Evolution on Network Technologies and its Impact on Traffic Engineering

Villy Baek Iversen
COM Center,Technical University of Denmark
vbi@com.dtu.dk

ITU-BDT Regional Seminar on Fixed Mobile Convergence and Guidelines on the smooth transition of existing mobile networks to IMT-2000 for Developing Countries for Africa Region

Nairobi, Kenya, 9-12 May 2005

International Teletraffic Congress

The International Teletraffic Congress was founded in 1955

Purpose: To bring together people from

- **Operators**
- **Industries**
- **Research**

To deal with all phenomena of control and transport of information within telecommunication networks, including all kinds of computer and data base applications.

Teletraffic engineering deals with methods and tools for

- **Modelling telecommunication systems and services**
- **Performance evaluation, resource dimensioning**
- **Cost optimization**
- **Forecasting, planning, and network management**

International Teletraffic Congress

Teletraffic science is based on methods of

- •probability theory (statistics, simulation,etc)
- •control theory (scheduling, synchronization, etc)
- •operations research (ptimization, economics, etc)

Since 1955:

18 ITC World Congresses

General conferences

16 Specilaist seminars

In-depth seminars on hot topics as Internet, mobile communication, architectures & protocols, etc)

18 Regional seminars

General seminars on applied teletraffic engineering (Mali, South Africa, Syria, St. Petersburg, etc)

International Teletraffic Congress

ITC-19 in Beijing August 29 – September 2, 2005

502 submitted papers

Tutorials Sunday 28 August

ITU/ITC Workshop for developing countries

Still submit papers for workshop (Ignat Stanev or r

Scholarships from ITU

Invited speakers:

Directors of ITU-T and ITU-D

http://www.itc19.org

International Advisory Board (IAC of ITC)

http:// www.i-teletraffic.org

ITC-20 in Canada 2007,

ITC-21 in Australia 2009

ITU-Semiar, Nairobi May 9-12, 2005

Outline

1. Technological Developments
2. Services Developments
3. QoS – Quality of Service
4. Traffic engineering principles
5. Traffic characterization
6. Case Studies
7. Conclusions
8. Training

Background

Erlang-B formula:

$$E_n(A) = p(n) = \frac{\frac{A^n}{n!}}{1 + A + \frac{A^2}{2!} + \cdots + \frac{A^n}{n!}}.$$

A: User traffic described by offered traffic A
N: Network described by number of channels n
E: Quality-of-Service described by blocking probability E

Robust to the traffic process => very successful

Economy of scale

A = 15 erlang	n = 20 channels	E = 4.5593%
A = 30 erlang	n = 40 channels	E = 1.4409%
A = 45 erlang	n = 60 channels	E = 0.5434%
A = 60 erlang	n = 80 channels	E = 0.2199%

E = 1 %

n = 20 channels	A = 12.03 erlang
n = 40 channels	A = 29.01 erlang
n = 60 channels	A = 46.95 erlang
n = 80 channels	A = 65.38 erlang

Traffic engineering tasks

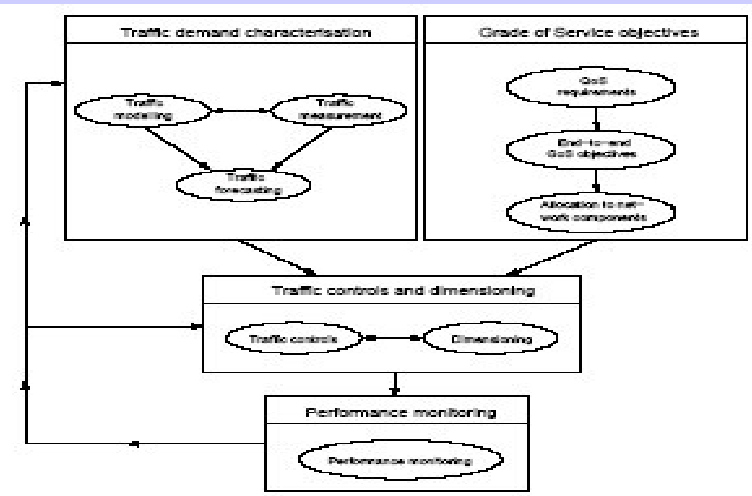


Figure 1.9: *Traffic engineering tasks.*

ITU-Semiar, Nairobi May 9-12, 2005

Networking development

Packet based transfer mode

Packetized voice

Wireless access networks

Mixed core networks

Photonic backbone networks

Centralized & decentralized control

Services development

Differentiated services

Narrowband & broadband

Real-time services:

- Delay sensitive
- Jitter (delay variation) sensitive

Non-real-time services

- Packet loss sensitive
- Best effort services

QoS – Quality of Service

User perceived QoS

Operator perceived QoS

System perceived Qos

Differentiated QoS

- **Gold – Silver – Bronze in UMTS**
- **Other classifications in e.g. ATM**

Service Level Agreements

Traffic engineering principles

QoS can only be guaranteed by ressource reservation End-to-end

1. Bandwidth based mechanism

- Separation: Imply low utilization => high cost
  - Minimum bandwidth guaranteed => worse case guarantee
- Sharing : Imply high utilization => low cost

Minimum guaranteed & Maximum bandwidth allowed combined

We may get obtain both QoS and low cost

Virtual circuit switched networks (ATM, MPLS)

Packet streams are characterized by their effective bandwidth

Traffic engineering principles

QoS can only be guaranteed by ressource reservation End-to-end

2. Priority mechanisms: split services into priority classes

- High priority traffic:

  Preemptive-resume: High QoS to limited amount of traffic

  Non-preemptive: Lower QoS to limited amount of traffic

- Low priority traffic: Best effort traffic

Requires Admission Control and Policing: specification of traffic characteristics + control of these.

Bandwidth based mechanism has built-in access control and policing

Priority Queueing system

Type 1: Load 0.1 erlang, mean service time 0.1 s

Type 2: Load 0.8 erlang, Mean service time 1.6 s

No priority: W = 12.85 s (for everybody)

Non-preemptive: W1 = 1.43 s

W2 = 14.28 s

Preemptive resume: W1 = 0.0056 s

W2 = 14.46 s

(twice as many type 1 jobs as of type 2)

Processor sharing - Generalized

Processor sharing: all users share the available capacity

Generalized Processor sharing: maximum capacity for each user

Robust to the service time (file size)

Mean performance measures are the same as for Erlang's waiting time system

This model is applicable for Best Effort traffic (Web traffic)

Traffic and service characterization

A service type is characterized by

- **Qos parameters (discussed above)**
- **Traffic characteristics**

Traffic characteristics are in general statistical (random variables).

Examples are:

Bandwidth demand (simple):
- Packetetized services(e.g. Web browsing): fluctuating
- Streaming services: constant
- VoIP: On/Off (two-level)

Packet arrival process (complex): Leaky bucket control

Traffic and service characterization

Bundling (QoS point of view)

Different services should be kept separate logically.

Connections with same characteristics should be bundled

Grooming (ressource utilization point of view)

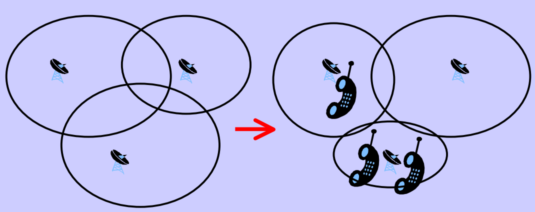
To save multiplexing equipment and to increase utilization.

This is important in core and backbone networks.

Recent development in traffic modelling

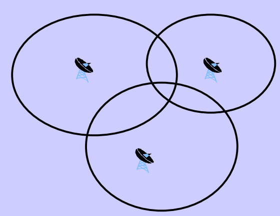
Case studies: hierarchical cellular systems

CDMA



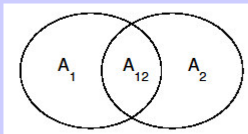
Cell size change happens automatically because of the introduced interference

GSM



Calls can handed to neighbour cell if full

Cellular System Overlapping Networks



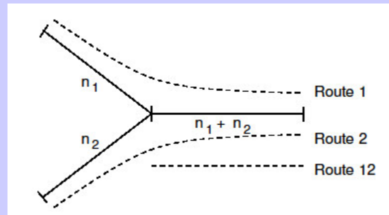
Two overlapping cells

Constrains

$0 \le x_1 \le n_1$

$0 \le x_2 \le n_2$

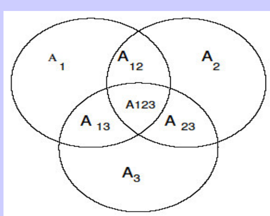
$0 \le x_1 + x_2 \le n_1 + n_2$



network with direct routing

	Route 1	Route 2	Route 12	Capacity
Link 1	1	0	0	n_1
Link 2	0	1	0	n_2
Link 12	1	1	1	$n_1 + n_2$

Route/Links networks



Link \ Route	1	2	3	12	13	23	123	Capacity
1	1	0	0	0	0	0	0	n_1
2	0	1	0	0	0	0	0	n_2
3	0	0	1	0	0	0	0	n_3
12	1	1	0	1	0	0	0	$n_1 + n_2$
13	1	0	1	0	1	0	0	$n_1 + n_3$
23	0	1	1	0	0	1	0	$n_2 + n_3$
123	1	1	1	1	1	1	1	$n_1 + n_2 + n_3$

General Problem definition

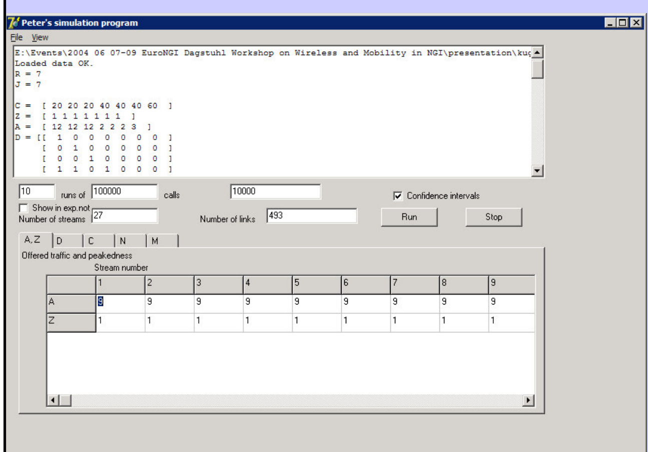
Input:
- Structure (Link/Route matrix)
- Offered load per route/zone A_i
- Capacities C_i
- Peekedness of streams (var/mean)

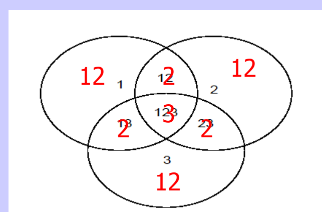
Calculate:
- Congestion levels (traffic, call and time) in every route – blocking probabilities
- Carried traffic

How to calculate?

- We use two different methods:
  - Analytical
    - Based on convolution algorithms (route convolution)
    - Precise
    - Cannot handle big networks
  - Simulation
    - Traffic is generated and results observed
    - Conf. intervals are estimated
    - Simulation time depends on required confidence interval
    - Still can take some hours for bigger networks

Screenshot





ITU-Semiar, Nairobi May 9-12, 2005

Analysis

```
R = 7
J = 7

C =  [ 20 20 20 40 40 40 60  ]
Z =  [ 1 1 1 1 1 1 1  ]
A =  [ 12 12 12 2 2 2 3  ]
D = [[  1  0  0  0  0  0  0  ]
     [  0  1  0  0  0  0  0  ]
     [  0  0  1  0  0  0  0  ]
     [  1  1  0  1  0  0  0  ]
     [  1  0  1  0  1  0  0  ]
     [  0  1  1  0  0  1  0  ]
     [  1  1  1  1  1  1  1  ]]
|                        OUTPUT                       |
--------------------------------------------------------------------------------
| Class | Time congestion | Traffic congestion | Call Congestion | Carried Traffic |
--------------------------------------------------------------------------------
   1       0.012944       0.014615          0.012931        11.8246
   2       0.013643       0.012872          0.013258        11.8455
   3       0.013673       0.009764          0.013451        11.8828
   4       0.004411       0.005894          0.004372         1.9882
   5       0.004298       0.015303          0.004616         1.9694
   6       0.004325       0.007646          0.004319         1.9847
   7       0.003571       0.004524          0.003299         2.9864
--------------------------------------------------------------------------------
| Total |          |    0.0114368    |           |    44.201848    |
--------------------------------------------------------------------------------
```

Simulation

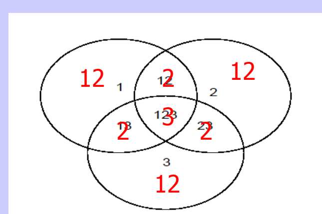
```
Total calls 100000 for each run
Time congestion:
1  0.012944 +-  0.000904 = [  0.012040   0.013849 ]
2  0.013643 +-  0.000967 = [  0.012676   0.014610 ]
3  0.013673 +-  0.000853 = [  0.012820   0.014526 ]
4  0.004411 +-  0.000398 = [  0.004013   0.004809 ]
5  0.004298 +-  0.000325 = [  0.003974   0.004623 ]
6  0.004325 +-  0.000369 = [  0.003956   0.004694 ]
7  0.003571 +-  0.000334 = [  0.003237   0.003905 ]
Traffic congestion:
1  0.014615 +-  0.005724 = [  0.008891   0.020339 ]
2  0.012872 +-  0.006754 = [  0.006118   0.019626 ]
3  0.009764 +-  0.004042 = [  0.005721   0.013806 ]
4  0.005894 +-  0.012352 = [ -0.006458   0.018246 ]
5  0.015303 +-  0.013229 = [  0.002074   0.028532 ]
6  0.007646 +-  0.012841 = [ -0.005196   0.020487 ]
7  0.004524 +-  0.012176 = [ -0.007651   0.016700 ]
Call congestion:
1  0.012931 +-  0.000534 = [  0.012397   0.013465 ]
2  0.013258 +-  0.000941 = [  0.012316   0.014199 ]
3  0.013451 +-  0.001149 = [  0.012302   0.014600 ]
4  0.004372 +-  0.000551 = [  0.003821   0.004923 ]
5  0.004616 +-  0.000671 = [  0.003945   0.005288 ]
6  0.004319 +-  0.000696 = [  0.003622   0.005015 ]
7  0.003299 +-  0.000546 = [  0.002753   0.003845 ]
Carried traffic:
1  11.824617 +-  0.068691 = [ 11.755927  11.893308 ]
2  11.845532 +-  0.081047 = [ 11.764485  11.926579 ]
3  11.882837 +-  0.048505 = [ 11.834331  11.931342 ]
4   1.988211 +-  0.024704 = [  1.963507   2.012916 ]
5   1.969393 +-  0.026458 = [  1.942935   1.995851 ]
6   1.984709 +-  0.025683 = [  1.959026   2.010391 ]
7   2.986427 +-  0.036527 = [  2.949900   3.022954 ]
Calculating time :  87.256000 seconds
```

Result analysis

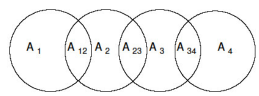
- It is easy to compare with full availability systems:

A = 15 erlang n = 20 channels E = 4.5593%
A = 30 erlang n = 40 channels E = 1.4409%
A = 45 erlang n = 60 channels E = 0.5434% ⟷ 1,14368%
A = 60 erlang n = 80 channels E = 0.2199%

E = 1 %
n = 20 channels A = 12.03 erlang
n = 40 channels A = 29.01 erlang
n = 60 channels A = 46.95 erlang
n = 80 channels A = 65.38 erlang

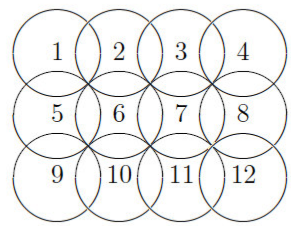


Examples different systems



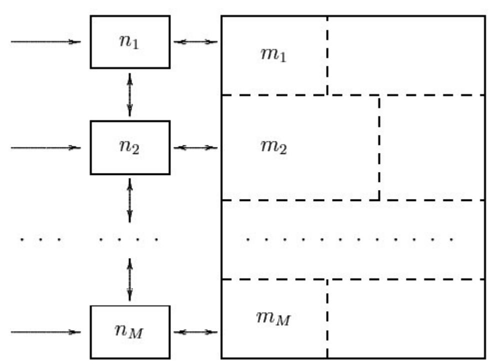
Link	Route 1	2	3	4	12	23	34	C
1	1	0	0	0	0	0	0	30
2	0	1	0	0	0	0	0	30
3	0	0	1	0	0	0	0	30
4	0	0	0	1	0	0	0	30
12	1	1	0	0	1	0	0	60
23	0	1	1	0	0	1	0	60
34	0	0	1	1	0	0	1	60
123	1	1	1	0	1	1	0	90
234	0	1	1	1	0	1	1	90
1234	1	1	1	1	1	1	1	120

tunnel scenario



Grid (real network?)

Hierarchical systems



Modelled as one cell with full overlap

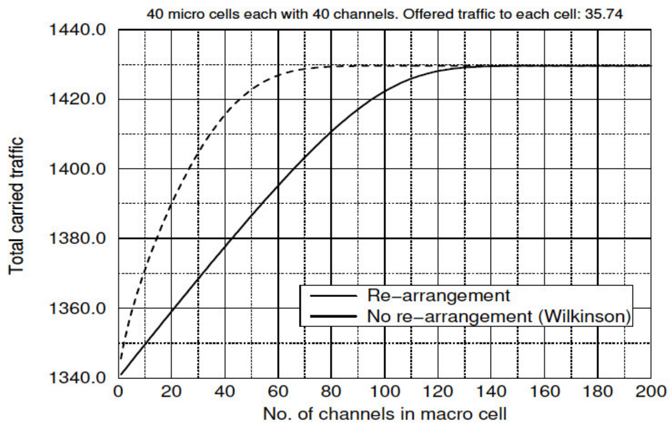


Fig. 6. *The total carried traffic as a function of the number of channels in the macro-cell. By adding 20 channels in the macro-cell we notice that the total carried traffic increases by 50 erlang.*

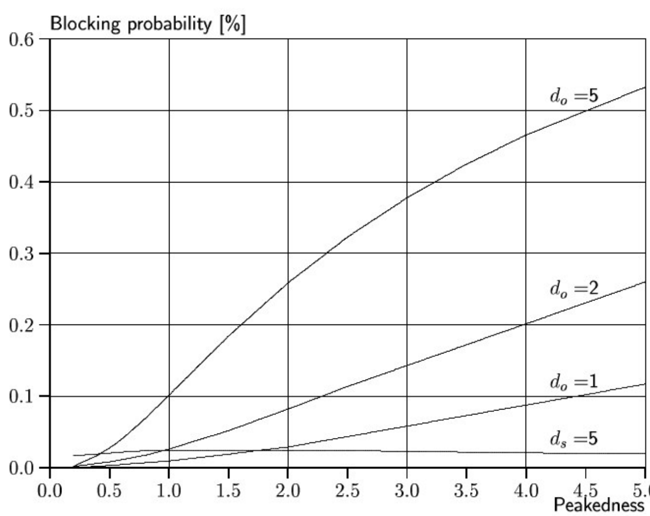
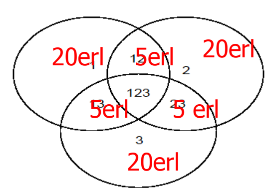


Fig. 7. *Traffic congestion as a function of peakedness and slot-size for the system*



Case studies: hierarchical cellular systems

- Analytical model
- Each service described by
  - Bandwidth (slots)
  - Minimum allocation
  - Mean value
  - Peakedness (var/mean)
  - Maximum allocation
  - Model is insensitive
  - Accessible base stations
- Results
  - Blocking for each service in each area

Teletraffic Engineering Handbook

Basic theory of teletraffic by elementary mathematics

Introduction & ITU-T traffic engineering activities

Mathematical background

Loss systems including multi-service models

Network dimensioning

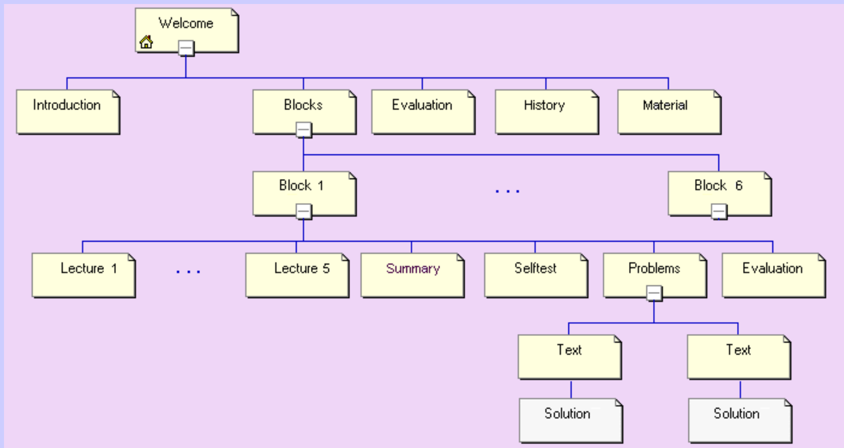
Queueing systems

Queueing networks

Traffic measurements

Training in TTE

Web-based training



ITU-Semiar, Nairobi May 9-12, 2005

Conclusions

For further details on Teletraffic engineering:

ITU/ITC Teletraffic Engineering Handbook

http://www.com.dtu.dk/teletraffic/

ITU-Semiar, Nairobi May 9-12, 2005

Title in AGaramond 24 pt bold

Title in AGaramond 24 pt bold

ITU-Semiar, Nairobi May 9-12, 2005