EL736 Communications Networks II: Design and Algorithms

Class1: Introduction

Yong Liu

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From Telephone Networks to Data Networks

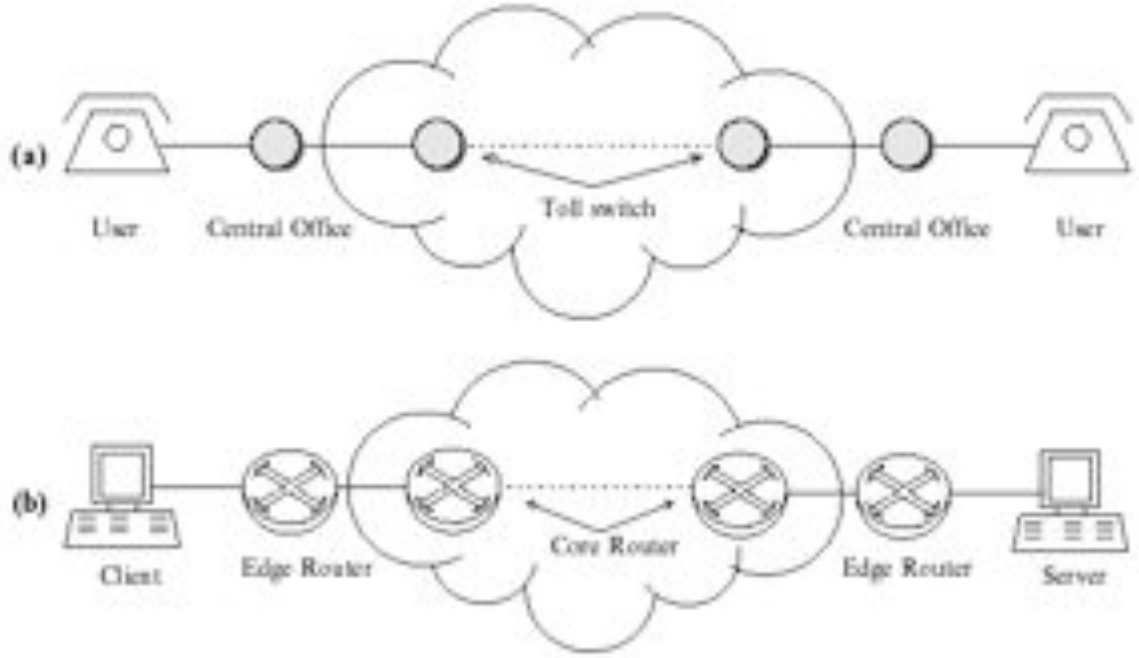


FIGURE 1.1 A Simple Example: (a) Telephone Call and (b) Internet Web Transfer

- voice calls vs. datagrams
- circuit switching vs. packet switching
- multiplexing/de-multiplexing at edge, shared network core

Network Service Providers

FIGURE 14 A Series of Networks

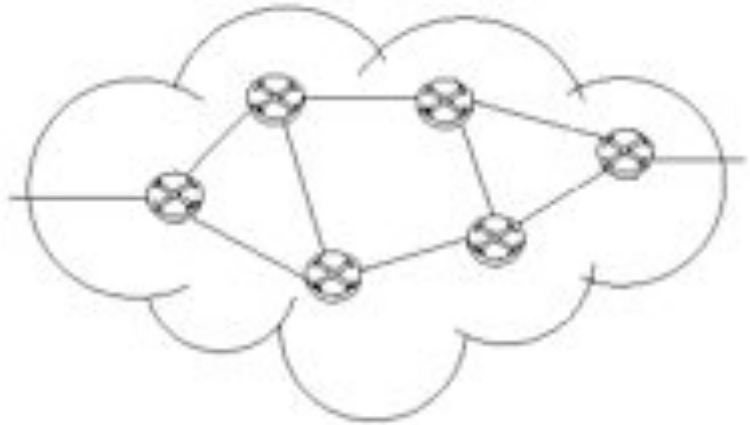


FIGURE 15 General Domain of Network Design Problems (Backbone Network)

- multiple autonomous systems (ASes) managed by different network providers
- peering at gateway routers
- dealing with network design within one admin. domain

Traffic Networks vs. Transport Networks

- Traffic Networks: provide application services to end users
  - the Internet
  - telephone networks
  - private networks
- Transport Networks: provide physical facility to transport traffic for customer networks
  - setting up leased circuits/trunks (semi-)permanently
  - SONET, WDM, cross connects

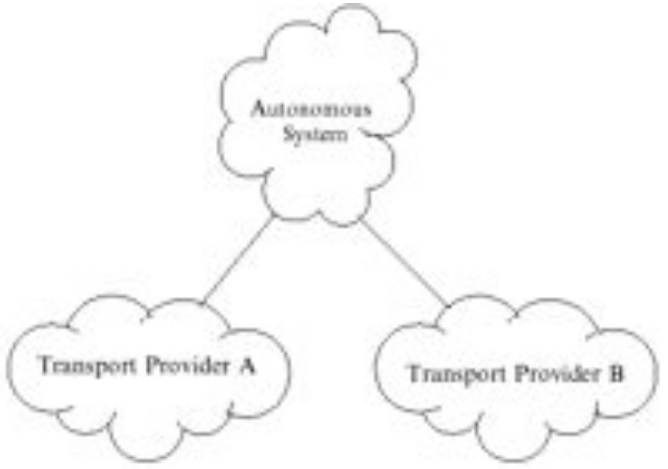


FIGURE 1.7 An Administrative Domain Using Multiple Transport Providers

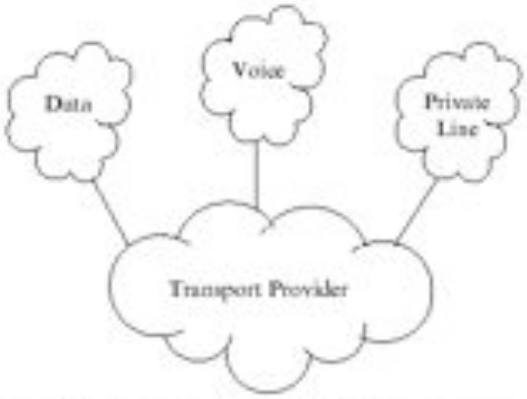


FIGURE 1.8 Multiple Service Networks Over One Transport Provider

Network Resource & Cost

- link capacity (bps, pps)
- router/switch
  - memory (bytes)
  - processing power (CPU, Hz)
- network cost:
  - provisioning cost ($, hours)
  - operational cost ($, hours)

Network Demand

- traffic characteristics
  - how much? point to point traffic volume
    - stationary+stochastic
  - + where? traffic demand matrix
- different natures for different networks
  - the Internet: packets
  - telephone network: calls
  - transport network: circuits
- demand of traffic networks generated by end users
- demand of transport network generated by its customer traffic networks

Traffic Demand in Internet

- bits,bytes,packets/second
- very "random"
  - controlled by end-users and protocol behaviors
  - highly variable, bursty, long-range-dependent, self-similar, …
  - predictable? reasonable models?
- characteristics on a single link
  - packet arrival process: approximately Poisson :)
  - packet size distribution: non-exponential :(

Packet Delay on a Single Link

- M/M/1 Approximation: $\mathcal{D}(\lambda_p, \mu_p) = \frac{1}{\mu_p - \lambda_p} = \frac{1/\mu_p}{1 - \rho_p}$
- packet delay on a T1(1.5Mbps) link
- benefit of multiplexing
  - ten 1.5Mbps links vs. one 15Mbps link

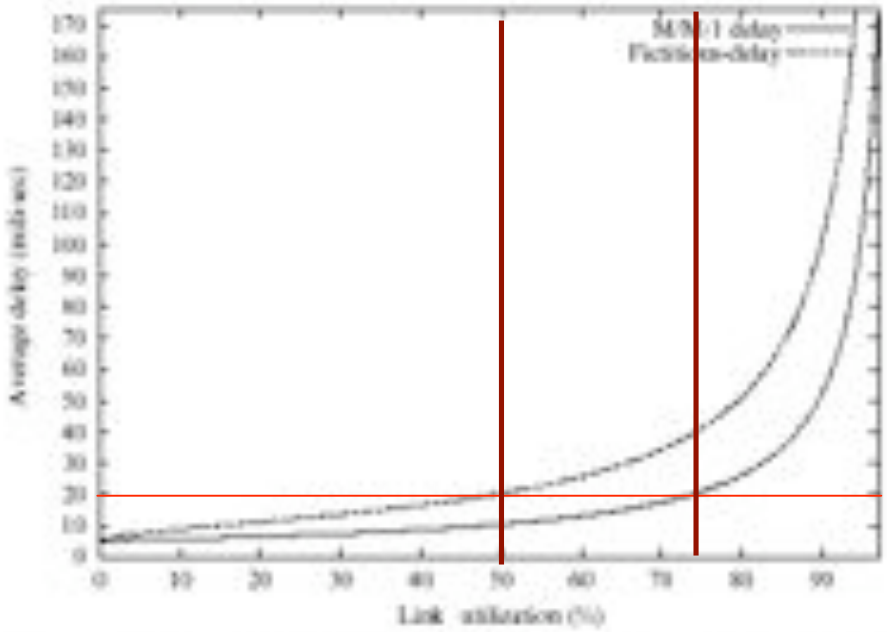


FIGURE 1.10 Average Delay Using *M/M/1* Delay Formula and a Fictitious Delay Formula

Traffic in Telephone Network

- circuit switching
  - calls blocked if no available circuit
- call arrivals approximately Poisson :)
- call duration approximately exponential :)
- offered load unit -- Erlang: $\alpha = \lambda_t \times \tau_t$
- call blocking probability
  - Erlang-B loss formula $\mathcal{B}(\alpha, c) = \dfrac{\alpha^c / c!}{\sum_{k=0}^{c} \alpha^k / k!}$
  - 24 Erls to link with capacity 24 --> 14.6% loss
  - 240 Erls to link with capacity 240 --> 4.9% loss

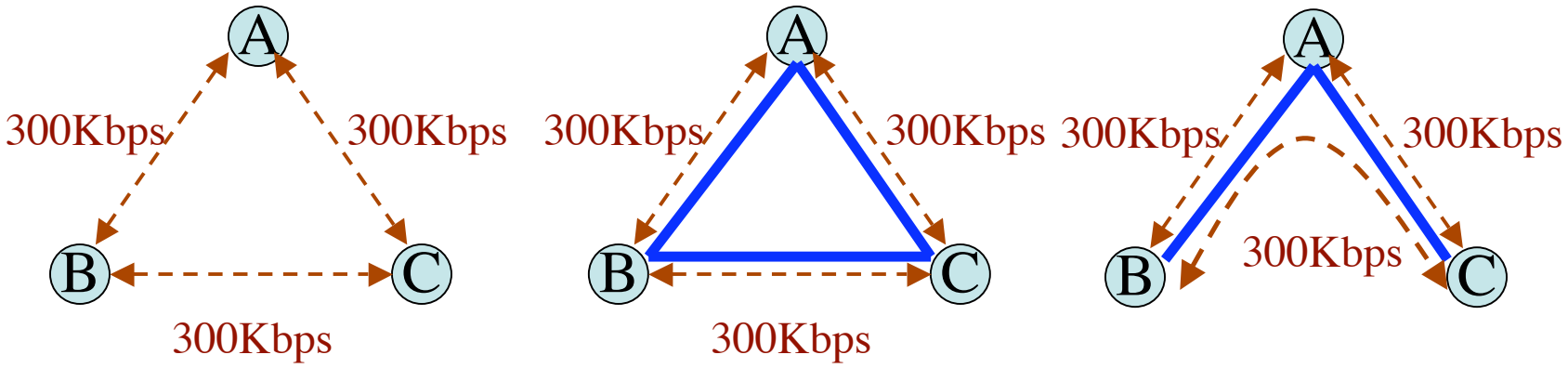
Demand in Transport Network

- demand to transport network is less dynamic
  - well specified start-end time
  - measured in modular data rates

Signal Name	Bit Rate (Mbps)
DS0 (voice)	0.064
T1	1.54
T3	45
OC-3	155.52
OC-48	2,488.32
OC-192	9,953.28

A Simple Design Example

- set up links to carry demand under link utilization constraint of 60%.



demand matrix

three T1 links
utili.=19.5%

two T1 links
utili.=39%

Logical vs. Physical Network View

- traffic networks runs on top of transport network
- two independent logical links might go through same physical link
- implications on failure recovery, restoration, network reliability
- multiple-layer network design

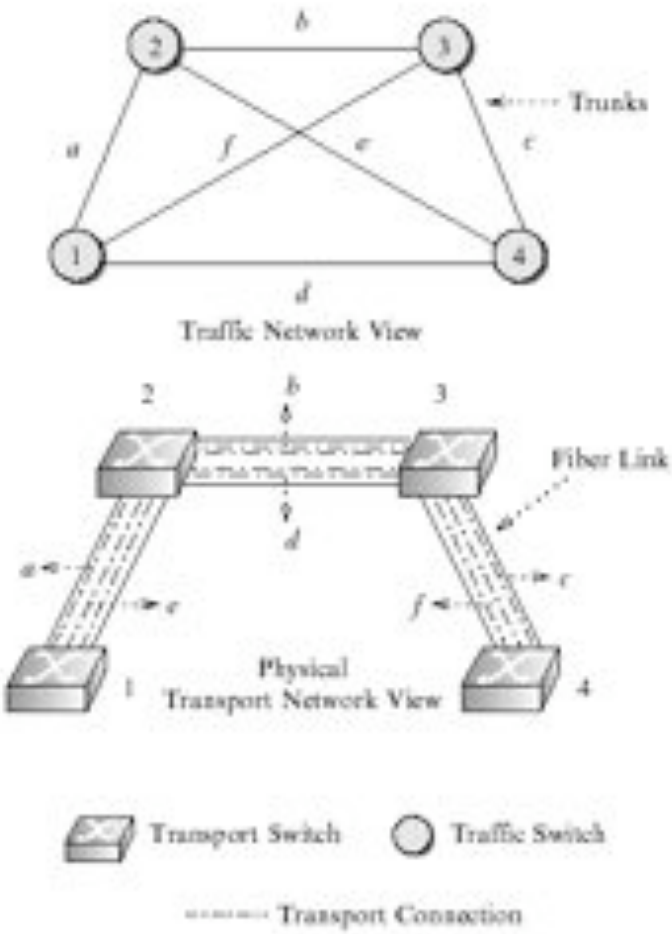
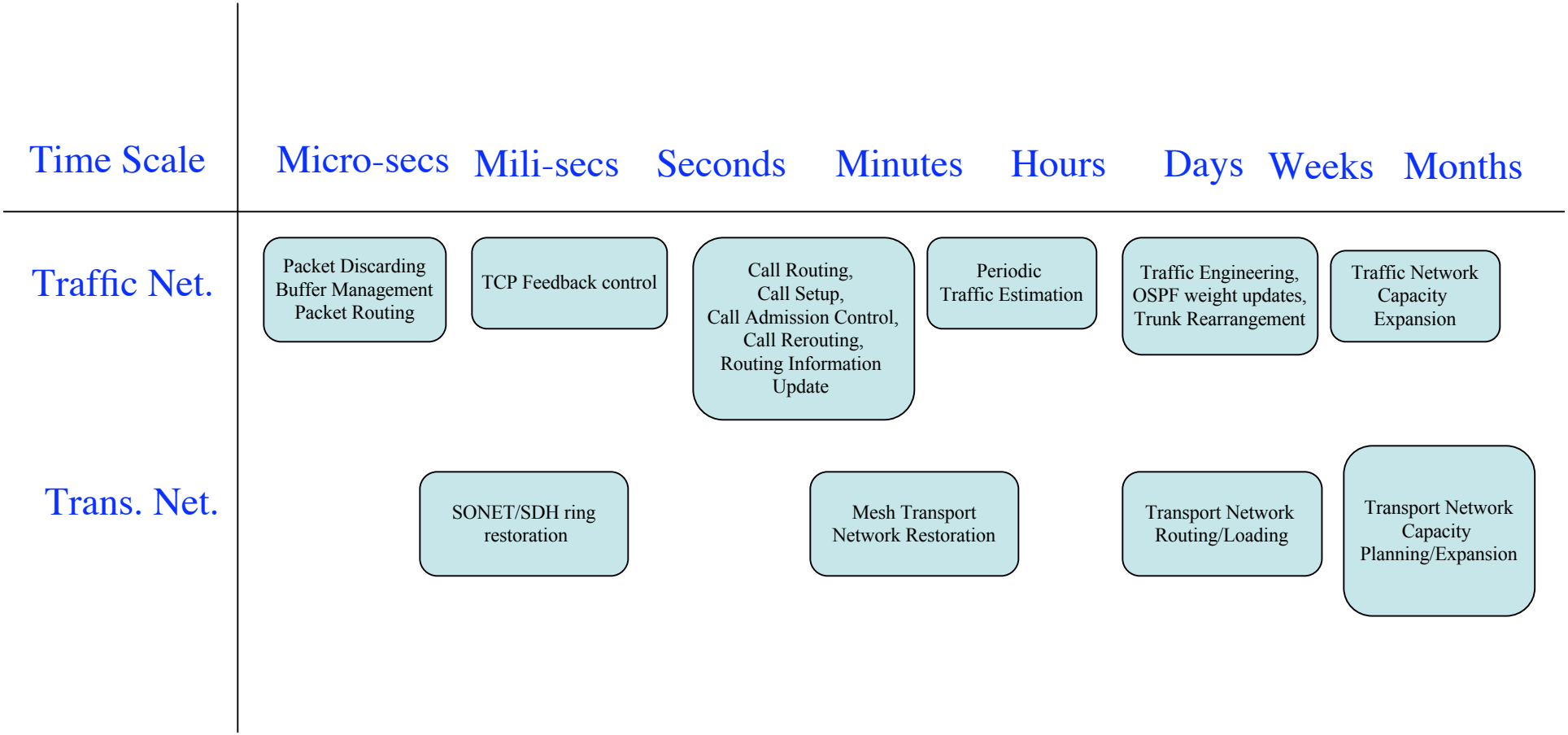
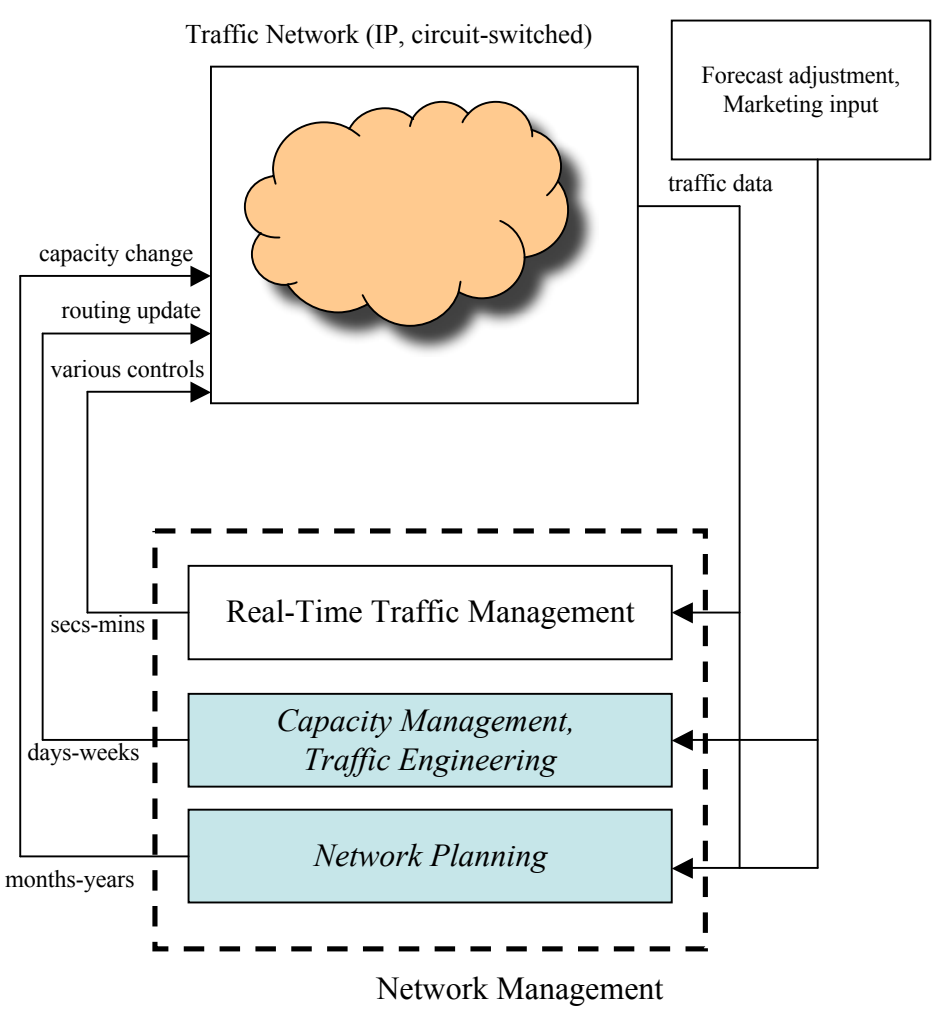


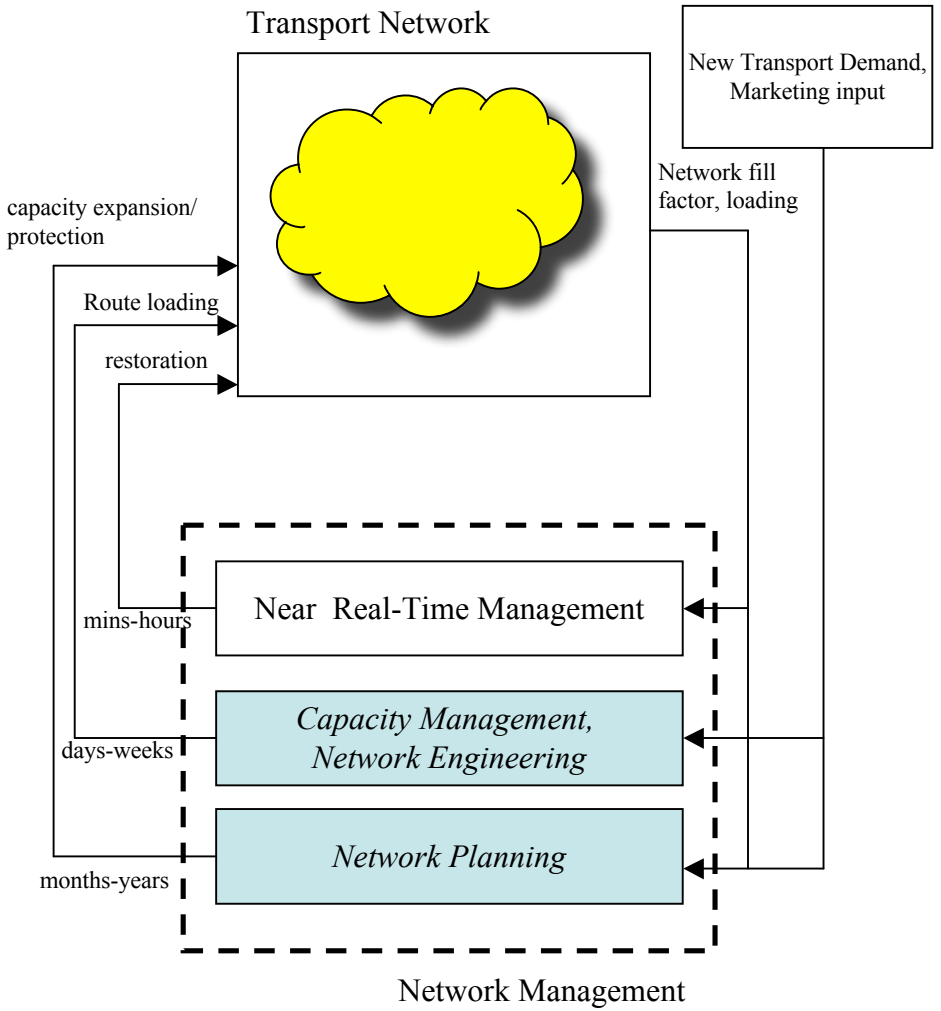
FIGURE 1.12 Traffic (Logical) Network and Transport Network View

Network Management Timescale



Network Management Cycle





Course Scope

- Network View
  - different routing, flow and link capacity representations
  - uncertainties: link/node failures, traffic variations
  - multi-layer interaction: traffic/transport, logical/physical
  - large scale problems
- Approaches/algorithms/theory view
  - model selection
  - solution with optimization tools
  - approximate/heuristic algorithms for large problems
  - fundamental principles
- Small timescale management not covered here
  - stochastic queueing analysis and simulation topics for EL735

List of Topics

- Network Design Problem Modeling
- Optimization Methods
- Multi-Commodity Flow Routing
- Location and Topological Design
- Fair Network
- Resilient Network Design
- Robust Network Design
- Multi-Layer Networks