# Modelling Issues of Integrating Services in Next Generation Networlds

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## Outline

1. **Background**
2. **Technological Developments**
3. **Services Developments**
4. **QoS - Quality of Service**
5. **Traffic engineering principles**
6. **Traffic characterization**
7. **Case Studies**
8. **Conclusions**
9. **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**



## 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 |

## 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

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

**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

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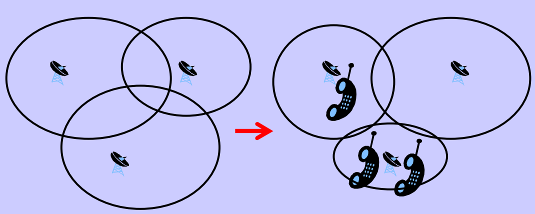
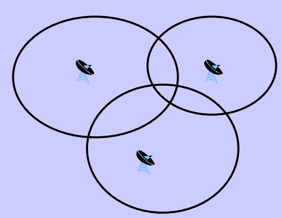
## Case studies: hierarchical cellular systems

**CDMA**



Cell size change happens automatically because of the introduced interference

**GSM**



Calls can handed to neighbour cell if full

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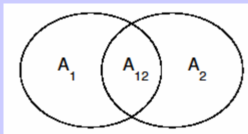
# Cellular System Overlapping Networks



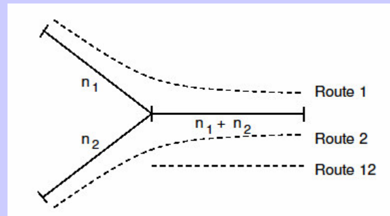

Two overlapping cells

**Constrains**

$0 \le x_1 \le n_1$

$0 \le x_2 \le n_2$

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

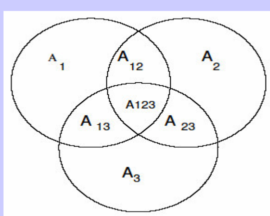



network with direct routing

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



# Route/Links networks




| | | 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 | $n_3$ |
| Link | 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)

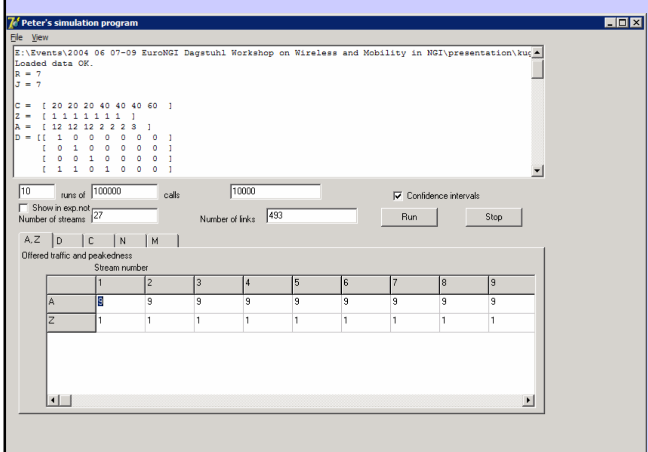
**Calculate:**
- Congestion levels (traffic, call and time) in every route – blocking probabilities
- Carried traffic

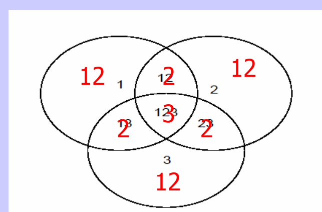
## How to calculate?

- 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



## 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 |
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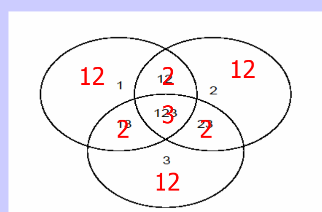
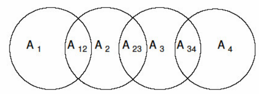
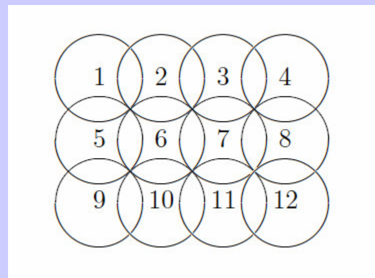


# Examples different systems




| | | Route | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 12 | 23 | 34 | c |
| Link | 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 |

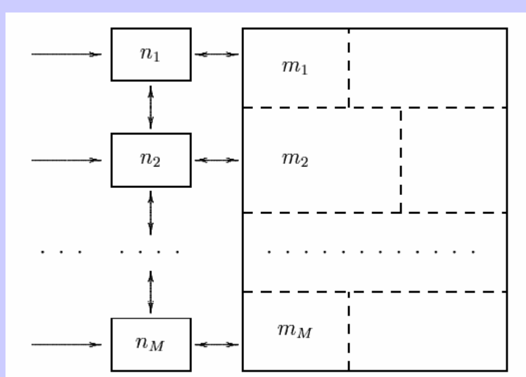
tunnel scenario




Grid (real network?)



# Hierarchical systems




Modelled as one cell with full overlap

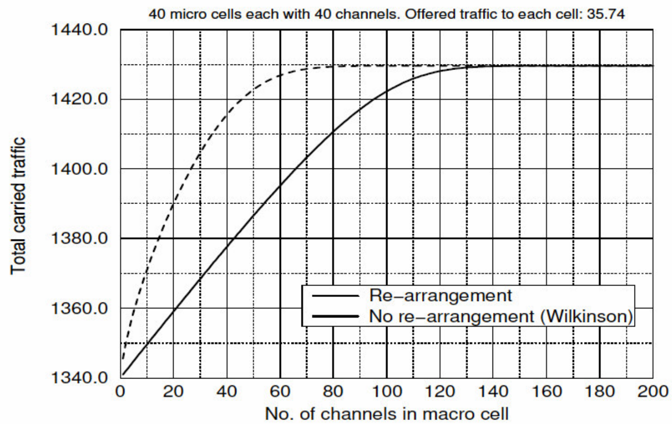
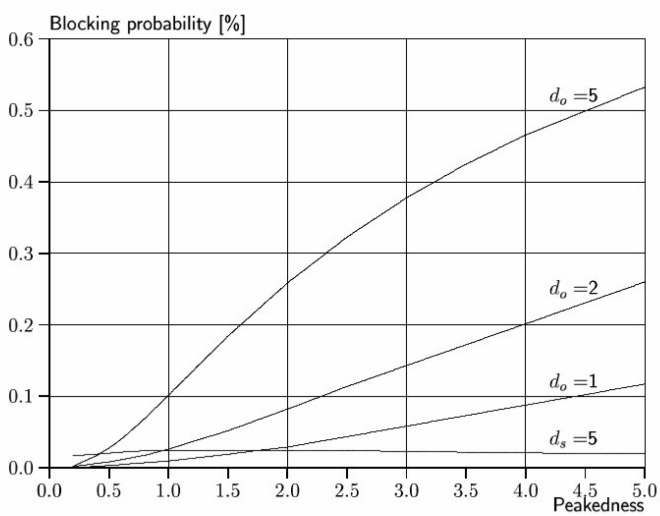



**Fig. 6.** *The total carried traffic as a function of the number of channels in the macro-cell. By adding 20 channels in the macro-cell we notice that the total carried traffic increases by 50 erlang.*





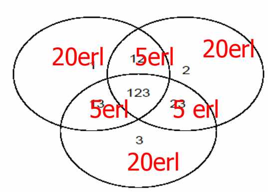




**Fig. 7.** *Traffic congestion as a function of peakedness and slot-size for the system*

## 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**

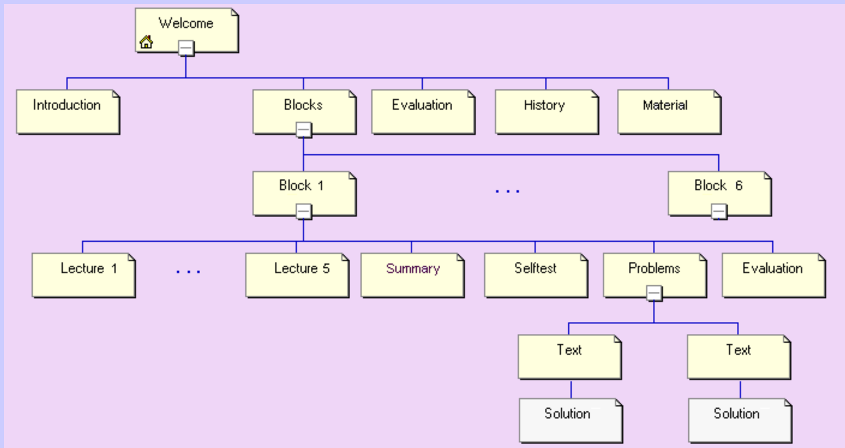
**Queueing systems**

**Queueing networks**

**Traffic measurements**

## Training in TTE

### Web-based training






## 7. Conclusions

**For further details on Teletraffic engineering:**

**ITU/ITC Teletraffic Engineering Handbook**

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