Exam in Access and transport networks TTM 4105 summer 2007 - English

The exam consists of for problems that count equally much.

Problem 1 Multiple access

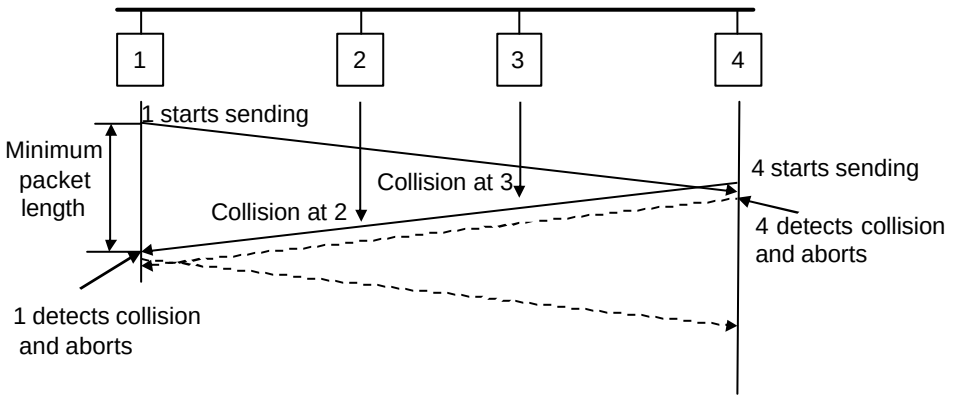
a) Describe the main principles of the following three random access methods: pure aloha, slotted aloha and CSMA/CD (carrier sense multiple access with collision detection)

Pure Aloha: the packet is sent as soon as it is ready to be sent. The contention window (the time interval where packets may overlap and thus destroy one another) is then twice the length of the packets.

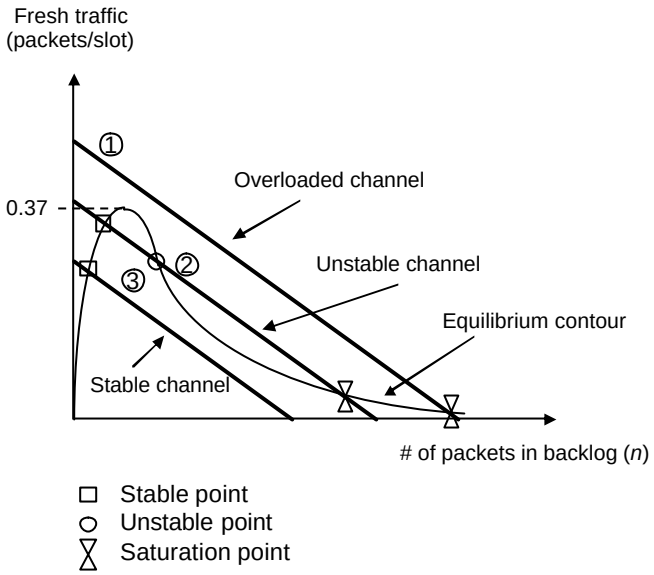
Slotted aloha: the packet is sent in the first possible timeslot after it is ready to be sent. Requires the existence of a synchronous slot pattern. The contention window is then equal to the slot length which is equal to the packet length if the differential delay between sources can be ignored. If the delay cannot be ignored, the slot length is equal to the packet length plus twice the delay.

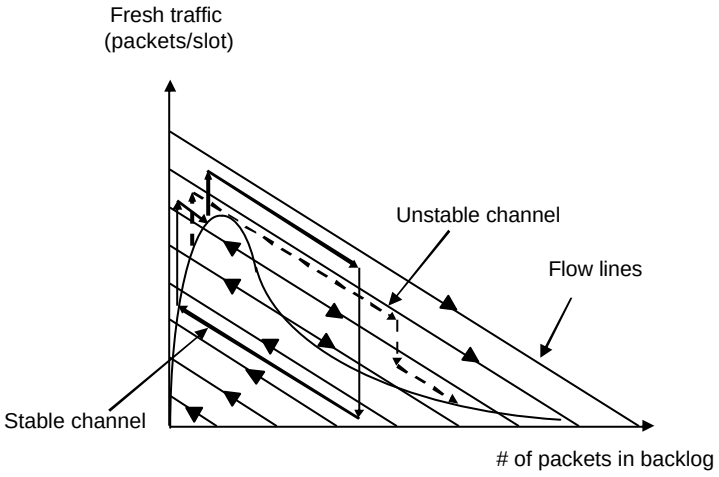
CSMA/CD: Each source listens to the channel all the time. If the channel is sensed idle when a packet is ready to be sent, the packet can be sent immediately. If the channel is busy, the source will follow an implementation dependent back-off (or waiting) algorithm before it is sent in order to reduce the probability that two sources accesses the channel simultaneously.

While sending the packet, the source listens to the channel. If the source detects that the voltage across the coaxial/twisted pair cable (or the light intensity in optical fibres) increases suddenly, it assumes that the packet collides with one or more packets sent by other sources. Sources at each end of the cable can detect collisions if the minimum packet length is equal to the two way delay along the cable plus other delays (signal rise time, signal relaxation time, detection time, processing time etc). Conversely, since the minimum packet length is given (64 bytes), this requirement determines the maximum length of the cable.



b) Draw the equilibrium curve for a slotted aloha channel and use this curve to explain what is meant by a stable channel, an unstable channel and a saturated channel. Explain also the dynamic behaviour of the different channels under varying load.





The arrows indicate the direction of flow

Shows two examples of the effect of sudden traffic increase: On a stable channel and on an unstable channel. The stable channel will return to the stable equilibrium after traffic load returns to normal. The unstable channel may saturate. However, the unstable channel may also return to the stable equilibrium if the excessive load is of short duration (not shown in the figure).

c) Explain why we cannot use CSMA/CD in wireless LANs.

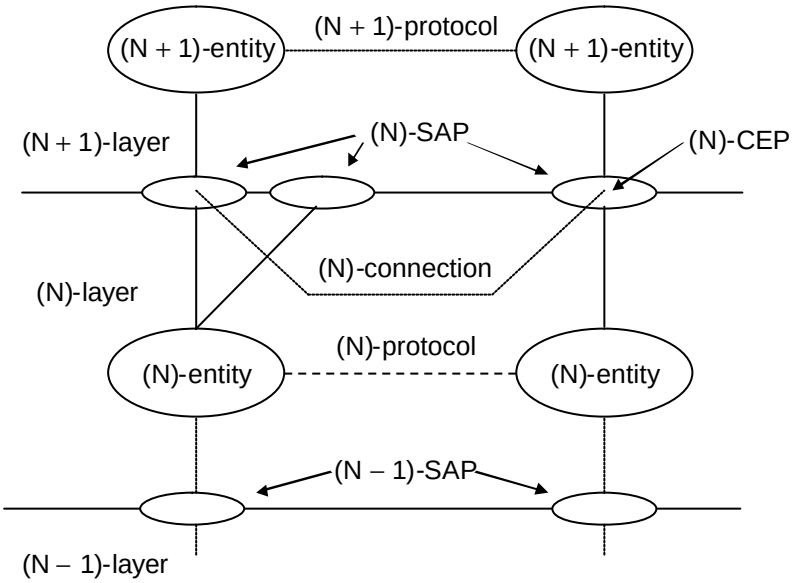
Wireless LANs are radio systems where all sources are sharing a common radio spectrum. This means that a source is sending and receiving in the same spectrum. This also means that if the receiver chain of the source is not switched off during sending, the source will receive

the signal it sends. The power level difference between the signal sent by the source and the signal received from other sources is usually large so that the signal from other sources cannot be detected because of the interference from the much stronger signal from its own sender.

Therefore collision detection cannot be used in WLANs.

Problem 2 Protokols

a) Explain what we mean by the terms "(N)-entity", "(N)-service", "(N)-protocol" and "(N)-SAP".



(N)-entity is the function processing the (N)-layer protocol.

(N)-service is the set of services or functions offered to the (N + 1)-layer (e.g., establishing or releasing an (N + 1)-connection, transfer of (N + 1) data protocol units, management of notifications and aborts etc).

(N)-protocol is the methods and information required for transfer of information between (N)-entities.

(N)-SAP is the point ((N)-layer address) where a particular set of services is offered to the (N + 1)-entity.

b) What is a primitive? Which four primitives are needed in a protocol description and for which purpose are each of them used.

A primitive is an elementary service offered via the SAP:

- *Request* (*req*) by which the (N + 1)-layer requests the (N)-layer to perform a specified task such as sending a message to the peer entity of the (N + 1)-layer. The primitive may also be used to request the (N)-layer to perform local tasks.

- *Confirm* (*cnf*) by which the (N)-layer acknowledges the receipt of a request primitive. The confirmation may be received from the peer (N + 1)-layer or be generated by the local (N)-layer.

- *Indication* (*ind*) by which the (N)-layer delivers a protocol data unit to the remote (N + 1)-layer. The indication message may be generated either by the sending entity of the (N + 1)-layer or locally by the (N)-layer.

- *Response* (*rsp*) by which the (N + 1)-layer acknowledges the receipt of an indication primitive.

c) Explain briefly the purpose of the four protocol layers physical layer, data link layer, network layer and transport layer.

Physical layer: interfaces the transport medium. May offer establishment of physical connection, synchronisation, forward error correction, envelope and frame delimiters.

Data link layer: may offer adaptive error correction by ARQ, flow control, encapsulation/delimitation of data units, multiplexing, segmentation and reassembly of higher layer data units

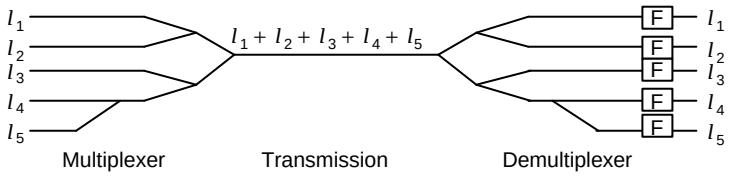
Network layer: primary function is to route information across the network. It will also establish, disconnect and manage connection-oriented network services. May also support security and mobility

Transport layer: ensures that information is delivered to the correct application entity, ensures integrity of data (obtain lost information, delete duplicated information, order received information in the correct order). May support security and multiplexing

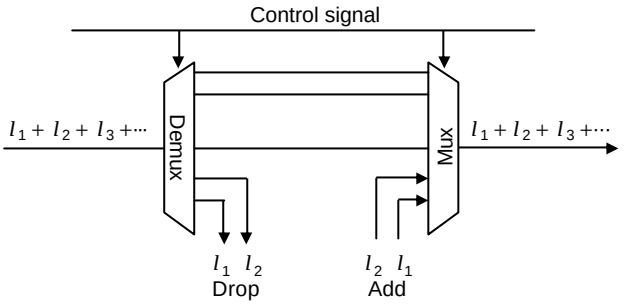
Problem 3 Optical systems

a) Explain what is understood by wavelength division multiplexing (WDM) and describe how WDM multiplexers and demultiplexers operate. Show how an add-drop multiplexer can be designed.

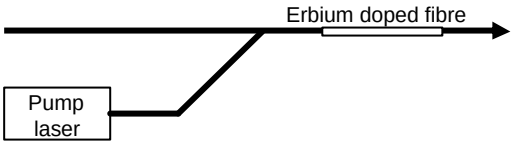
WDM means that different information is sent on optical carriers with different wavelengths and non-overlapping spectra. Combiners and splitters are used as follows:



Add-drop multiplexer:



b) Explain briefly how an erbium doped amplifier is constructed and how it operates.



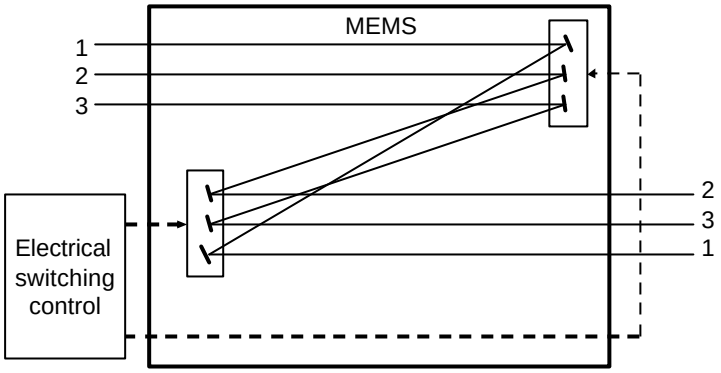
The most common amplifier used on optical fibres is the *erbium doped fibre amplifier* (EDFA). The EDFA can amplify signals with wavelengths in the range 1525 nm to 1560 nm. The wavelength of minimum damping is 1550 nm so that the EDFA is particularly suitable for direct amplification of light along the fibre. Praseodymium-doped fluoride fibre amplifiers are used in a similar way in the band between 1280 nm and 1330 nm. Praseodymium (Pr) is also a rare earth element with atomic number 59.

Erbium (Er) is a rare earth element with atomic number 68. Rare earth elements have a particularly rich spectrum of energy levels because of a rather unusual structure of the outer electron orbits.

The EDFA amplifier is shown in the figure. The amplifier consists of an erbium doped section of the fibre (a few metres). The pump laser emits a strong signal with wavelength of 980 nm or 1480 nm into the fibre. The pump signal excites the erbium doped section such that the incoming optical signal is amplified by stimulating the erbium atoms to emit photons of the same wavelength.

The photons injected by the pump will suffer considerable attenuation so that the pump signal dies off after a few kilometres of fibre length.

c) Sketch how an optical switch may be designed by use of mirrors.



Problem 4 Switching

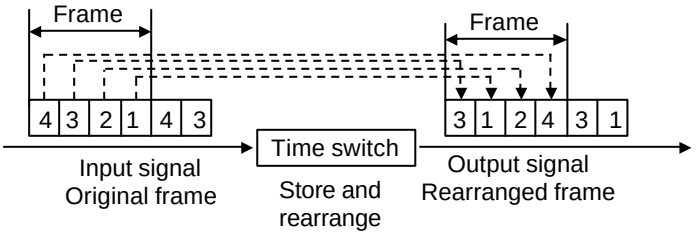
a) Explain briefly what is meant by circuit switching, connection oriented packet switching, and connectionless packet switching. Which of the three methods are used by IP in the internet?

Circuit switching: A connection between two terminals is first established by setting up a dedicated sequence of communication links interconnected in exchanges. The connection is retained throughout the conversation and released at the end of the conversation. Only one pair of users can occupy the links during a conversation.

Connection-oriented packet switching is similar to circuit switching except that the pair of users are only occupying the link when it transfers a packet. The individual links can thus be allocated to several users simultaneously. The data packets of a single conversation are sent along the same links and via the same routers so long as the conversation exists.

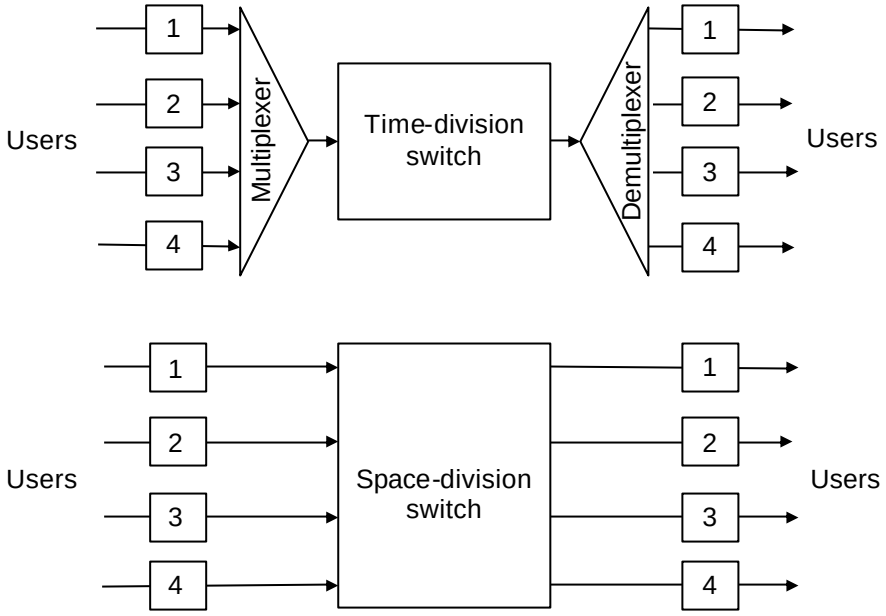
Connectionless packet switching means that an end-end connection is not established between the users. Each individual packet is treated as a separate instant of a call. Packets belonging to the same conversation (established by a higher layer) may follow different routs via the network.

b) Explain how a time-division switch operates. Use a simple sketch to show that a time-division switch can be replaced by an equivalent space-division switch.

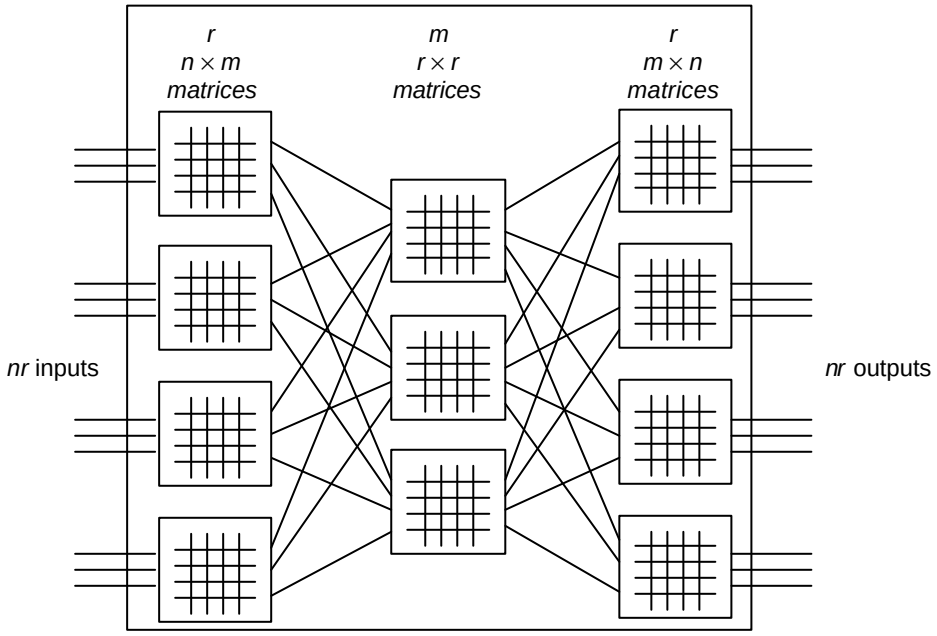


Switching principle: rearranging the timeslots.

Equivalence of time and space switching:



c) Sketch how a Clos(-Benes) network is constructed. Derive the condition that the network is strictly non-blocking.



In the example, $n = 3$, $m = 3$, $r = 4$

The $N \times N$ ($N = nr$) network is strictly non-blocking if the number of midmost matrices is $m = 2n - 1$. This is easily seen. The task is to connect a call on an arbitrary input port of one input matrix to an arbitrary output port of an output matrix irrespective of how many other calls are connected through the switch. If all other $n - 1$ input ports of the input matrix and all other $n - 1$ output ports of the output matrix are already occupied but none of these connections are between the chosen input and output matrices, then $2n - 2$ midmost matrices are already

occupied. Therefore, one more matrix in the middle row is required in order to connect the new call; that is, $m = 2n - 1$.