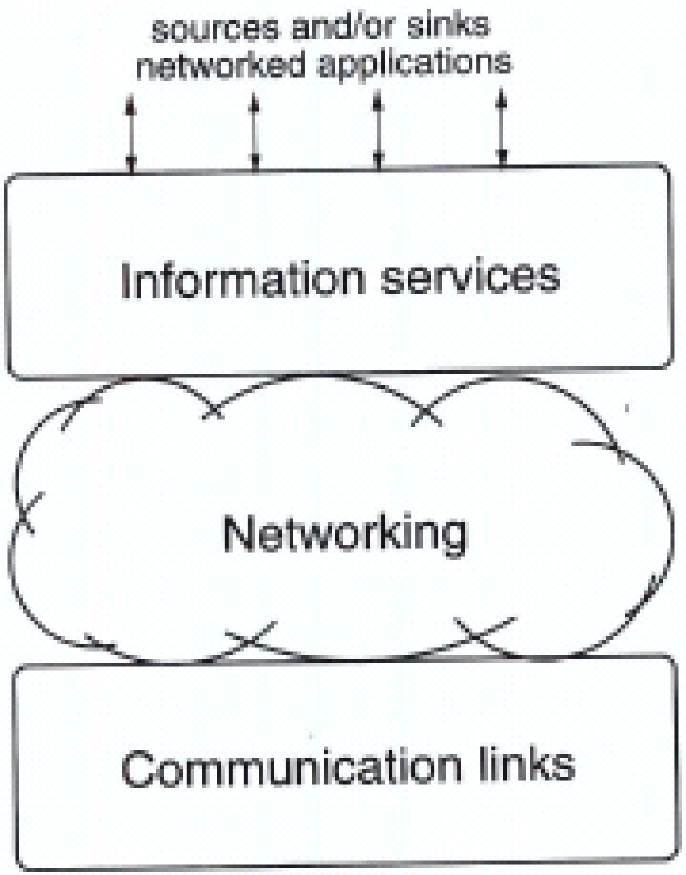
Introduction to Research on Networks

Nelson Fonseca
State University of Campinas

Communication Networks

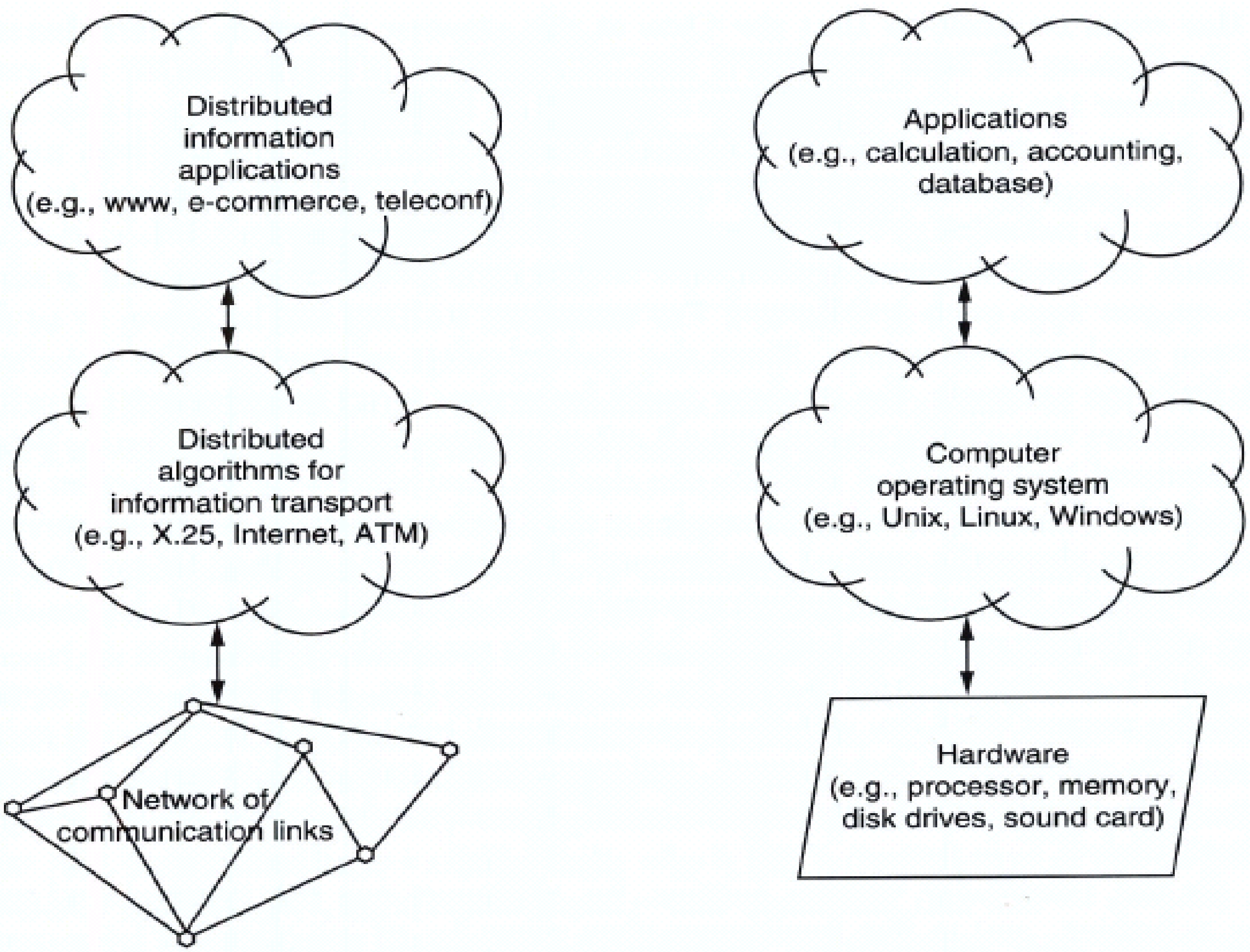


Common Information Services
User interfaces, transducers, servers, browsers, source compression, storage, buffering, jitter removal, etc.

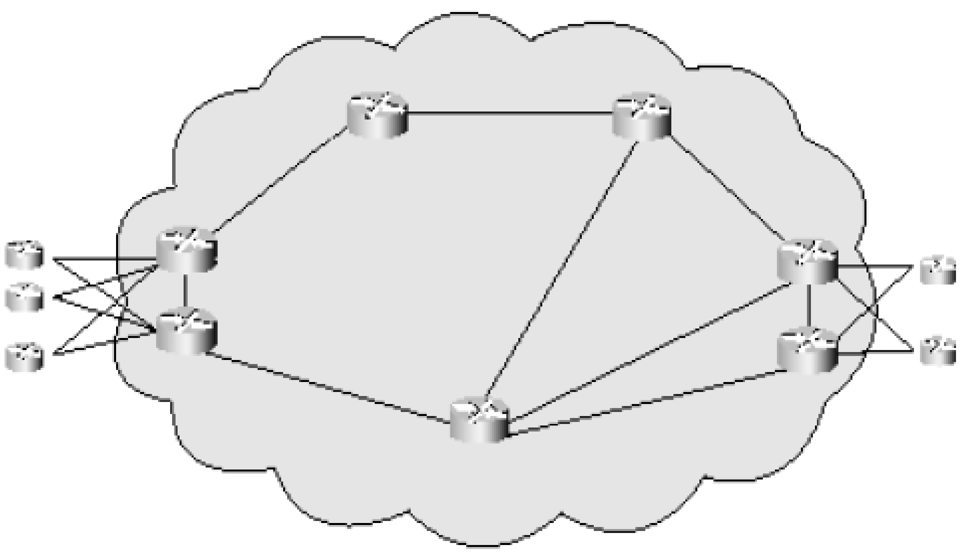
Resource Sharing Mechanisms
Dynamic and intelligent control of infrastructure and traffic flow: Multiplexing, scheduling, routing, network management

Bit Carrier Infrastructure
WDM, Optical crossconnects, SDH, DSL, cable, Ethernet, satellite, fixed or mobile wireless links

Communication Networks



Communication Networks

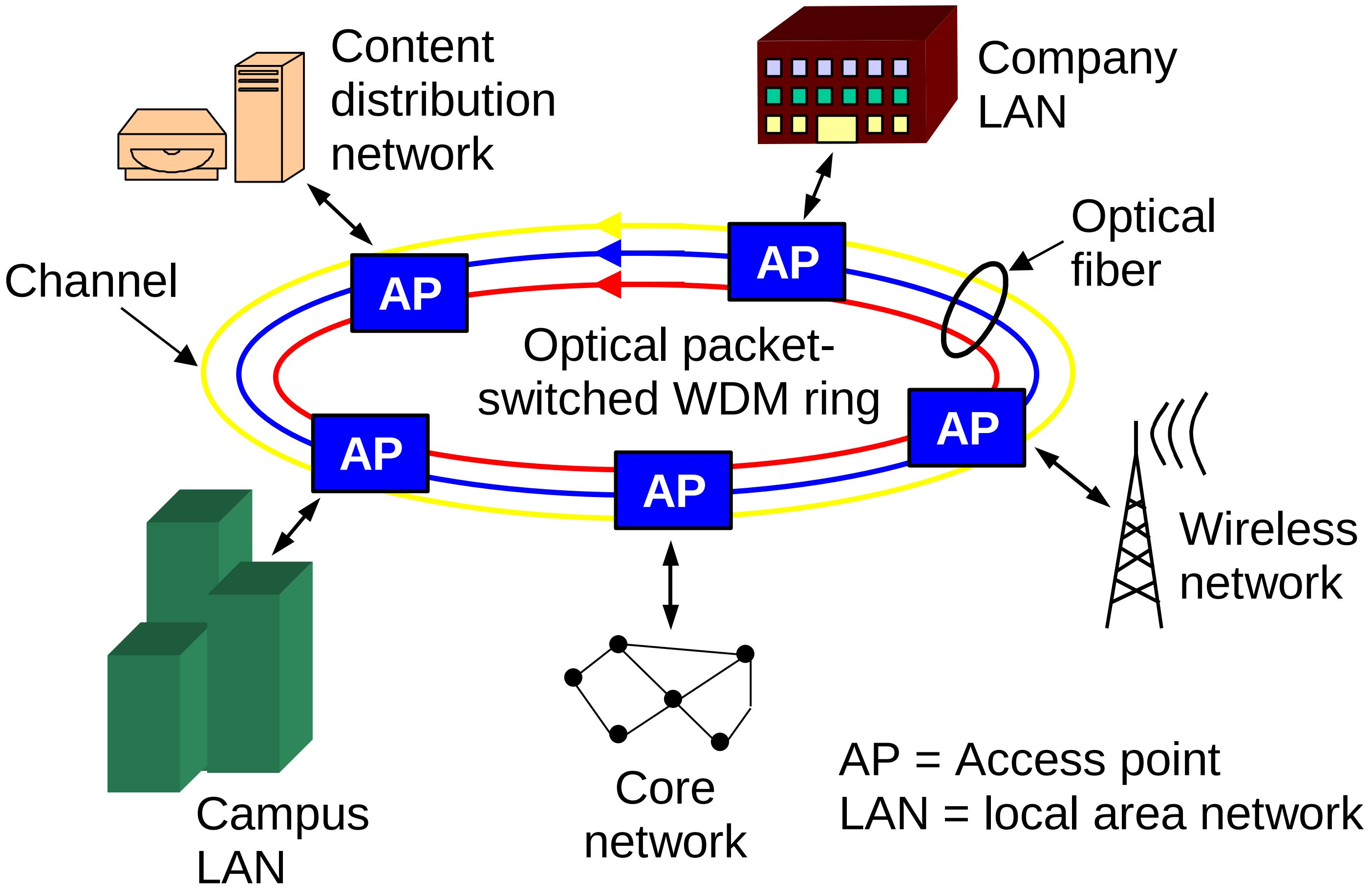


Communication Networks

- Transport of bits generated by the applications under the requirement of supportin the Quality of Service demanded by the applications

- Quality of Services – quality of transport needed by the application/service so that users can have a perception of good quality

Communication Networks

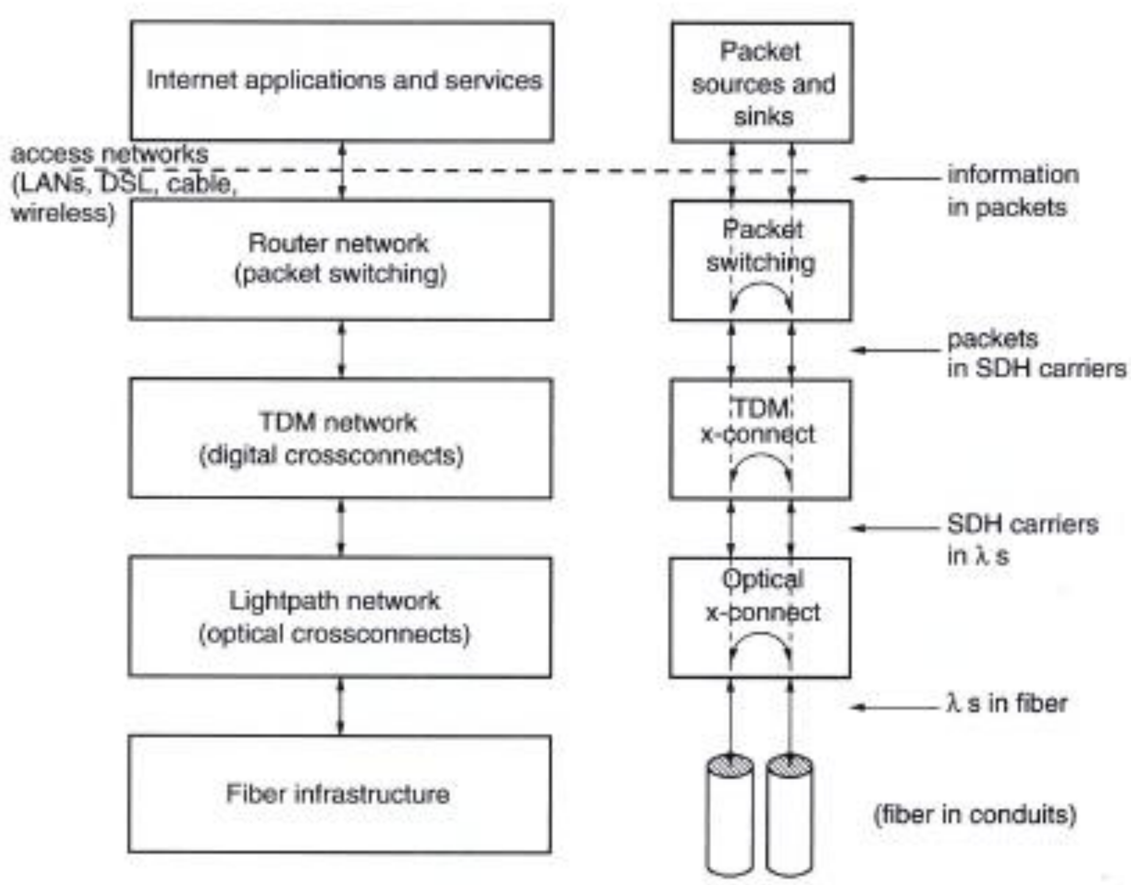


Traffic Control

- To support the Quality of Service requirements of the applications the bits generated by them should flow though appropriate paths and the flows should have expected patterns

- Traffic control
  - ✓Congestion control
  - ✓Flow control
  - ✓Routing

Traffic Control



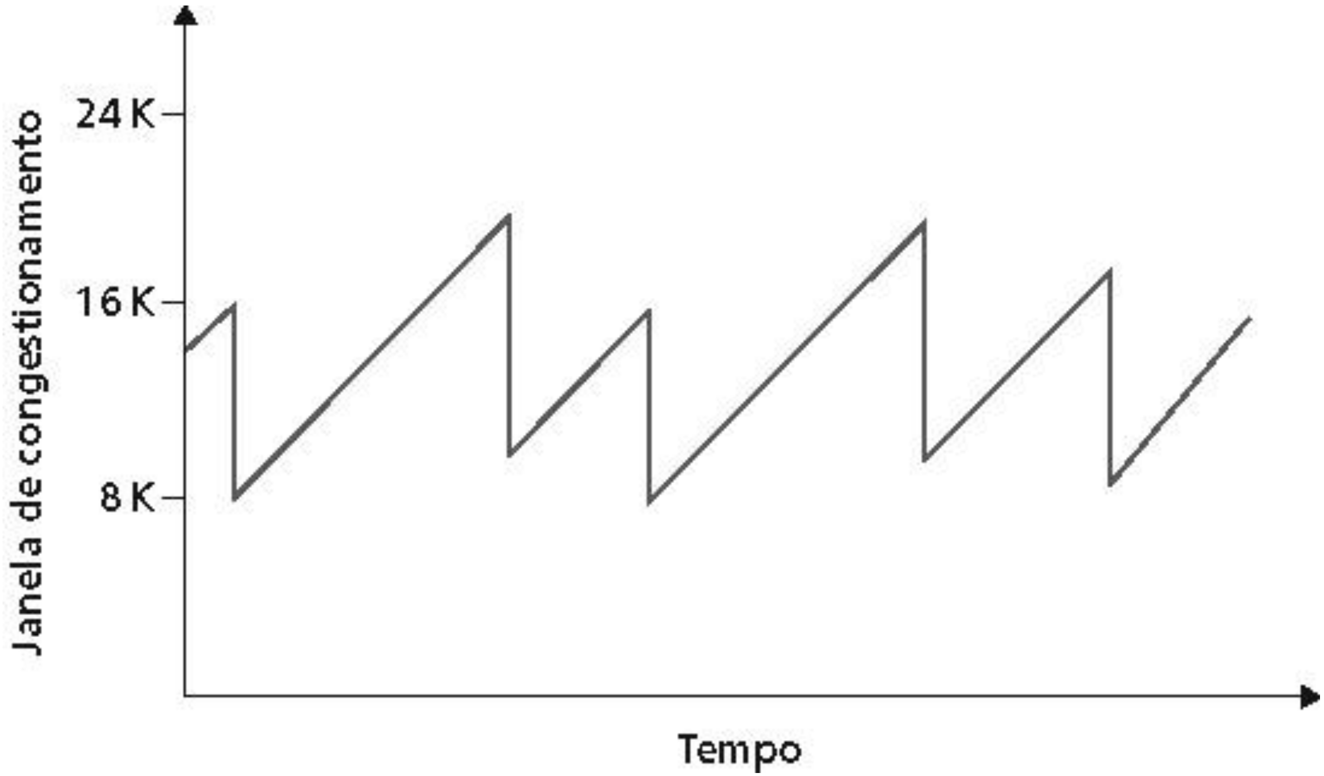
Traffic Control Mechanisms

- Policing
- Selective Discard
- Active queue management
- Scheduling
- Classification
- Admission control
- Routing

Performance Evaluation

- Aim to assess how efective objectives are achieved
  - Exemple: to evaluate the behavior of TCP variants developed to high speed networks
    - Does the mechanism behaves in the same way conceived during its design? What are the operational limits of the proposed mechanism?

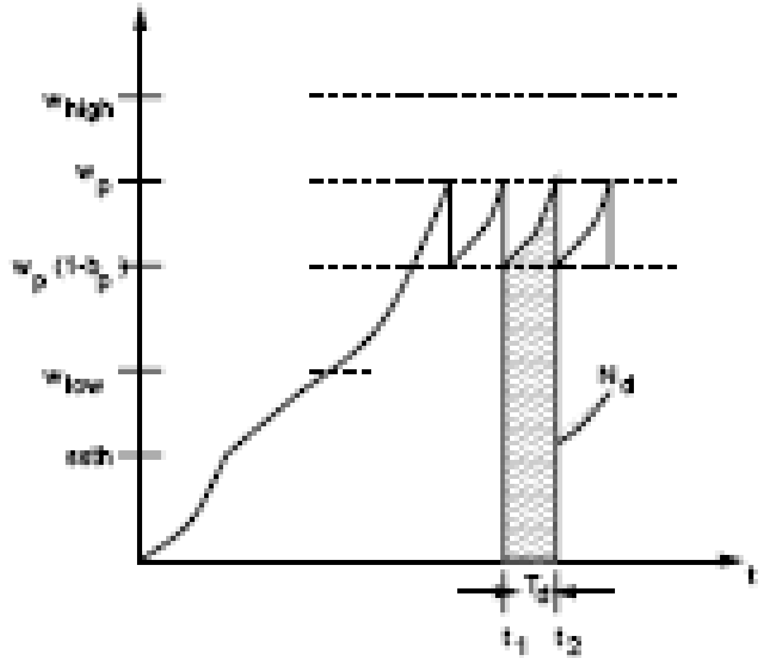
Performance Evaluation



Performance Evaluation

$$a(w) = \frac{2w^2 b(w)\, p(w)}{2 - b(w)}$$

$$b(w) = \frac{\log(w / w_{low})}{\log(w_{high} / w_{low})} (b_{high} - 0.5) + 0.5$$



Performance Evaluation

- The aims is the analysis of the system and not numerical statements
- The tool (theory) used depends on the nature of the problem under study, including the time scale of interest

Common Approaches

- Analytical Models
- Simulation
- Measurement
- Emulation

Analytical Models

- Queueing Theory
- Stochastic Processes
- Optimization
- Control Theory
- Graph Theory

- Reproductable and verifiable results
- Limited capacity of representation
- Complexity growth with the level of detail

Analytical Models

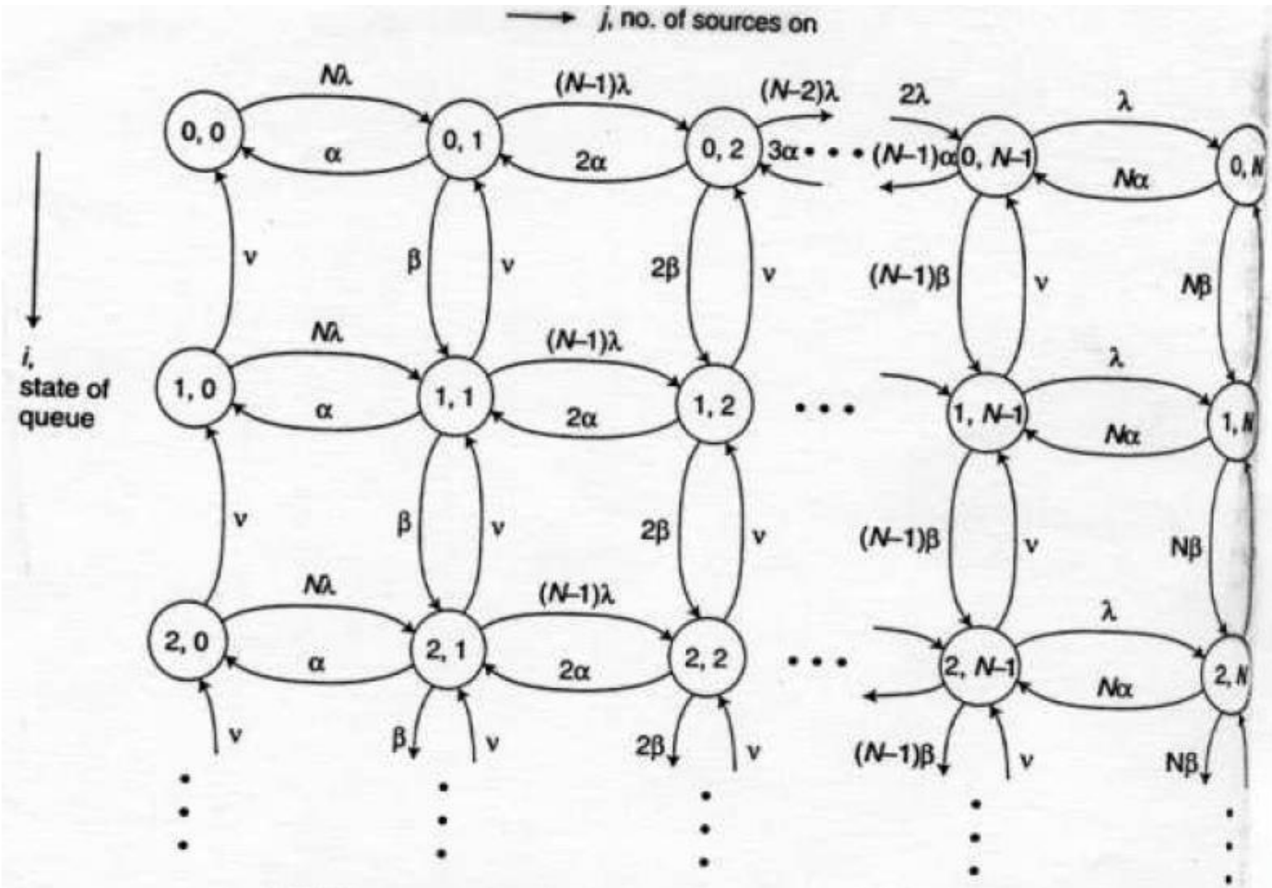
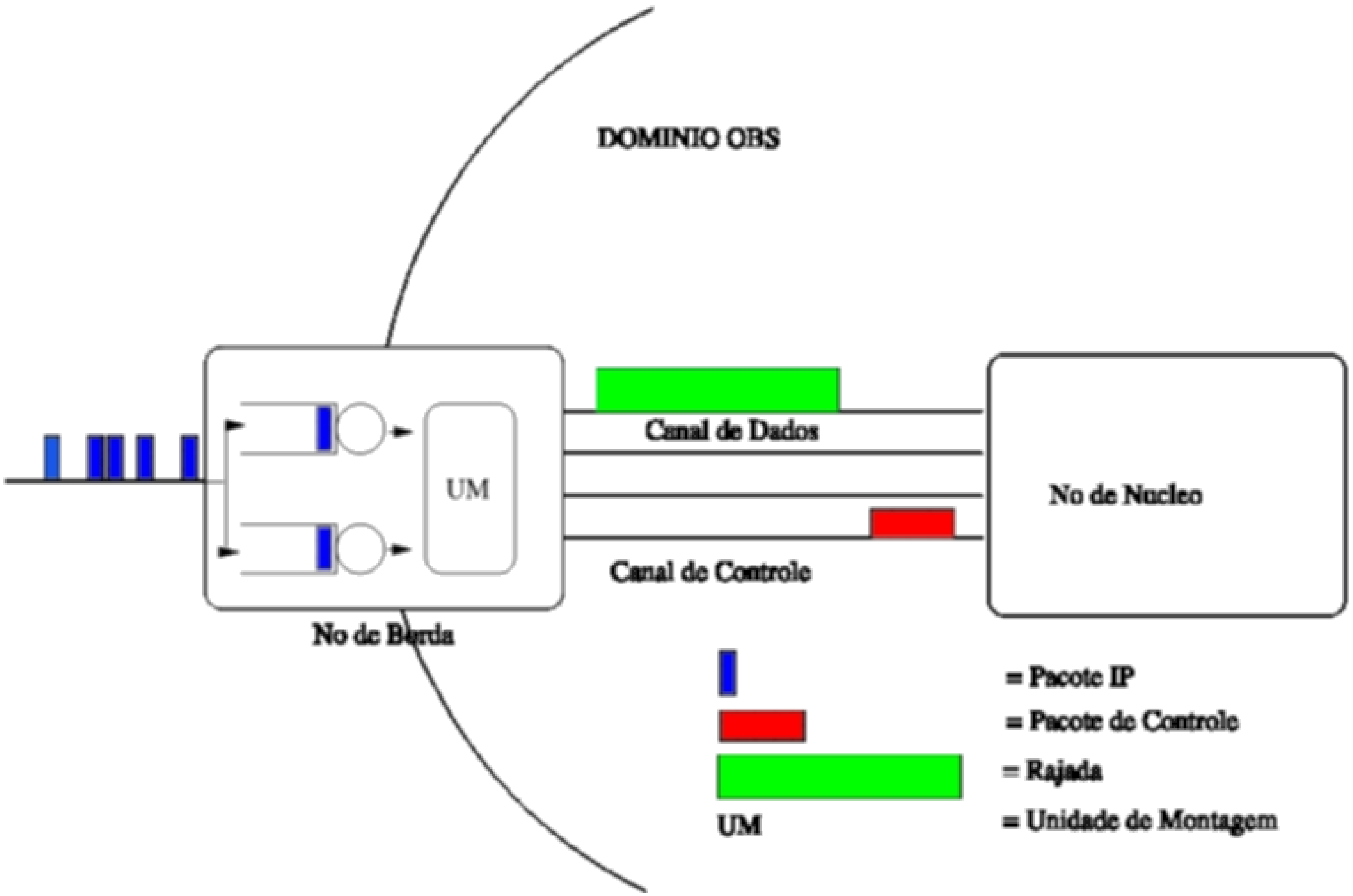


FIGURE 3–15 ■ State space representation, multiplexer, Figure 3–14.

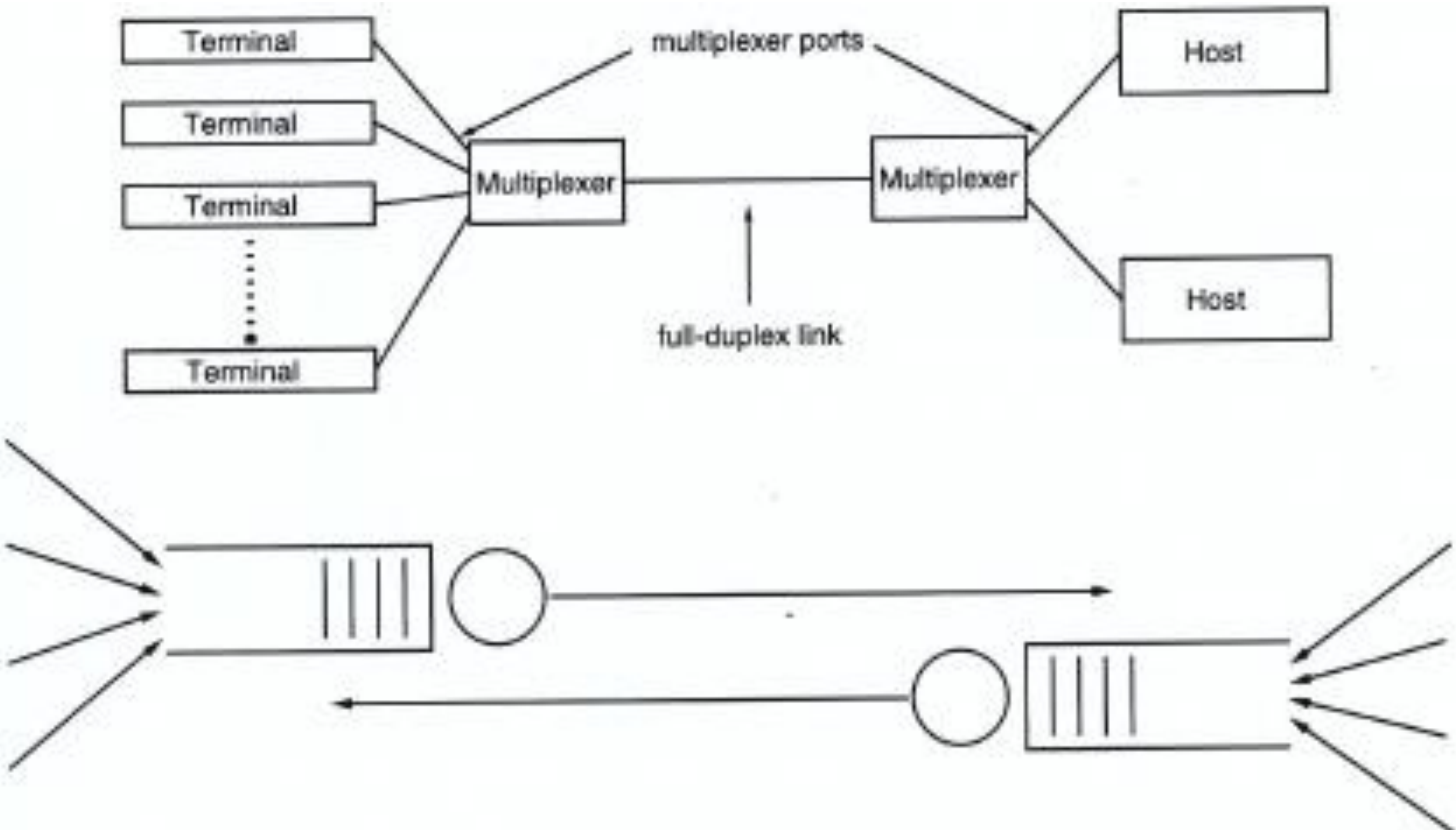
Queueing Theory

- Queues Everywhere
- Delay, loss probabilty, utilization, accessbility…
- Language of networks…

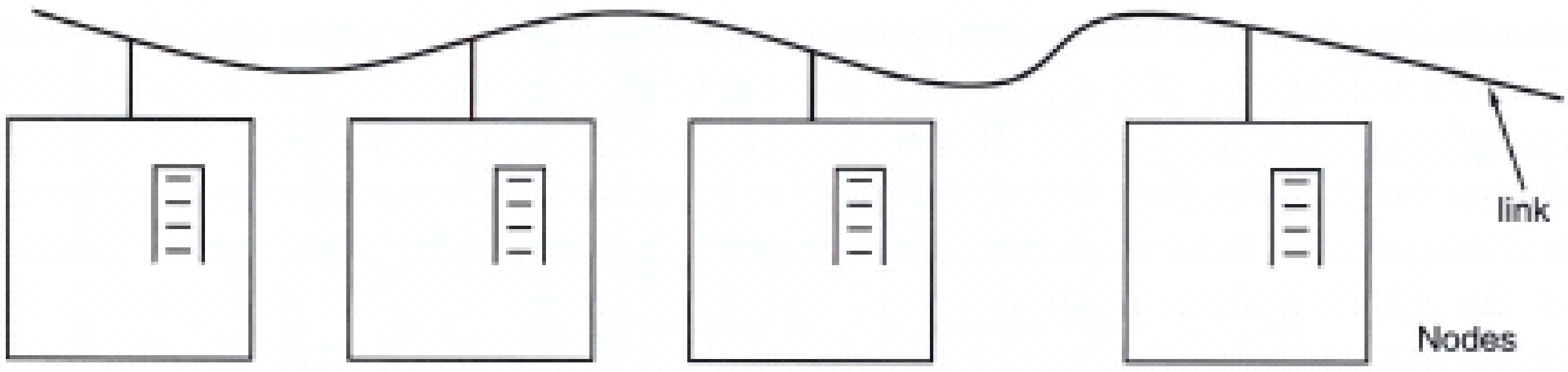
Queueing Theory



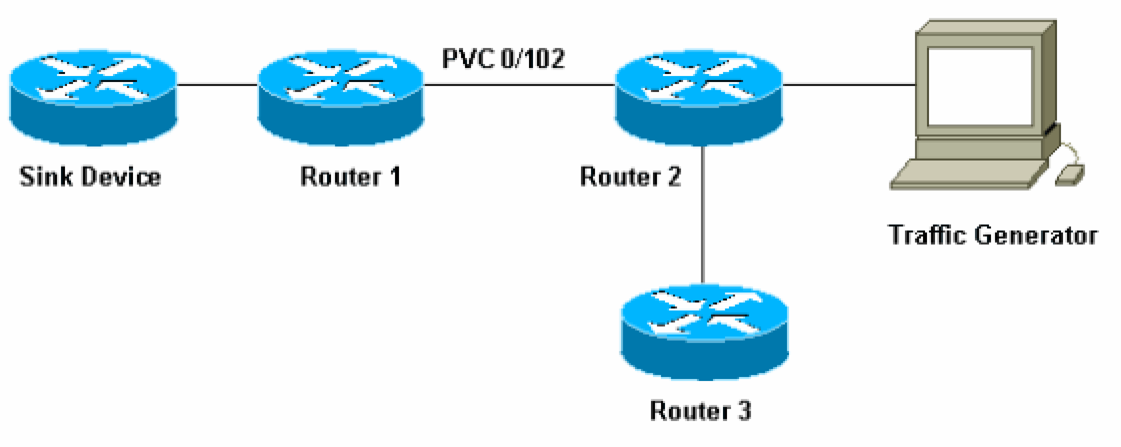
Queueing Theory



Queueing Theory

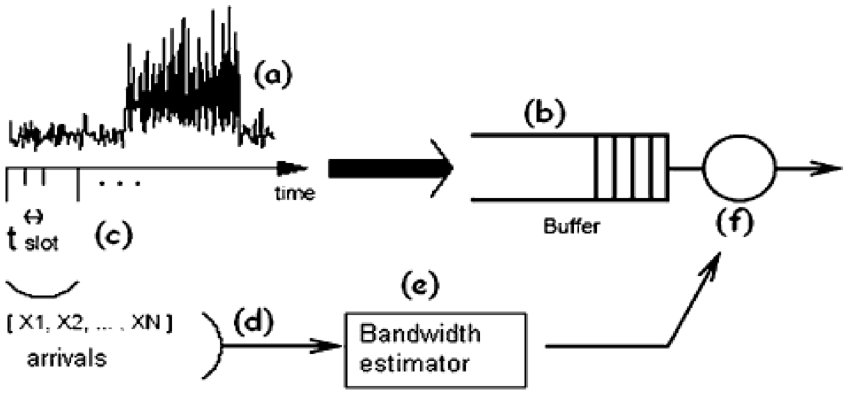


Queueing Theory

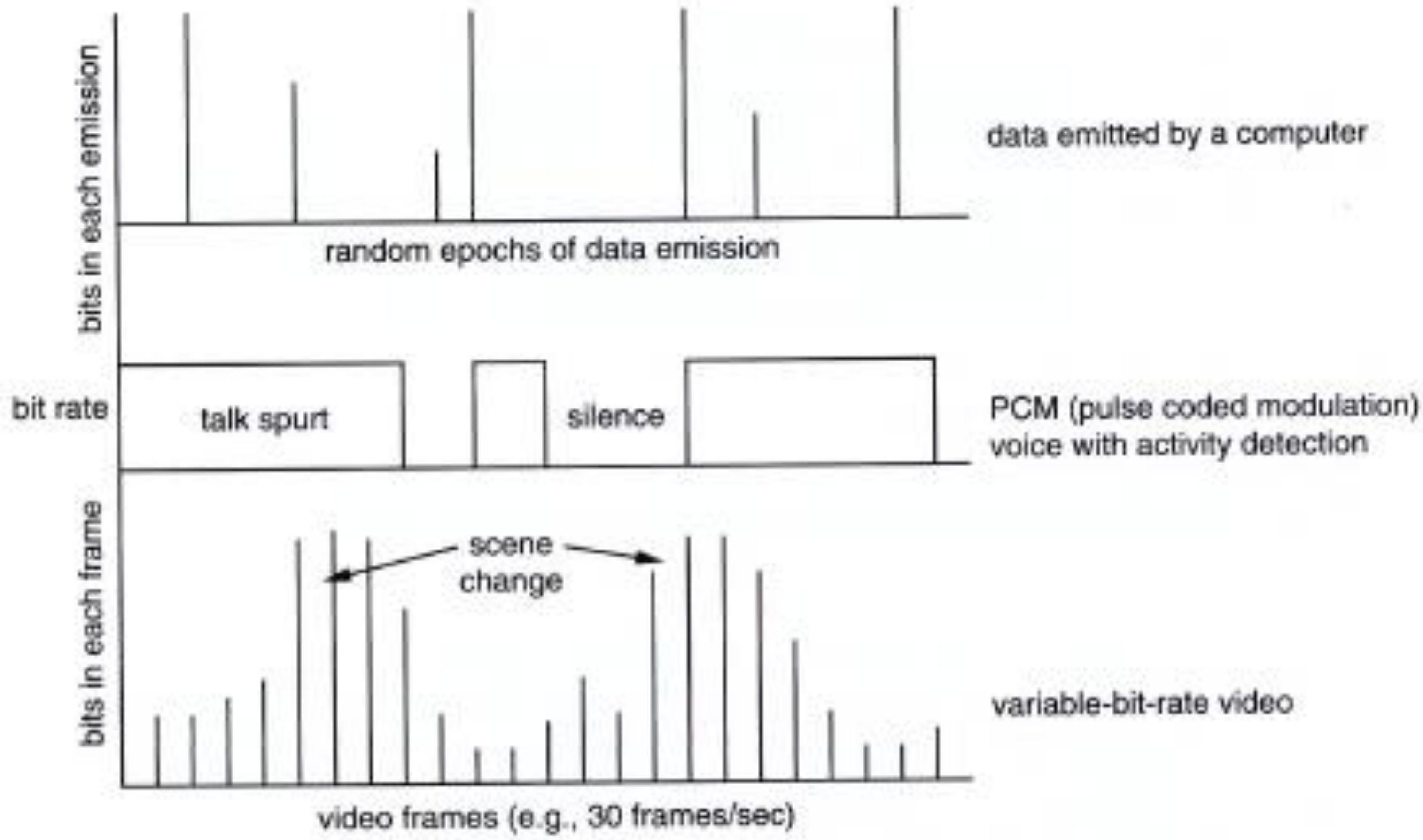


Stochastic Process

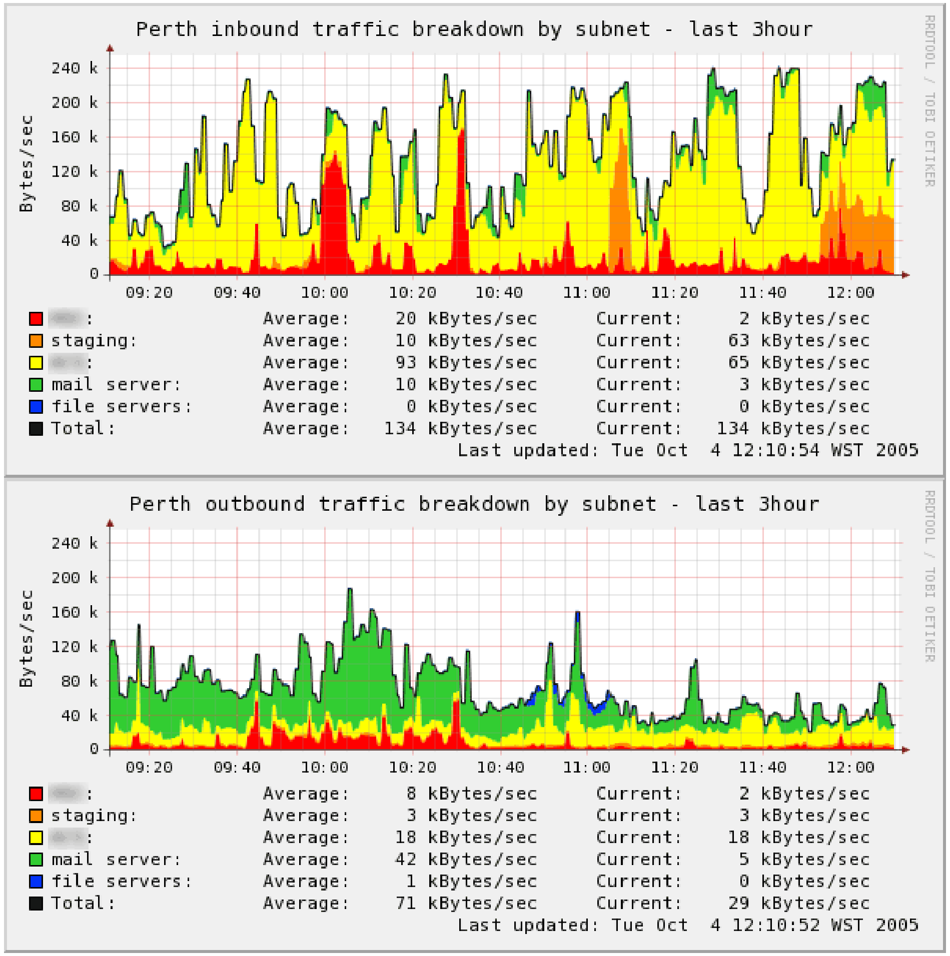
- How is the network traffic
- What is important to characterize the traffic?



Stochastic Process



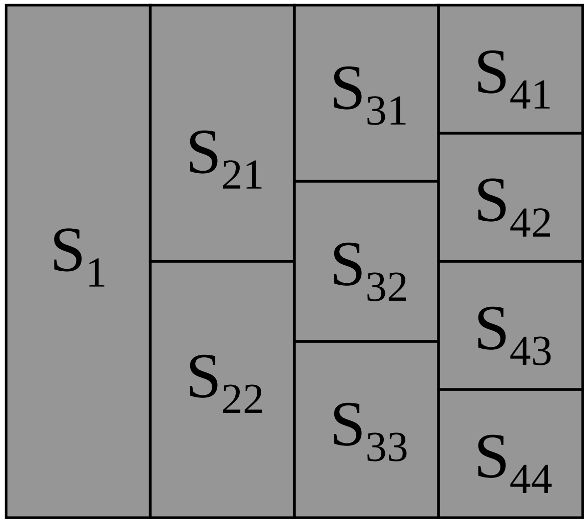
Stochastic Process

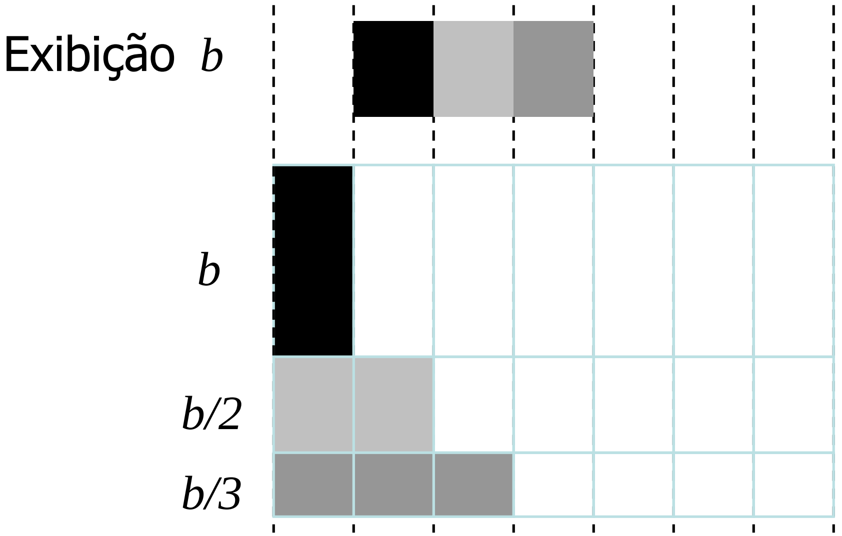


Optimization

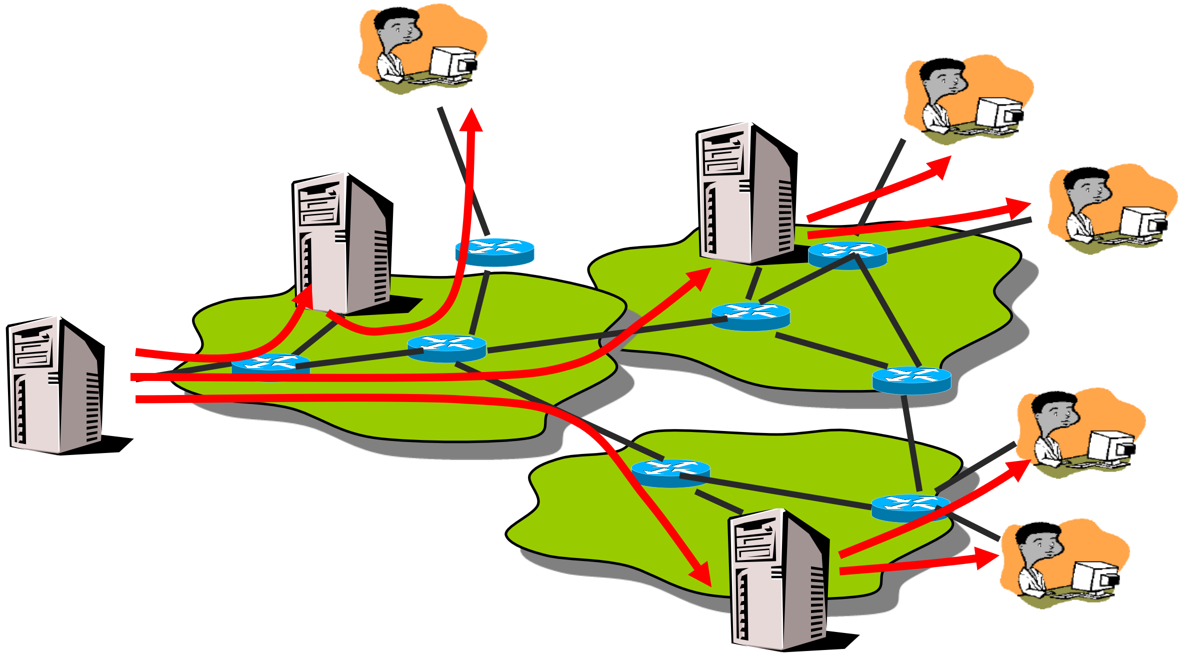
- Resource allocation
- Topological design
- Scheduling of tasks
- Linear, non-liear, integer, mixed, heuristics..

Optimization

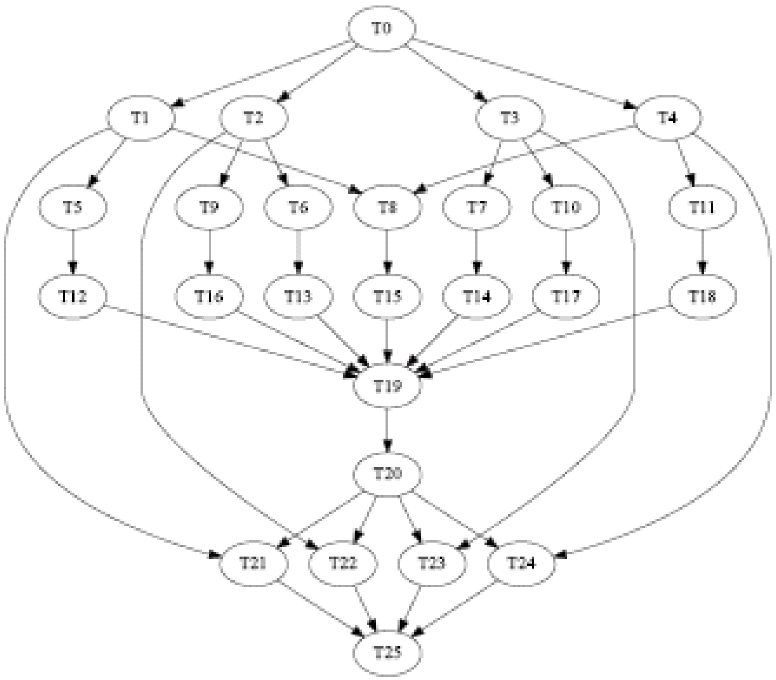


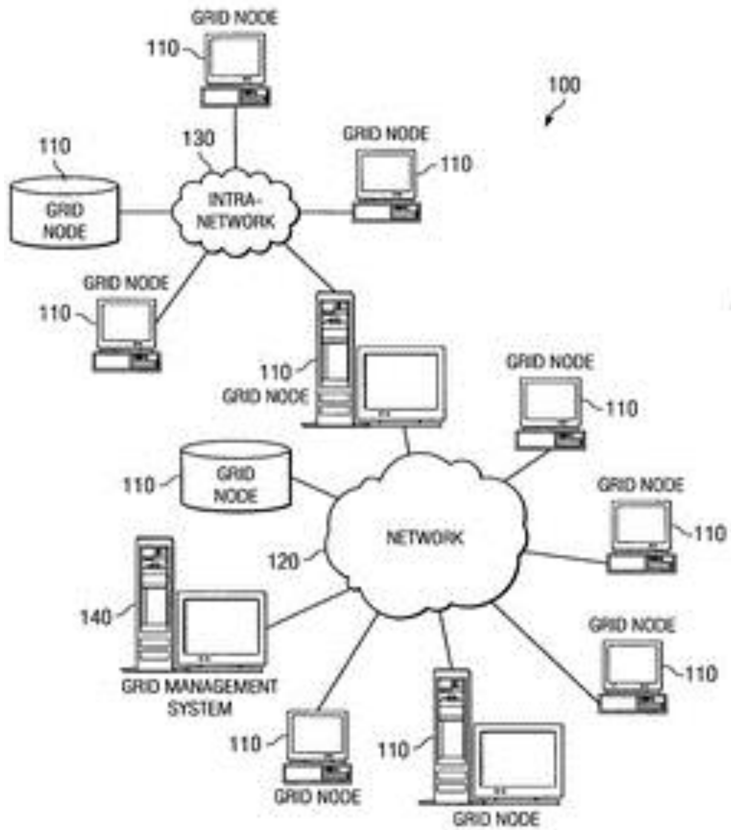


Optimization



Optimization



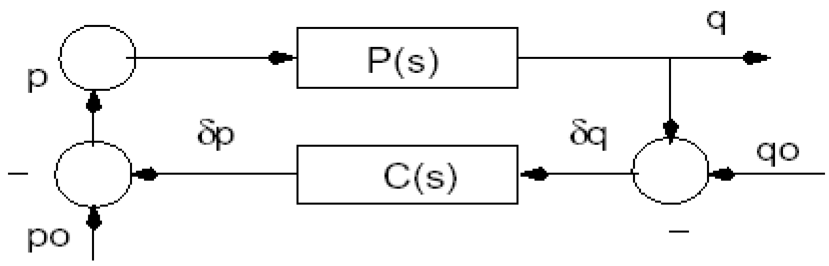


Optimization

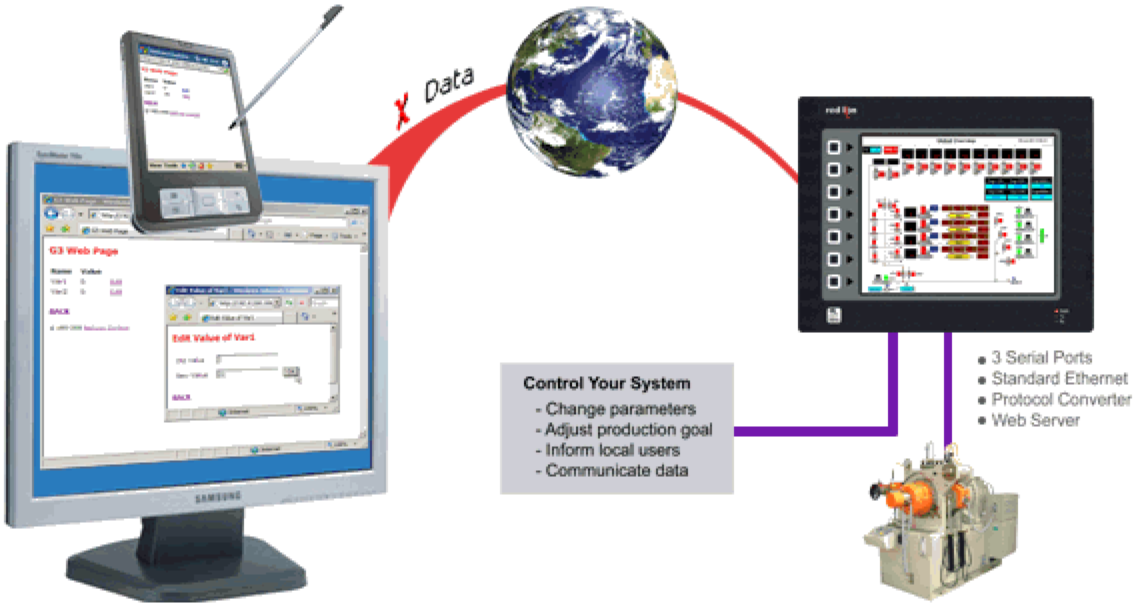
- Game Theory

Control Theory

- Traffic fluid model
- System stability
- Active queue management, ABR, policing, Internet stability
- Linear, non-linear, optimum, adaptative



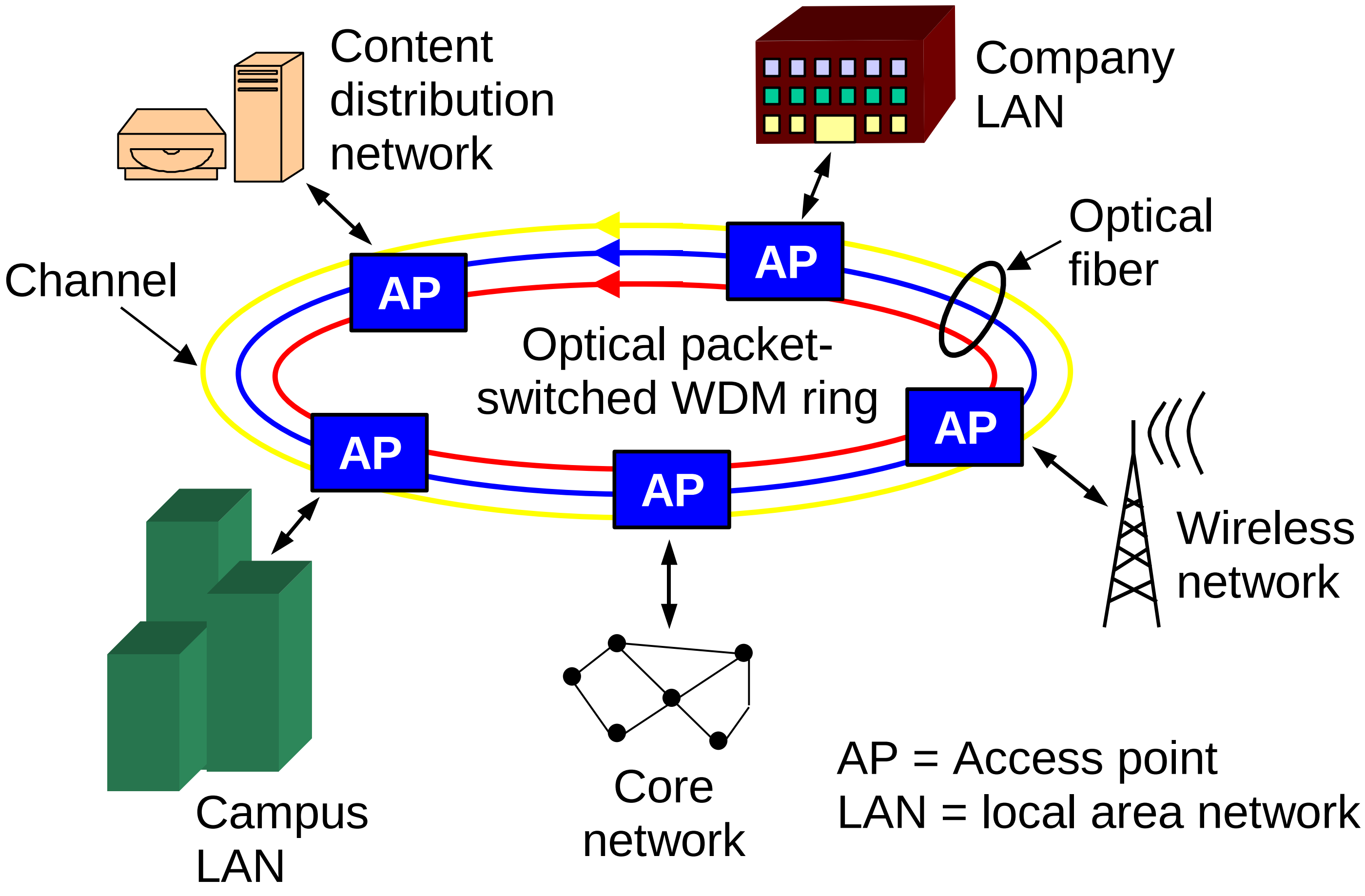
Control Theory



Graph Theory

- Network flow, coloring
- Routing
- Channel allocation in wireless and optical networks

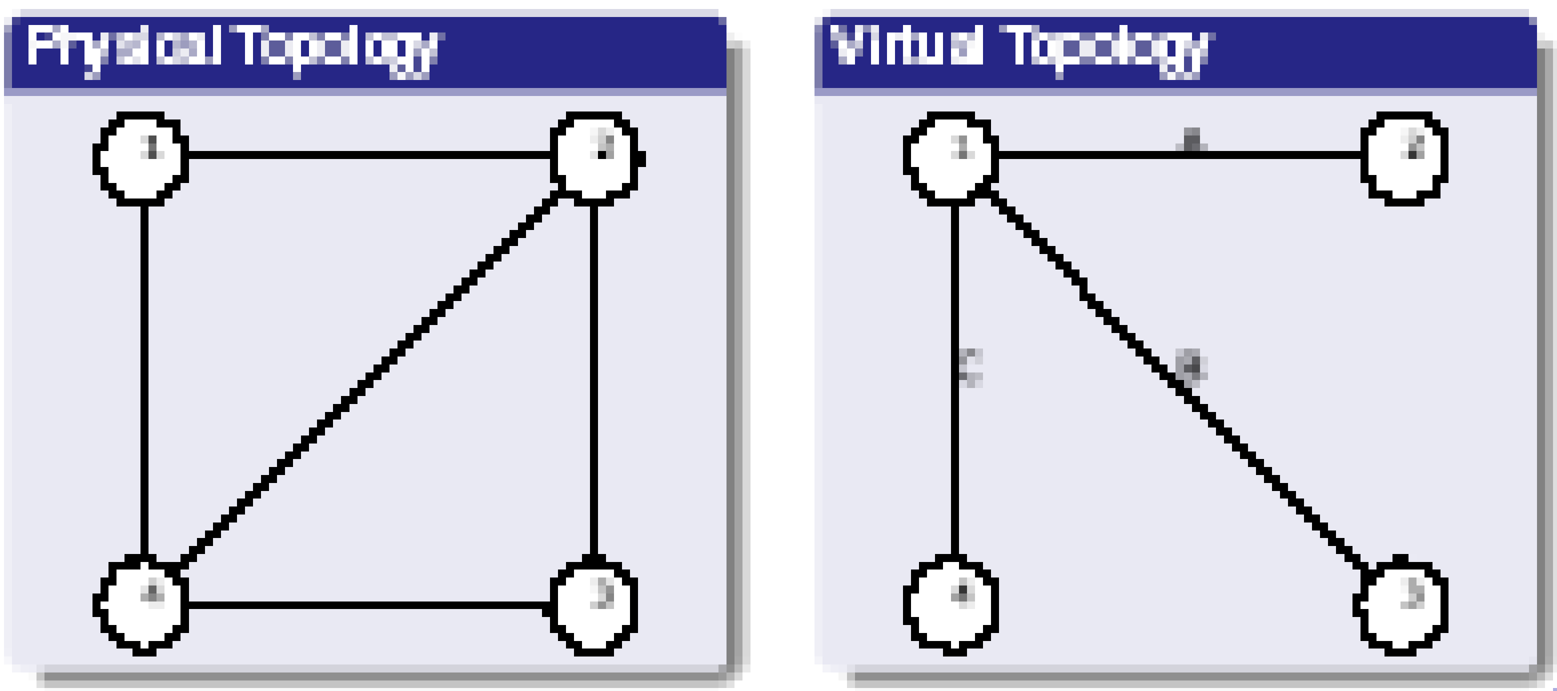
Coloring



Content
distribution
network
Company
LAN
Optical
fiber
Channel
AP
AP
AP
AP
AP
Optical packet-
switched WDM ring
Wireless
network
Campus
LAN
Core
network
AP = Access point
LAN = local area network

Graph Theory

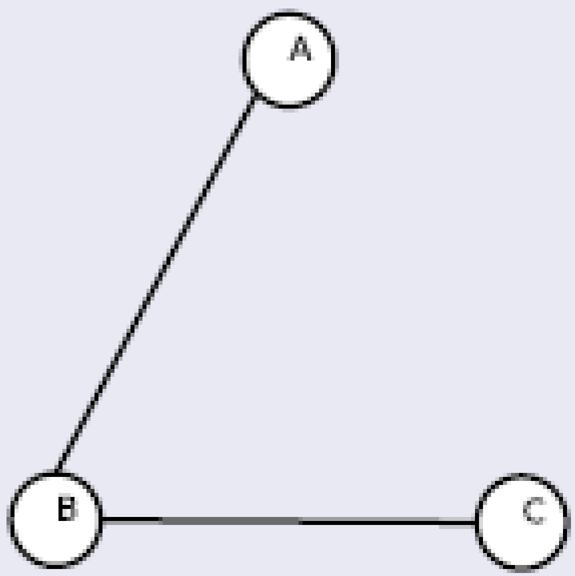
- Lightpaths to be established:
- A (1-4-2) | B (1-4-3) | C (1-2-3-4)



Graph Theory

- Auxiliary Graph (each vertex represents a lightpath)
- Connect vertices (lightpaths with shared links)
- Compute a minimum coloring (adjacent vertices receive different colors)

Auxiliary Graph



Colored Auxiliary Graph

Graph Theory

- Auxiliary Graph (each vertex represents a lightpath)
- Connect vertices (lightpaths with shared links)
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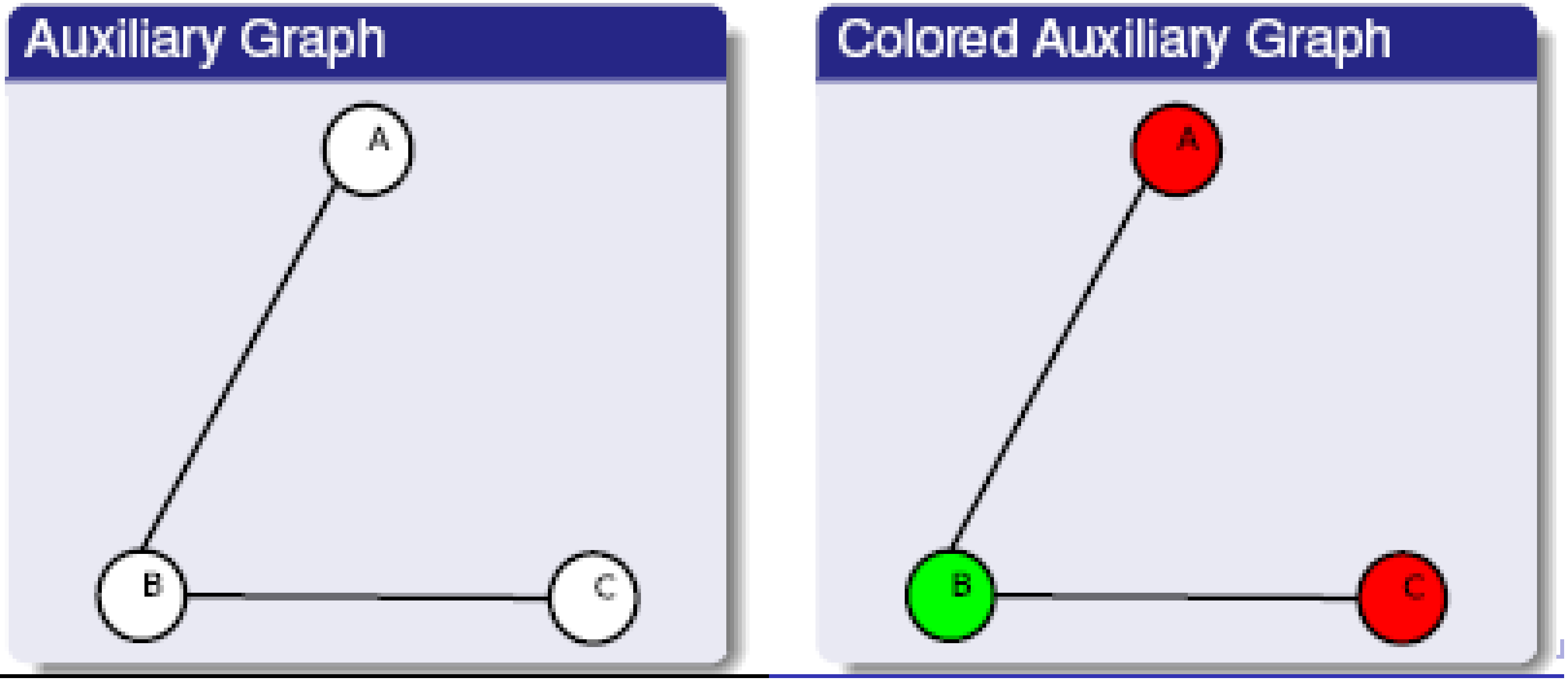
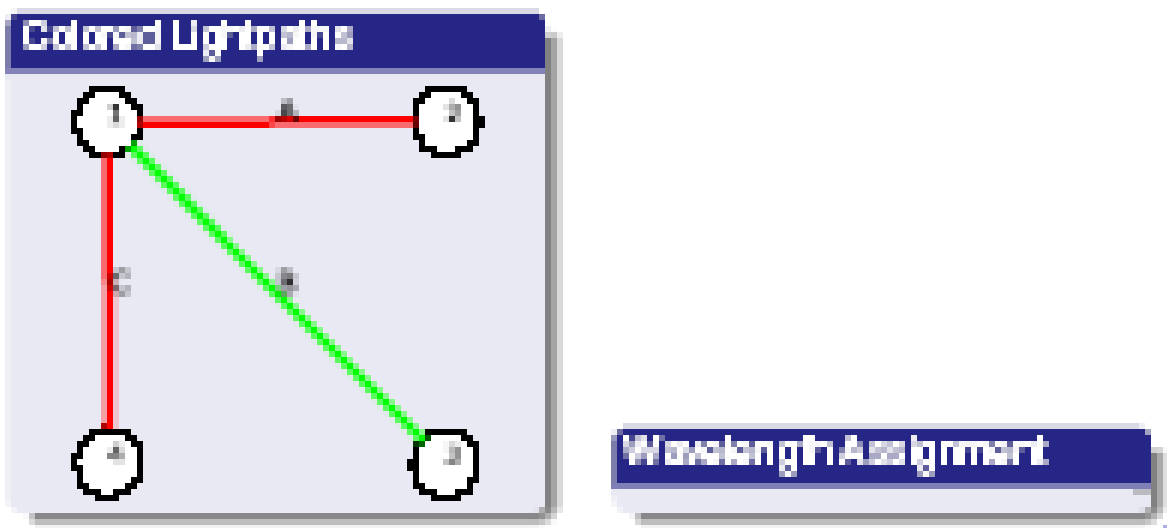


Graph Theory

- Coloring can be directed mapped onto wavelengths
- Wavelength Assignment completed



Graph Theory

- Coloring can be directed mapped onto wavelengths
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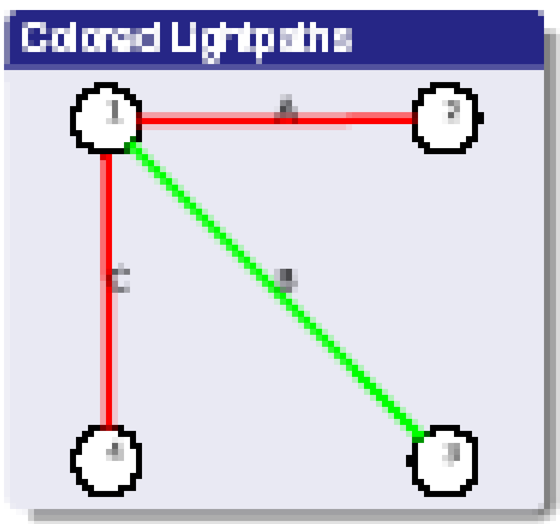
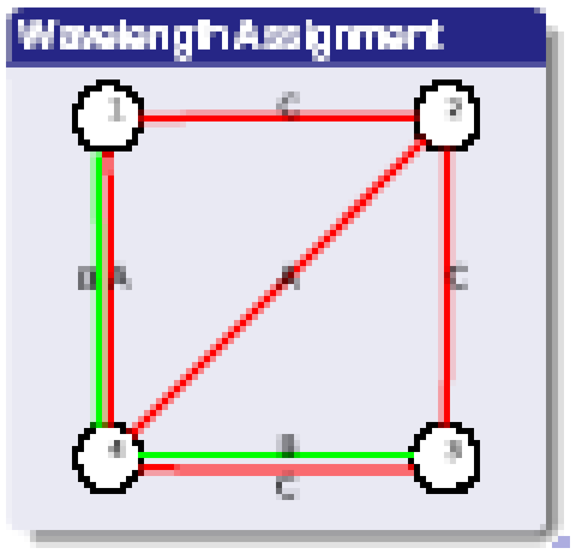
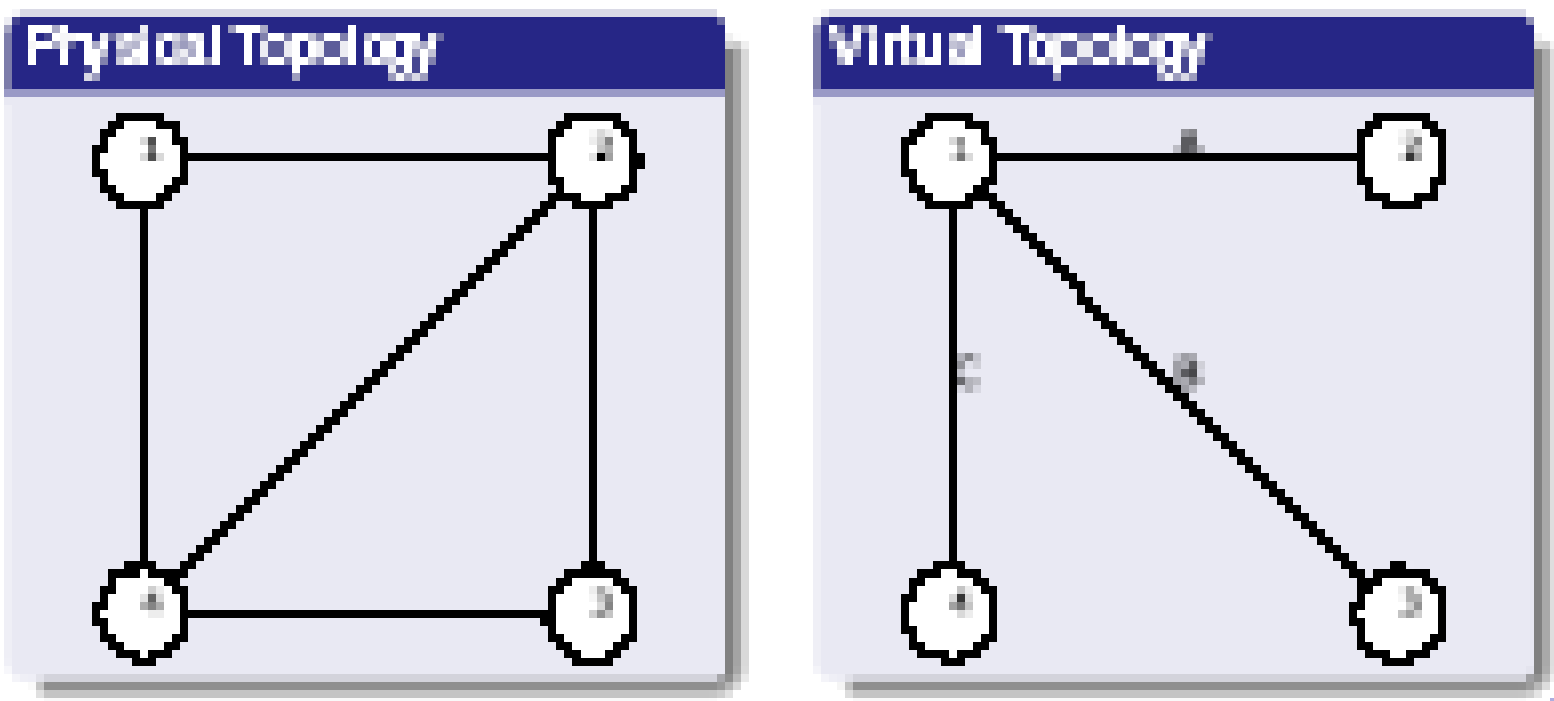


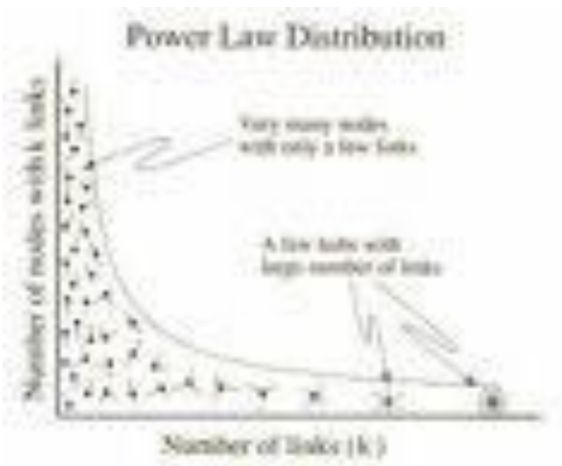


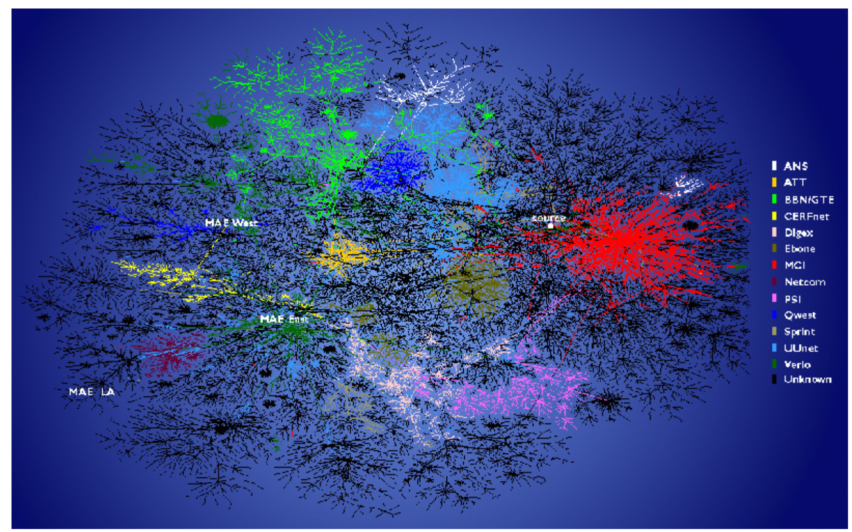
Graph Theory

- Lightpaths to be established:
- A (1-4-2) | B (1-4-3) | C (1-2-3-4)

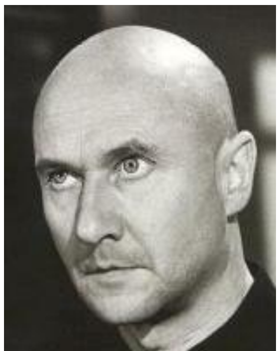


Complex Networks

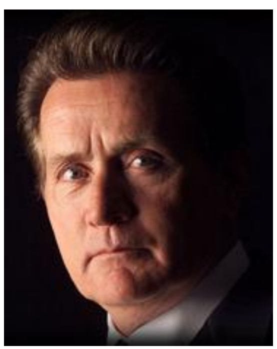




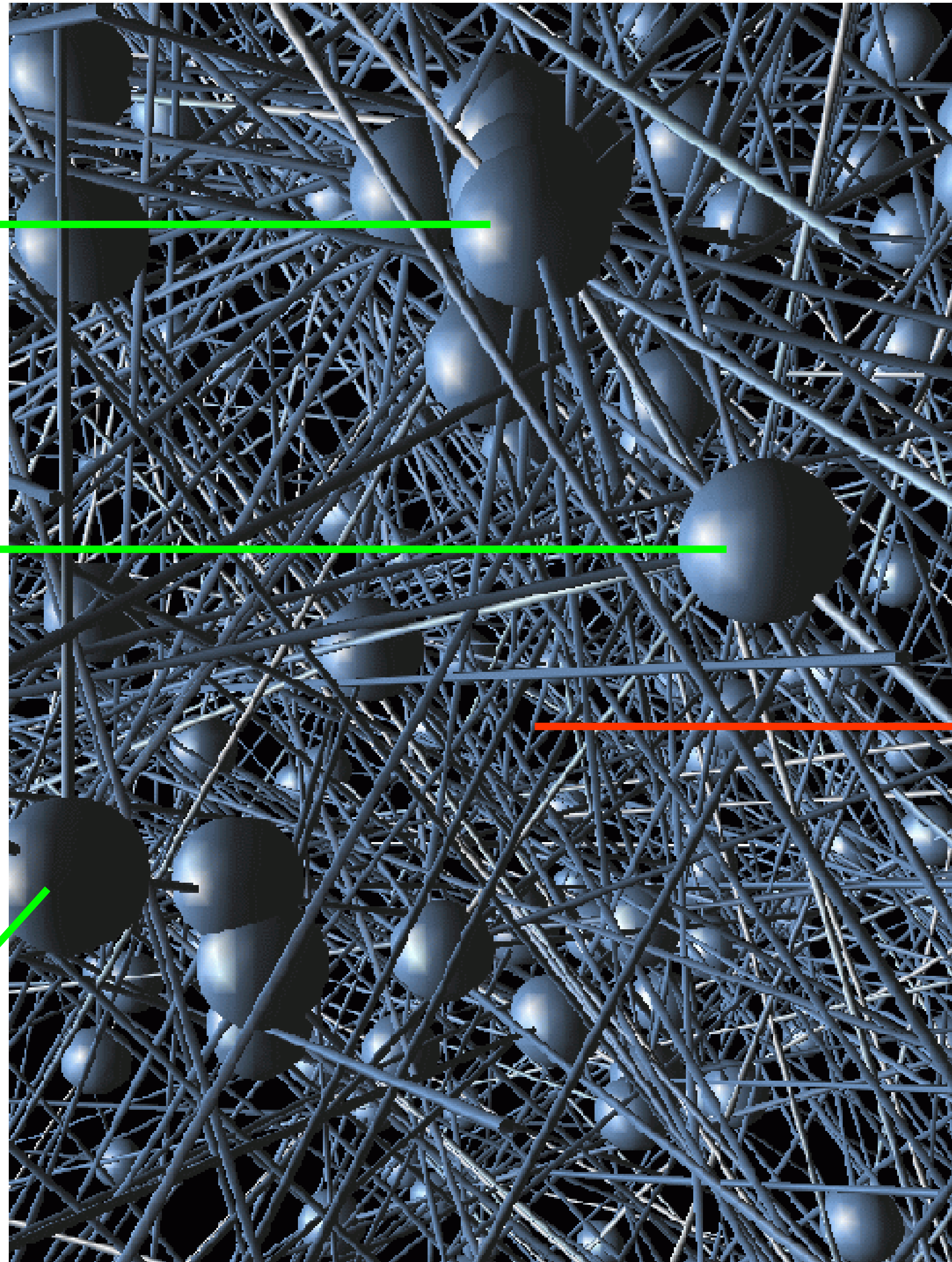
#1 Rod Steiger



#2 Donald Pleasence



#3 Martin Sheen



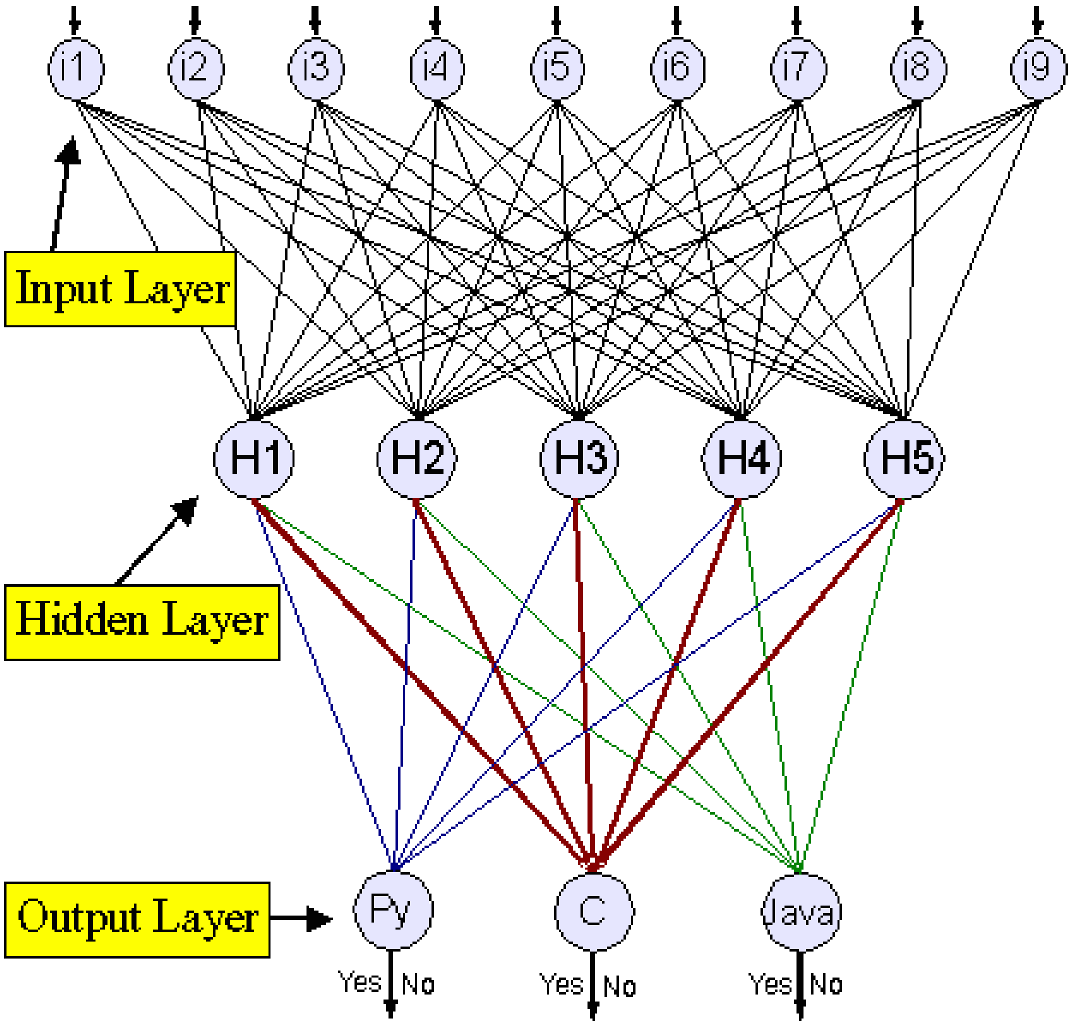
#876 Kevin Bacon

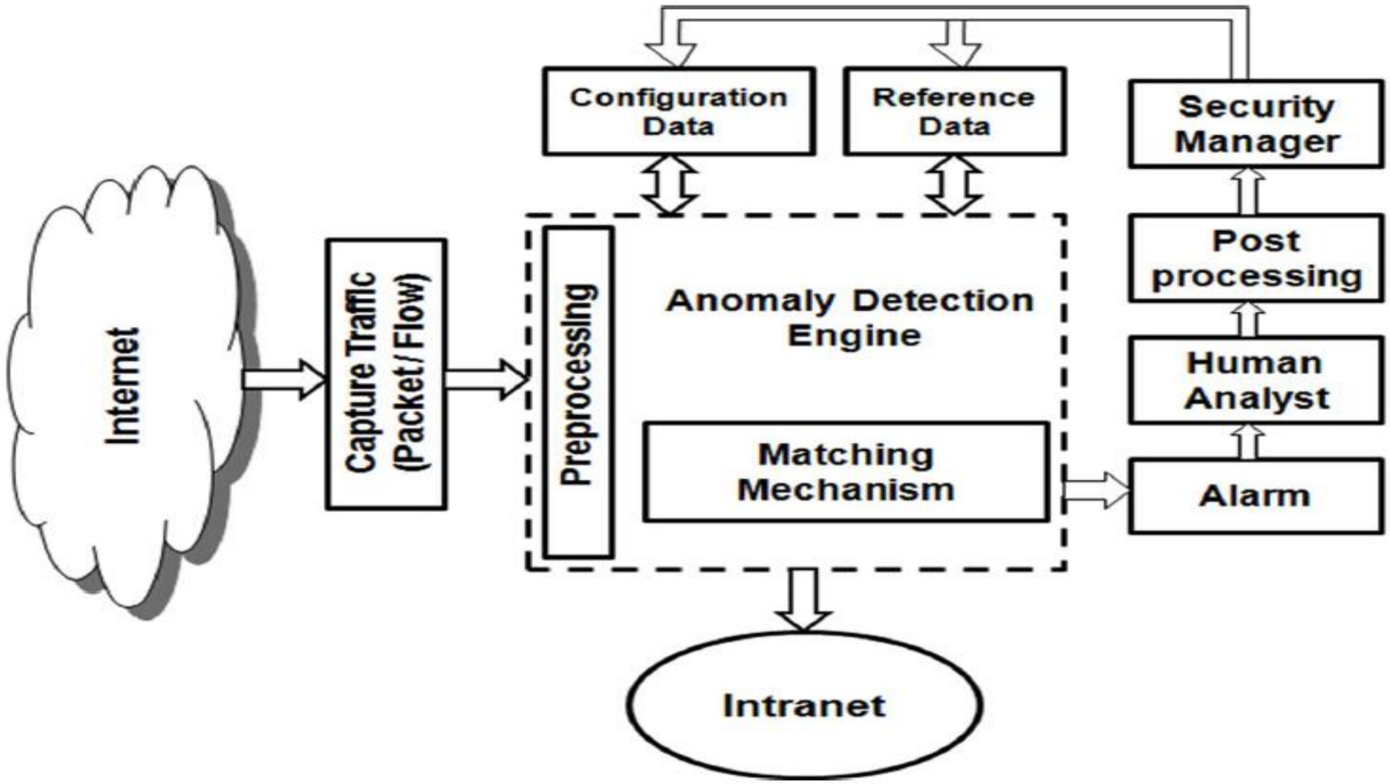
Machine Learning Algorithms

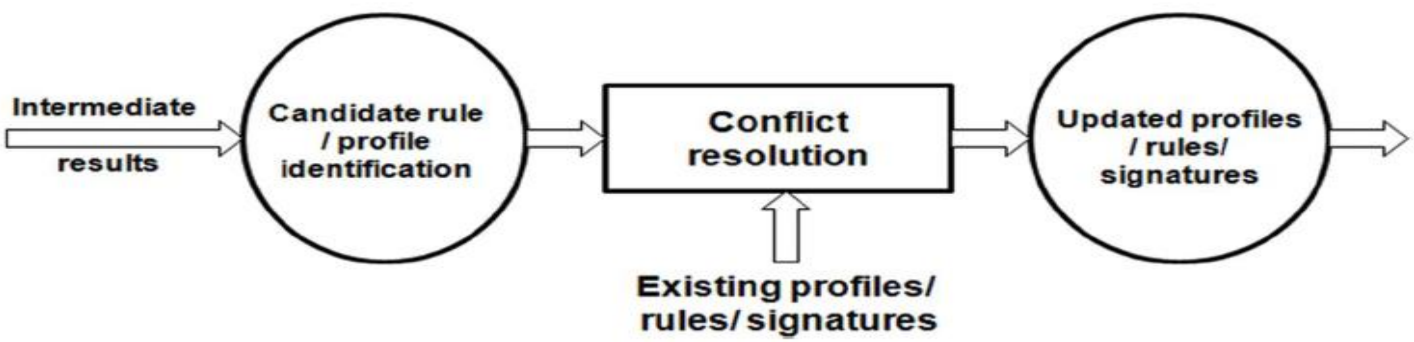
	Supervised	Unsupervised
Categorical	(Classification) *k* Nearest Neighbors Support Vector Machine Neural Networks	Hidden Markov Model
Continuous	Decision Trees Random Forests Regression	(Clustering and Dimensionality Reduction) Principal Component Analysis Singular Value Decomposition Gaussian Mixture Model

Neural Networks

•

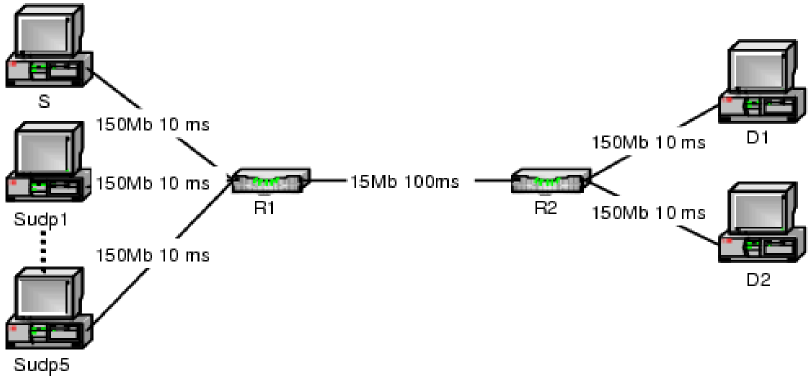



Configuration Data
Reference Data
Security Manager
Internet
Capture Traffic (Packet / Flow)
Preprocessing
Anomaly Detection Engine
Post processing
Human Analyst
Matching Mechanism
Alarm
Intranet

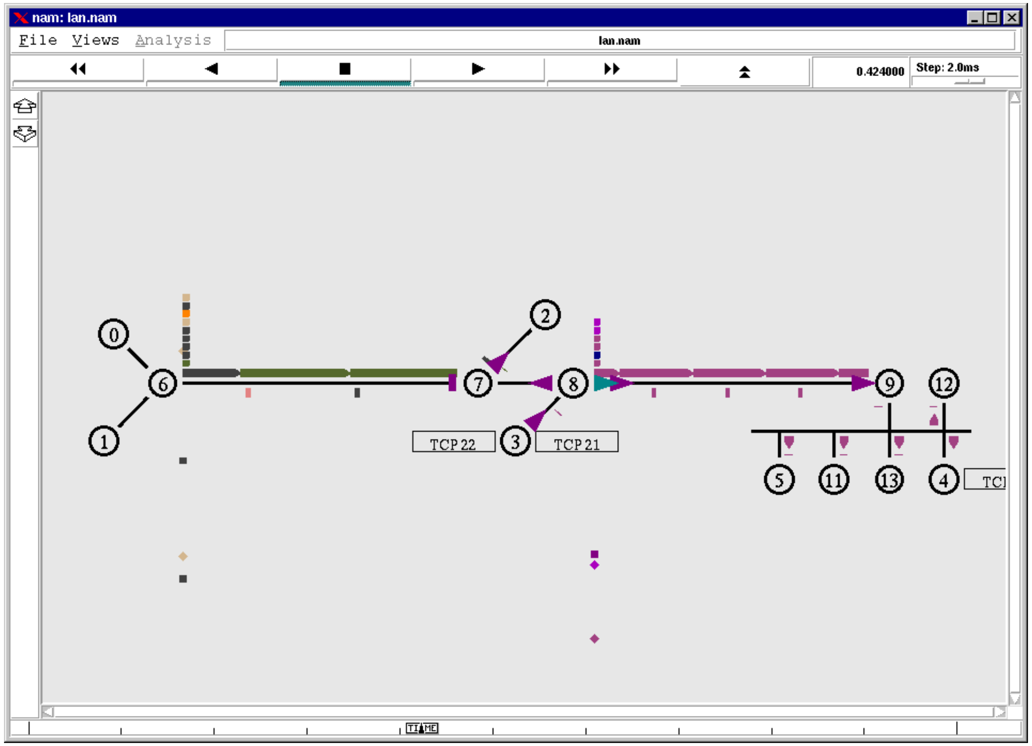

Intermediate results
Candidate rule / profile identification
Conflict resolution
Updated profiles / rules/ signatures
Existing profiles/ rules/ signatures

Simulation

- Reproduces the dynamics of the system
- Statistic techniques
- Easy to program
- High computational demand
- Not always well accepted



Simulation



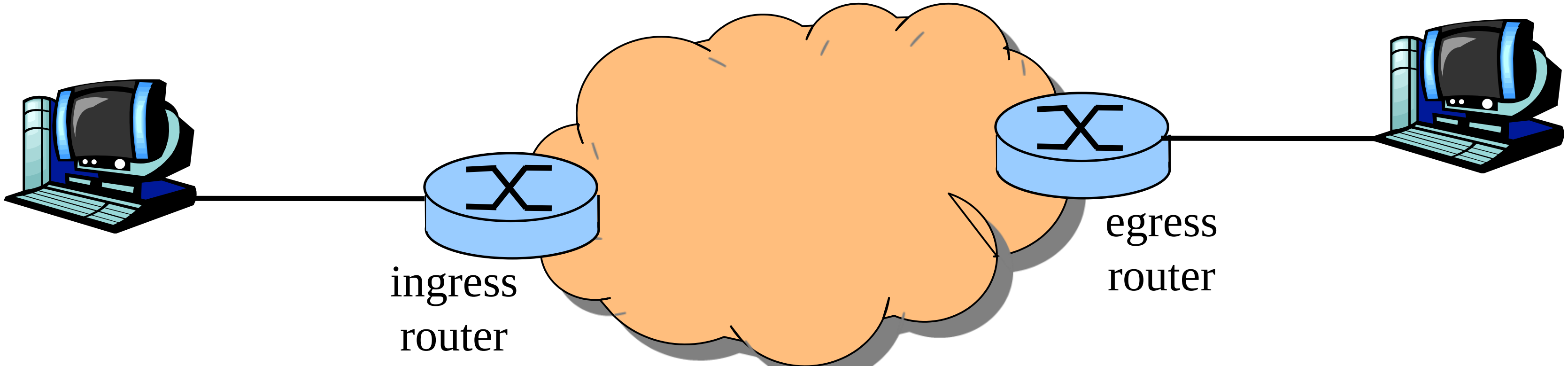
nam: lan.nam
File Views Analysis
lan.nam
0.424000
Step: 2.0ms
0
1
6
7
2
8
3
TCP 22
TCP 21
9
12
5
11
13
4
TIME

Simuation

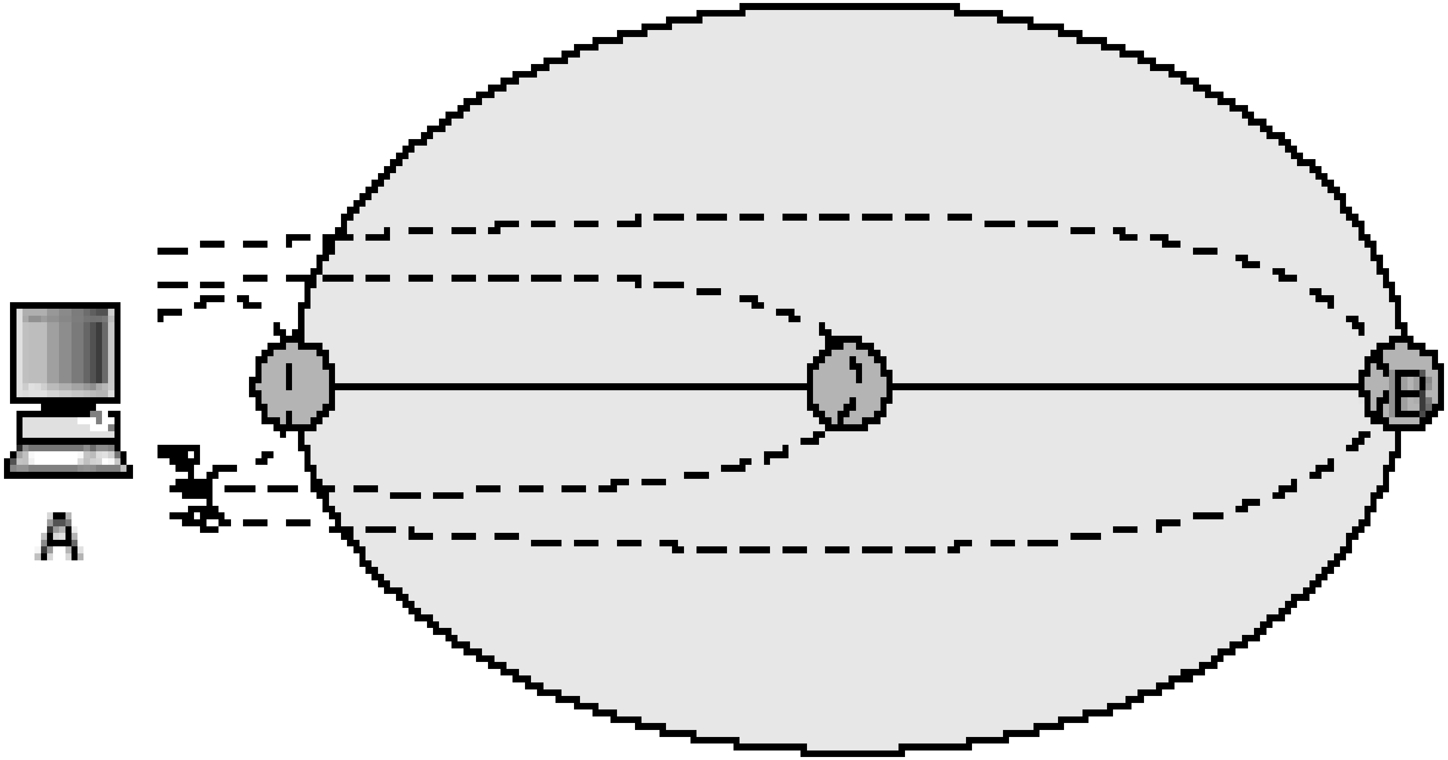
```
r 0.240667 2 3 cbr 1000 ------- 2 1.0 5.0 0 0
+ 0.240667 3 5 cbr 1000 ------- 2 1.0 5.0 0 0
- 0.240667 3 5 cbr 1000 ------- 2 1.0 5.0 0 0
r 0.286667 3 5 cbr 1000 ------- 2 1.0 5.0 0 0
+ 0.9 1 2 cbr 1000 ------- 2 1.0 5.0 1 1
- 0.9 1 2 cbr 1000 ------- 2 1.0 5.0 1 1
r 0.914 1 2 cbr 1000 ------- 2 1.0 5.0 1 1
+ 0.914 2 3 cbr 1000 ------- 2 1.0 5.0 1 1
- 0.914 2 3 cbr 1000 ------- 2 1.0 5.0 1 1
+ 1 0 2 tcp 40 ------- 1 0.0 4.0 0 2
- 1 0 2 tcp 40 ------- 1 0.0 4.0 0 2
```

Measurement

- To measure the real system
- Laborous
- Difficulty to replicate



Measurement

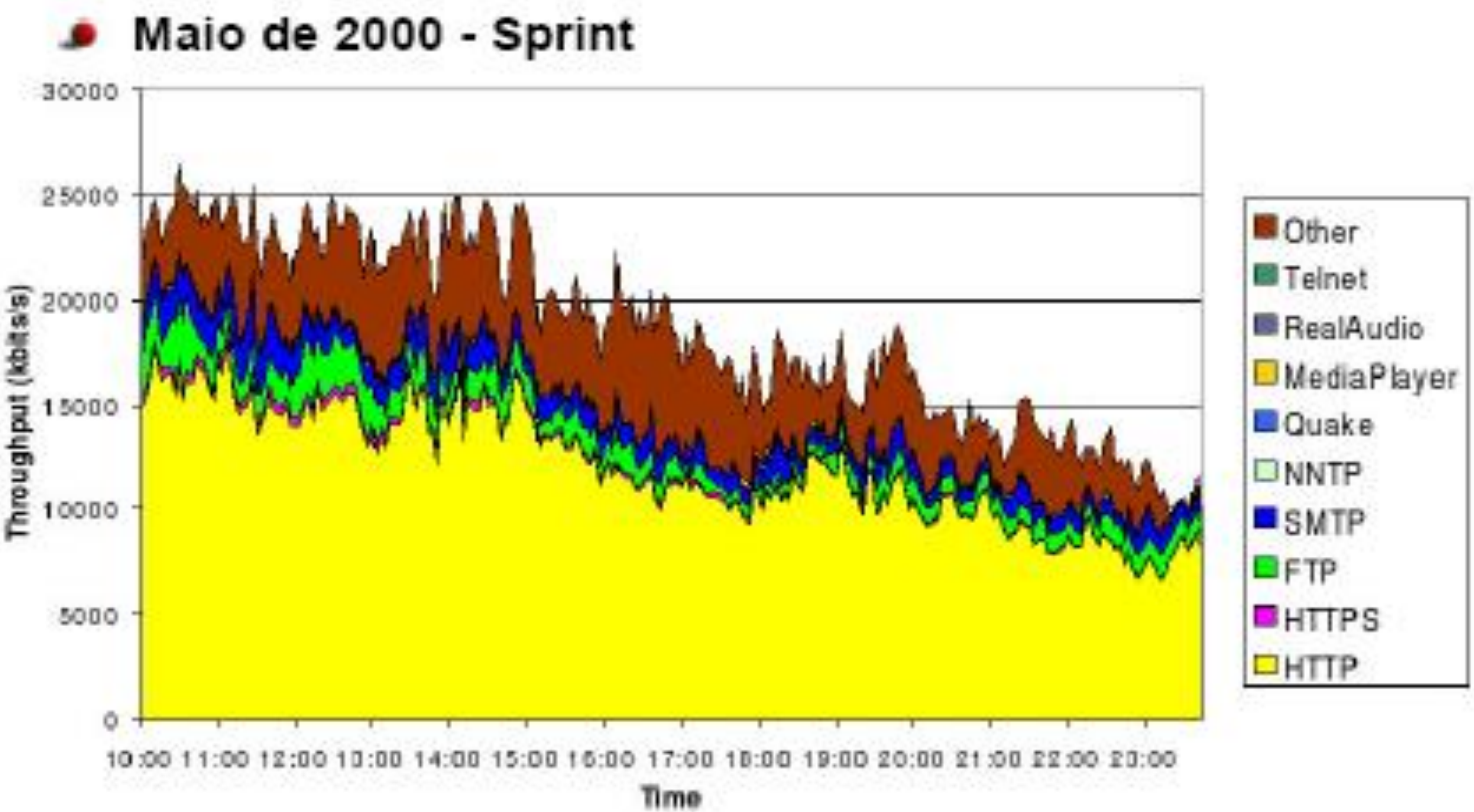


Maesurement

traceroute: routers, rt retardo em rota origem-destino
also: pingplotter, diverso programas basedo em janelas

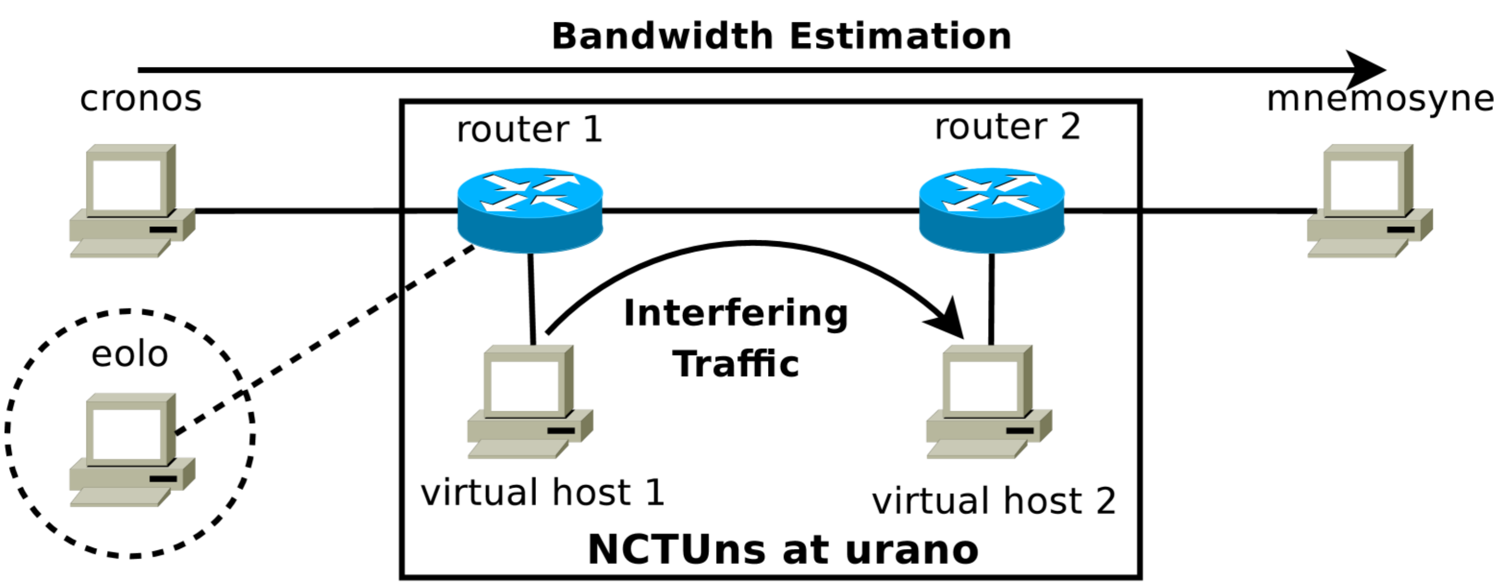
```
1  cs-gw (128.119.240.254)  1 ms  1 ms  2 ms
2  border1-rt-fa5-1-0.gw.umass.edu (128.119.3.145)  1 ms  1 ms  2 ms
3  cht-vbns.gw.umass.edu (128.119.3.130)  6 ms 5 ms 5 ms
4  jn1-at1-0-0-19.wor.vbns.net (204.147.132.129)  16 ms 11 ms 13 ms
5  jn1-so7-0-0-0.wae.vbns.net (204.147.136.136)  21 ms 18 ms 18 ms
6  abilene-vbns.abilene.ucaid.edu (198.32.11.9)  22 ms  18 ms  22 ms
7  nycm-wash.abilene.ucaid.edu (198.32.8.46)  22 ms  22 ms  22 ms
8  62.40.103.253 (62.40.103.253)  104 ms 109 ms 106 ms
9  de2-1.de1.de.geant.net (62.40.96.129)  109 ms 102 ms 104 ms
10  de.fr1.fr.geant.net (62.40.96.50)  113 ms 121 ms 114 ms
11  renater-gw.fr1.fr.geant.net (62.40.103.54)  112 ms  114 ms  112 ms
12  nio-n2.cssi.renater.fr (193.51.206.13)  111 ms  114 ms  116 ms
13  nice.cssi.renater.fr (195.220.98.102)  123 ms  125 ms  124 ms
14  r3t2-nice.cssi.renater.fr (195.220.98.110)  126 ms  126 ms  124 ms
15  eurecom-valbonne.r3t2.ft.net (193.48.50.54)  135 ms  128 ms  133 ms
16  194.214.211.25 (194.214.211.25)  126 ms  128 ms  126 ms
17  * * *
18  * * *
19  fantasia.eurecom.fr (193.55.113.142)  132 ms  128 ms  136 ms
```

Measurement



Emulation

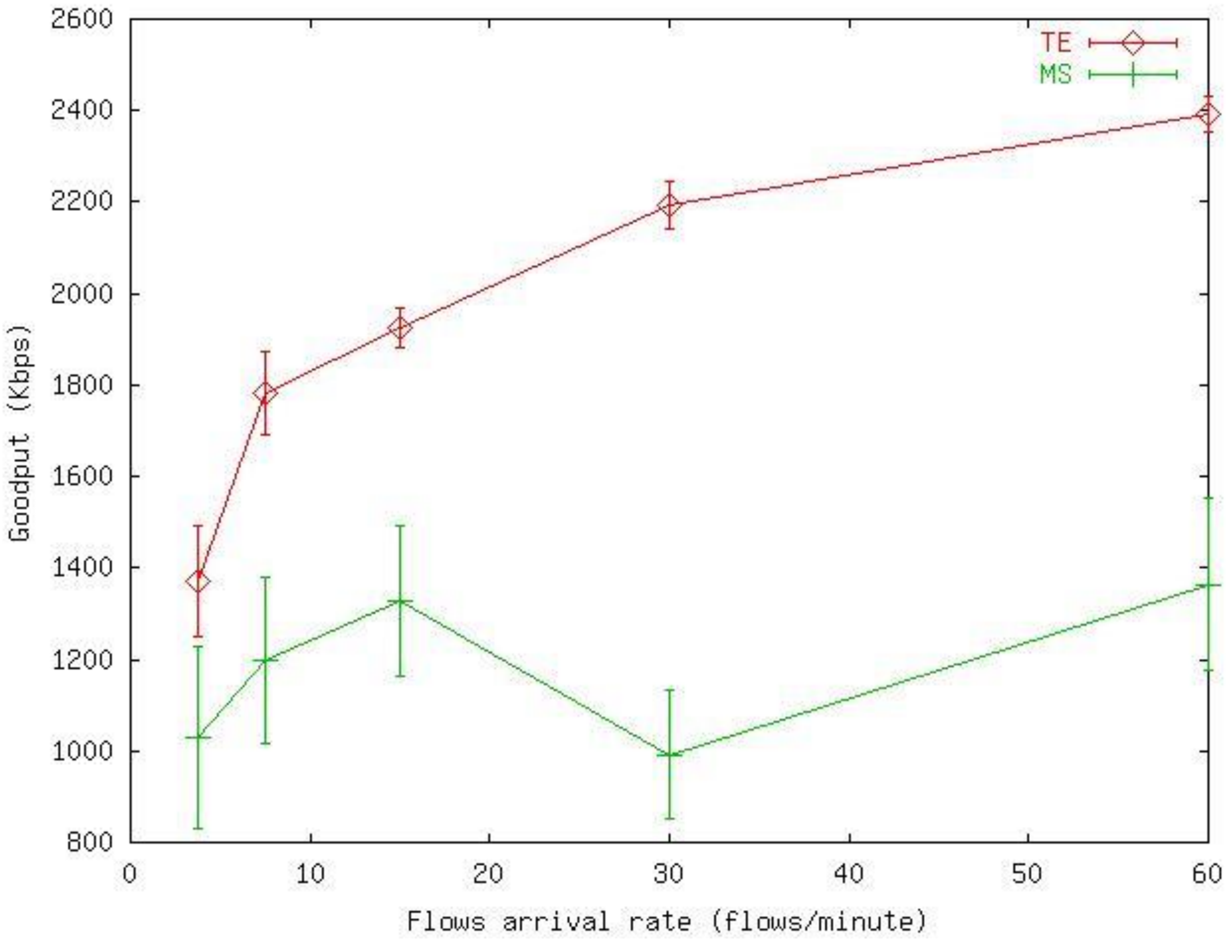
- Uses Small scale network
- Not simulation



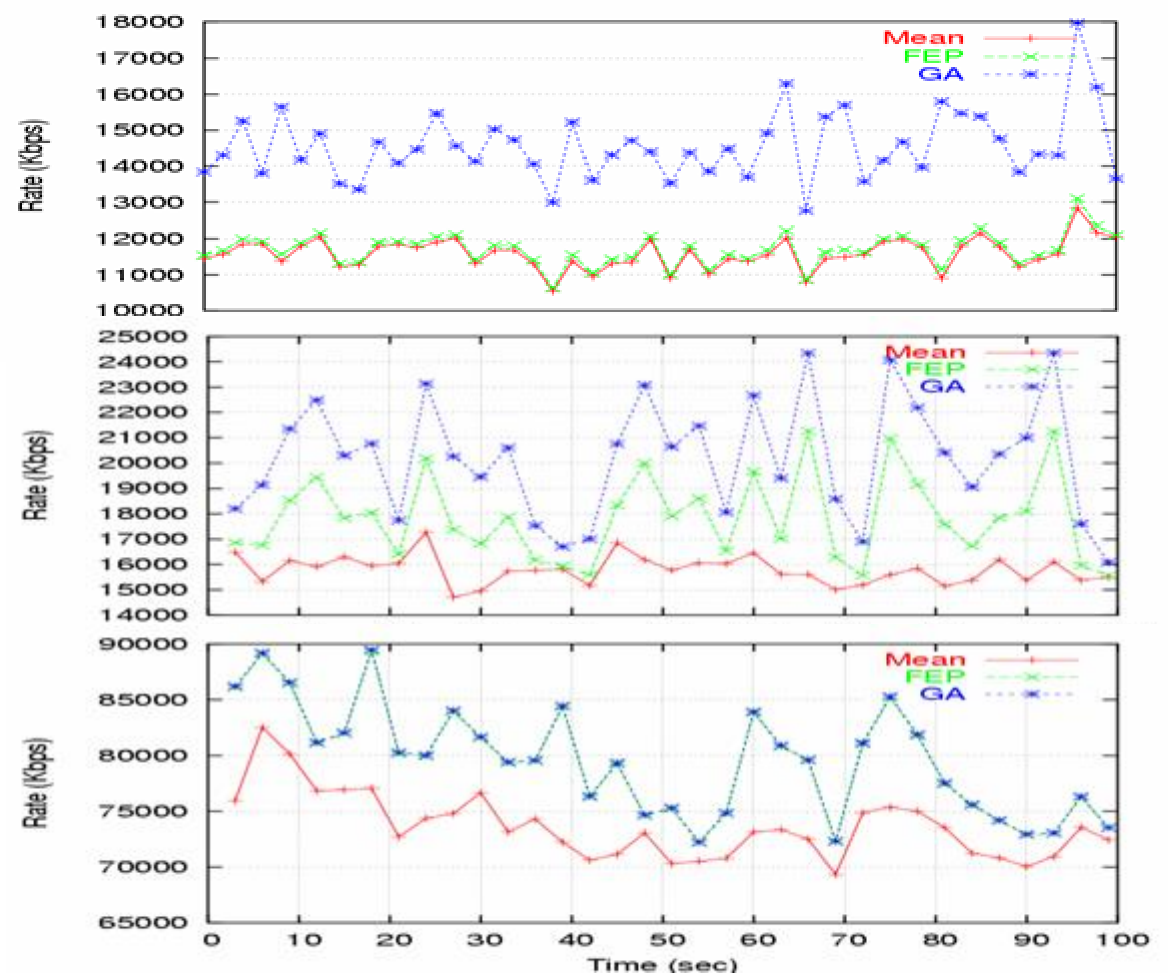
Tips

- Your study needs to have an objective and the design and verification should be in accordance with the proposed objectives
- The level of detail should be sufficient to answer the questions posed
- Analysis of the system
- Comparison with other proposals
- Sensitivity analysis

System Analysis



Analysis of Sensitivity



Outcome of your Study

Conclusions