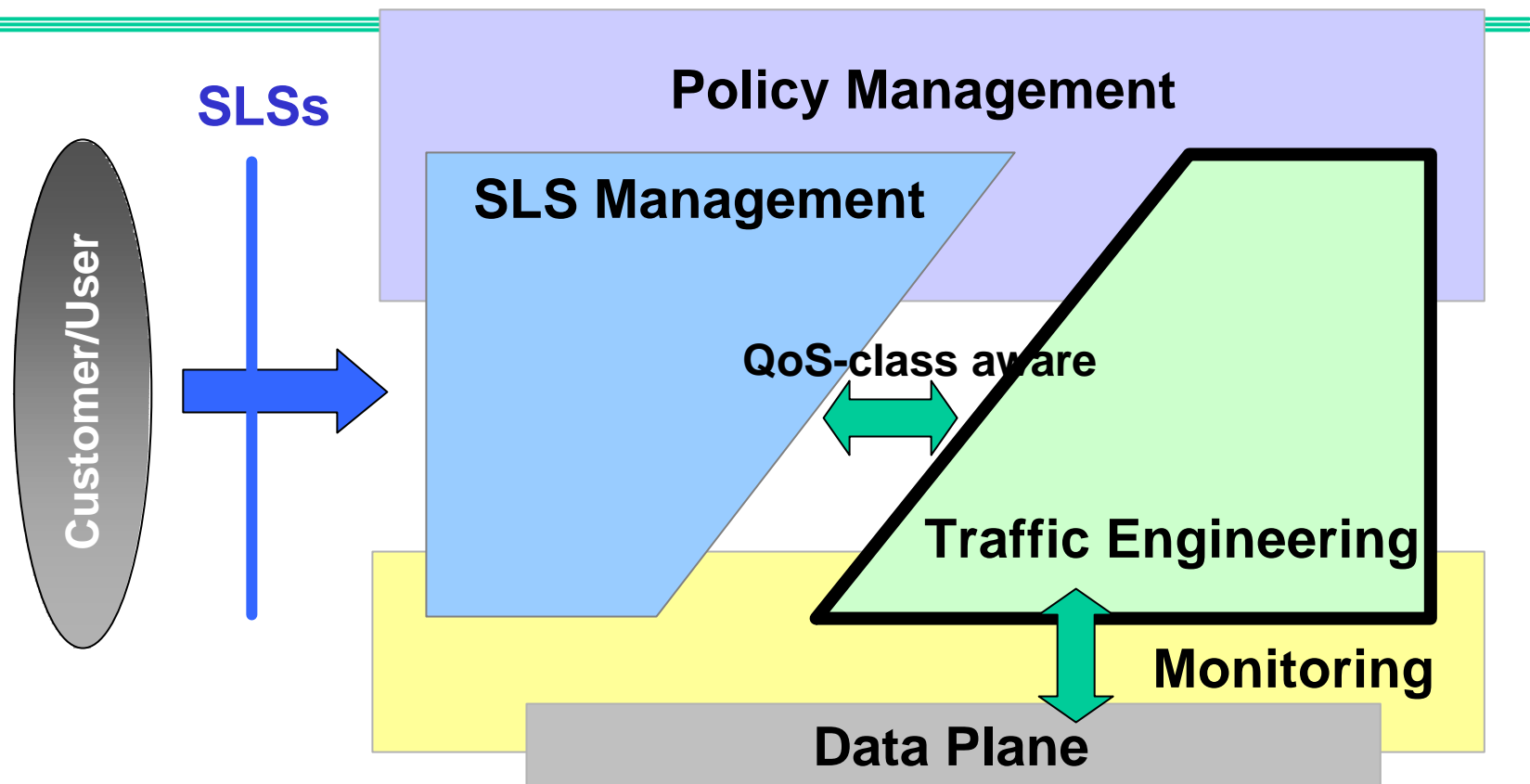
- **UCL** - University College London, UK
- **NTUA** - National Technical University Athens, Greece
- **UniS** - The University of Surrey, Guildford, UK

- **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 Trunk (TT)**

- **Ingress, set of egresses**

- pipe or hose

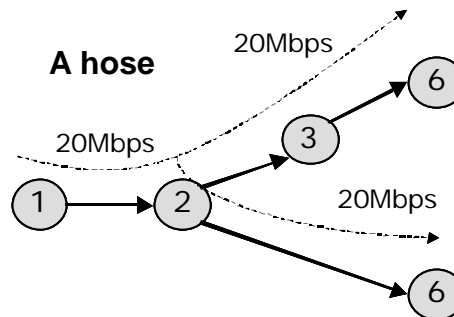
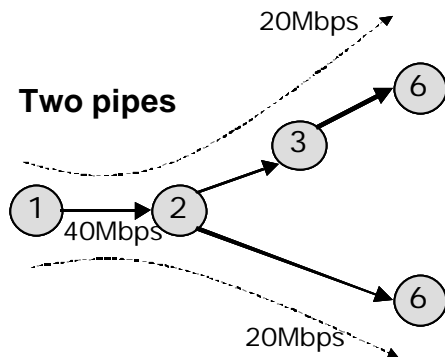
- **QoS class**

- blocking probability, loss probability, delay bounds

- mapped into an OA (ordered aggregate)

- **Bandwidth demands**

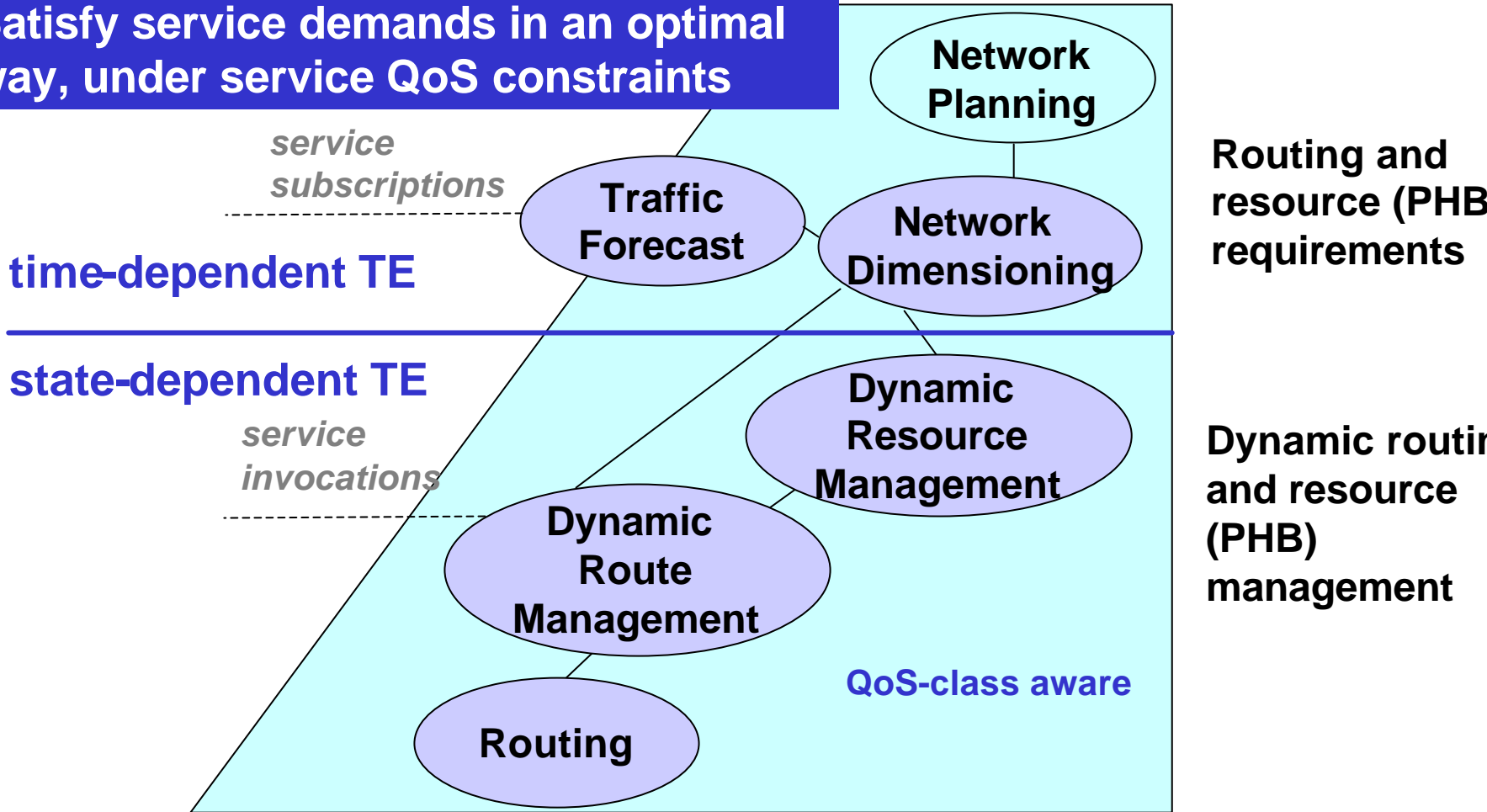
- derived from service contracts and/or 'ad-hoc' estimates





# Traffic Engineering Model

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





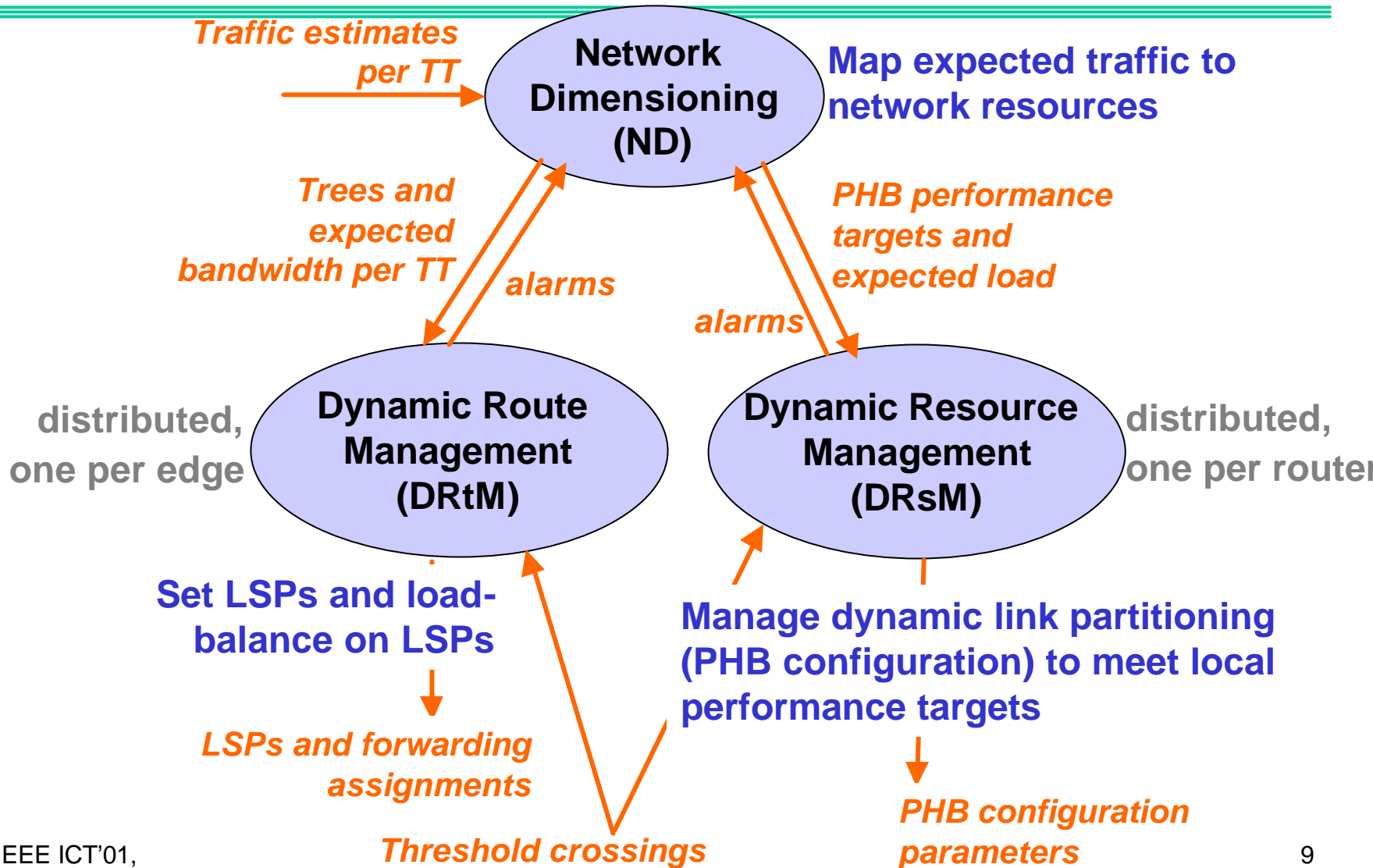
# TE Approaches

- **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

centralised





# 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

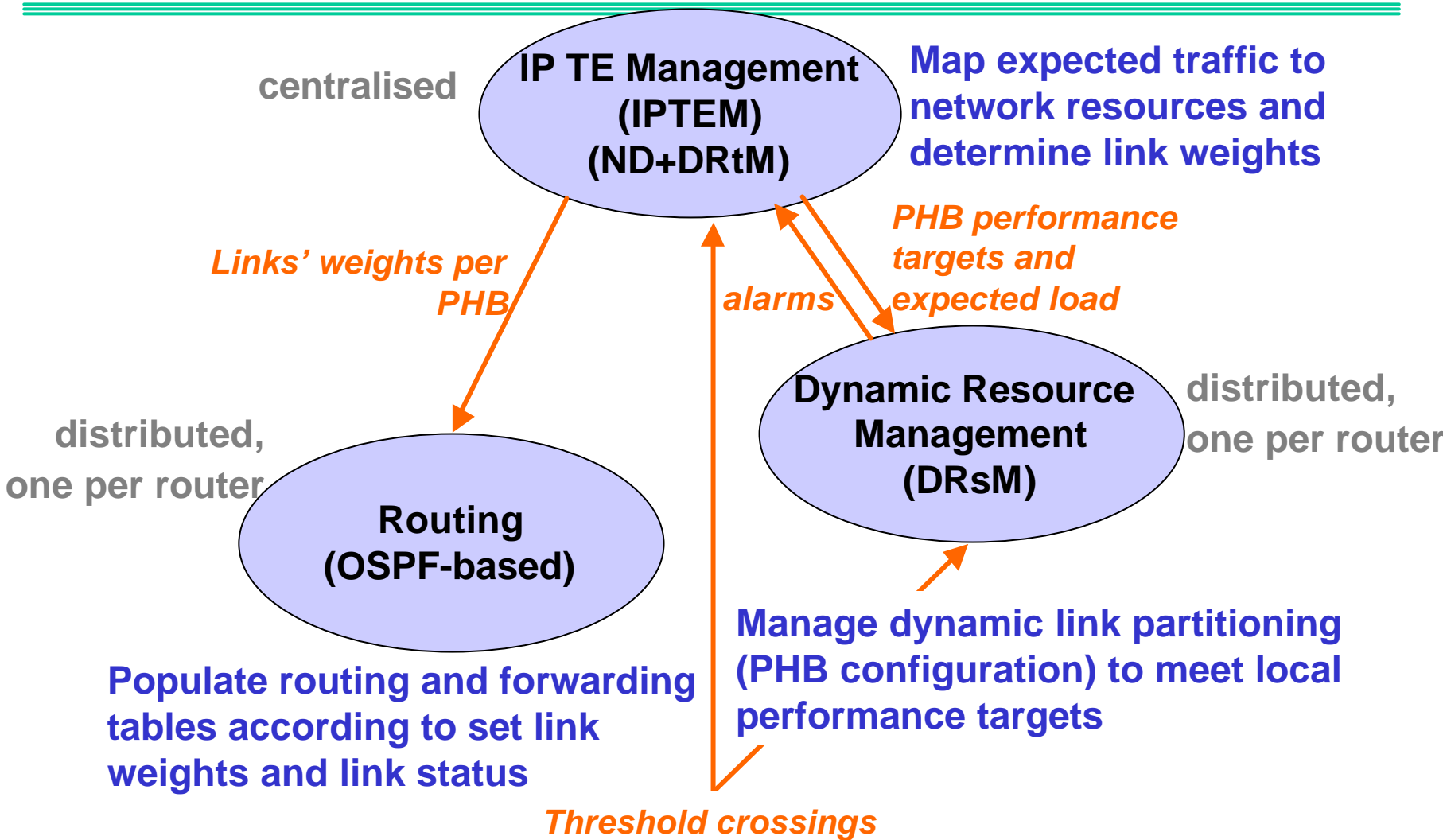
- supported PHB (types of queues, scheduling mechanisms and their parameters) and their performance targets
- expected load per local PHB
- **threshold crossings on local PHB performance**

## 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

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- **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

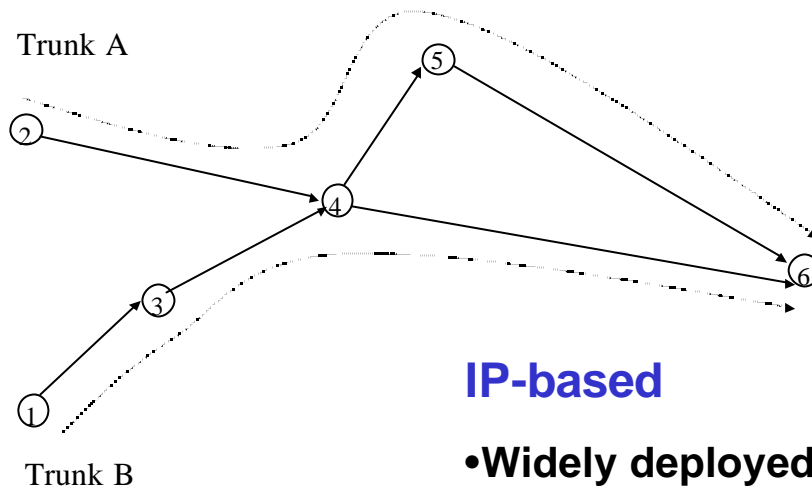
**Dynamic Resource  
Management  
(DRsM)**

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



- 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>***