This is a written exam for the course "*Performance Analysis of Communication Networks*"
Lecturers: prof.dr. R.D. van der Mei and dr. T. Kielmann
Date and location of exam: Thursday, December 21, 2006, 15.15-18.00 in Q1.12

Rules for the exam:

1. Allowed material: This is an open book exam. For answering the questions, you are allowed to use all kinds of written material like textbooks, printouts of the lecture slides, your own notes, etc. You are allowed to bring your laptop for looking up electronic versions of course reading material, but electronic communication during the exam is strongly prohibited.

2. Language disclaimer: You are kindly asked to answer the questions using the English language. However, if it helps clarifying your answers, you may use some Dutch here and there. Doing so, will not affect your result.

3. Calculation of end grade for the course: the end grade for the course is built up in two parts: homework assignments and a written exam.

   - *Homework assignments*: during the course three homework assignments have been distributed among the students and placed on the Web site. The average of the three grades counts to 50% of the final grade.
   - *Written exam*: for this written exam you get a grade between 1 and 10. This grade will count for the remaining 50% of the final grade.
   - *Final grade*: the final grade is calculated as the average of the grade for the written exam on the one hand, and the average homework grade on the other hand, with the restriction that the grade for the written exam must be at least 4.0.

4. Credits: This written exam consists of four questions (A, B, C and D), each of which consists of a number of sub-questions. The maximum number of credits you can get is 60, which is distributed as follows amongst the sub-questions:

question	1	2	3	4	5	6	total
A	2	2	2	2	2	2	**12**
B	4	3	3	3	3		**16**
C	3	4	5	8			**20**
D	2	2	2	2	2	2	**12**

Good luck!

QUESTION A: About good-old Erlang...

A.1 Erlang's blocking formula is known to have some *insensitivity property*. What *exactly* does that mean? Don't be vague, be precise!

A.2 The Erlang model assumes that the arrival process is a Poisson process. What exactly is a Poisson process? Does the Erlang blocking formula also hold if arrivals are not Poisson? If so, explain why; if not so, give a counter-example.

A.3 Poisson processes occur naturally in the modelling in human-initiated events, such as telephone-call initiation moments and Web-session initiation moments. Why is that? Be precise.

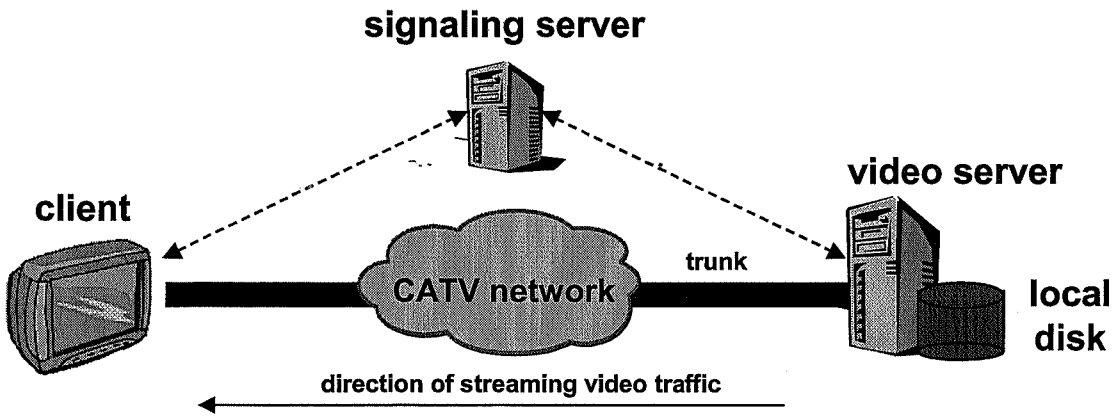
A.4 The Erlang formula relies on the PASTA property. What exactly is the PASTA property, and give an intuitive argument for it. Why does the PASTA property not hold for finite-source models (i.e., models with a finite population of customers)?

A.5 What is the relation between a Poisson *process* and a Poisson *distribution*? And what is the difference between them? Be precise!

A.6 What happens to the call blocking probability if the call-attempt rate doubles, while the mean call duration is divided by two? Give an intuitive explanation for this. Be clear!

QUESTION B: Capacity planning for Video-on Demand for CableCom

Cable TV company CableCom plans to offer Video-on-Demand (VoD) services, allowing their customers to watch videos upon request *at any time*. This is fundamentally different from the current situation, where CableCom only offers standard cable TV services: for each TV channel pre-scheduled TV programs (see your TV guide) are simply broadcast to all customers at specific times. CableCom has installed two types of servers: a signaling server and a video server. The process of setting up a VoD session consists of two phases: First, the client send a request to the signaling server to set up a connection between the video server and the client (phase I). Once a connection between the video server and the client has been established, the video server immediately starts to send the video traffic steam to the client TV (phase II).



CableCom expects that VoD will be a big business success, and therefore, wants to plan the capacity of its infrastructure properly and timely anticipate on performance problems when the number of users increases in the near future. In this context, CableCom wants to make sure that the signaling server is well-dimensioned so that the connection set-up phase does not take too long. Moreover, they want to make sure that the amount of network bandwidth is sufficiently large.

We make the following simplifying assumptions:

Regarding Phase I: The average amount of time involved in processing a connection set-up request by the signalling server is 1 second. The signaling server handles connection set-up requests in the order of arrival, and can handle one request at a time (single-threaded). The network latency and bandwidth consumption involved in establishing a connection are negligible.

Regarding Phase II: Once the connection is established the video server will generate a traffic steam over the CATV network trunk at a constant rate of 5 Megabits per second for the duration of a movie. The duration of a movie has a gamma distribution with mean 2 hours. The CATV network trunk is shared by all clients of CableCom and its capacity is 1 Gigabit per second. When there is insufficient bandwidth available for running a VoD session over a newly established connection, the session is blocked and the connection is terminated. The time involved in terminating a connection is negligible.

B.1 Formulate a performance model that encompasses *both* the delay involved in setting up a connection and the blocking of VoD sessions. Define the relevant notation and the performance metrics. Motivate your assumptions and be precise!

B.2 Give a formula for the expected time it takes to set up a connection between the video server and the client. Be precise.

B.3 CableCom wants to deliver good service to its VoD customers, and requires that the average connection establishment phase is less than 5 seconds. What is maximum number of connection set-up requests per minute that can be handled while meeting this constraint?

B.4 How many VoD sessions can the CATV network trunk handle simultaneously?

B.5 Give an expression for the session blocking probability.

QUESTION C: Packet Dispersion

Suppose you can use the following functions to build measurement procedures:

```
ReadClock()  // reads the system clock of the computer
SendPacket() // sends a packet
RecvPacket() // receives a packet, waits until the packet has arrived
```

Somebody has written the following functions for sending and receiving packet trains:

```
void send_train(int packets){
  for (i = 0; i < packets; i++){
    SendPacket(to_receiver,size_in_bytes);
  }
}

long receive_train(int packets){
  RecvPacket(from_sender,size_in_bytes);
  t1 = ReadClock();
  for (i = 1; i < packets; i++){
    RecvPacket(from_sender,size_in_bytes);
  }
  t2 = ReadClock();
  return (t2 - t1);
}
```

C.1 Give a simple formula for computing bw as the bandwidth measured using the function `receive_train()`.

C.2 Somebody proposes to change the order of the first two statements in `receive_train()`, such that also the first packet of the train gets into the measurement. Do you think this is a good or a bad idea? Explain why!

C.3 Explain the term "self-induced congestion."

C.4 Explain (in words, no code needed) how self-induced congestion can be used to measure the available bandwidth of a network path.

QUESTION D: Traffic Management in IP networks

D.1 IP networks are said to only provide "best effort" QoS. What does that mean?

In order to realize good and predictable Quality of Service over IP networks a variety of traffic management techniques has been proposed. A few short questions about them: please only give short, but to-the-point, answers.

D.2 What is *traffic policing*? What is the motivation for implementing traffic policing, and how does it work?

D.3 What is *traffic shaping*? What is the motivation for it, and how does it work?

D.4 What is the *difference* between policing and shaping?

D.5 What is *Admission Control*? What is the motivation for it? A powerful means to enforce admission control is the concept of Equivalent Bandwidth (EBW). Explain what it is.

D.6 What is *IP Diffserv*, what is *IP Intserv* and what are the pros and cons of both.