Multiplexing

Lecture 2

- TDM variants
- Statistcial multiplexing
- Hello to Queuing theory
- CDMA

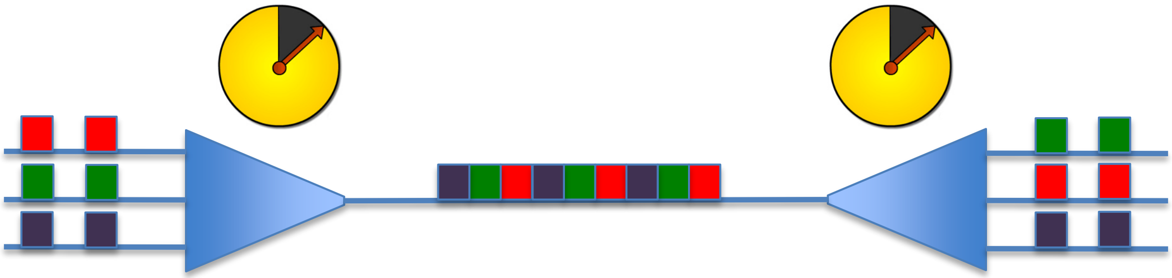
Multiplexing

- Space Division Multiplexing
  - reuse of channel in different places
    - e.g. terrestial TV
- Frequency Division Multiplexing
  - use of different frequencies within a channel
    - e.g. err… terrestial TV
- Time Division Multiplexing
  - Coming next
- Code Division Multiplexing
  - Coming later

Multiplexing (STM)

- Telephone network is referred to as STM

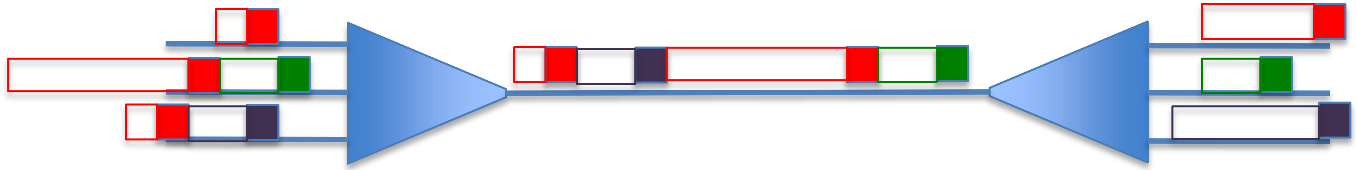
  "synchronous transfer mode"
- the destination of data in the network depends on where it comes from, and *when* it came
- Problems with STM
  - idle users consume bandwidth
  - links are shared with a fixed cyclical schedule
    - quantization of link capacity
    - can't adjust bandwidth



Multiplexing (PTM)

- The Internet uses PTM

  “packet transfer mode”
- the destination of data in the network depends is based on a label (header) in the front of the packet
  - Label can be global
    - connectionless – e.g. IP
  - Or context sensitive
    - Connection oriented or virtual circuit - e.g. MPLS
- Packets can be an arbitrary size…

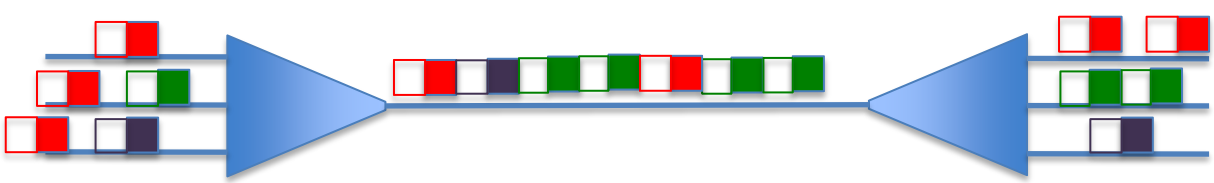


Multiplexing (ATM)

- Enter STM

"asynchronous transfer mode"

- the destination of data in the network is based on a label
- all packets are the same size



Statistical multiplexing

- The benefit of PTM and ATM is…

- Consider a 10Mbps link and an application that uses 1Mbps for 10% of the time
- How many can you support in STM v. PTM/ATM?
  - STM, N = 10
    - must allocate 1Mbps of BW to each application
  - PTM, $10 \le N \le 100$
    - depending on how lucky you are, how much delay and how much loss you can tolerate

Randomness

- Say no buffering in the network and packet loss is intolerable
  - If everyone talks at once, N = 10
  - If magically just 10 from the 100 talk at the same time, N = 100
  - Hence we might ask what is the probability that more than 10 talk at once to figure out what is the probability we loose packets
- To do this means understanding the random transmission of packets or *stochastic process* of the packets from the application
  - A research topic for the last 30 years…
  - And as new applications arise we find new behaviours

This is an old problem

- Erlang 1909; how many phone lines does a small village need to the outside world to ensure that the proability of a call blocking is < 5%.

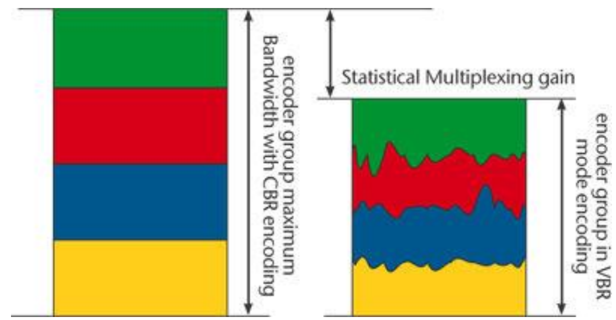
1. THE THEORY OF PROBABILITIES AND TELEPHONE CONVERSATIONS

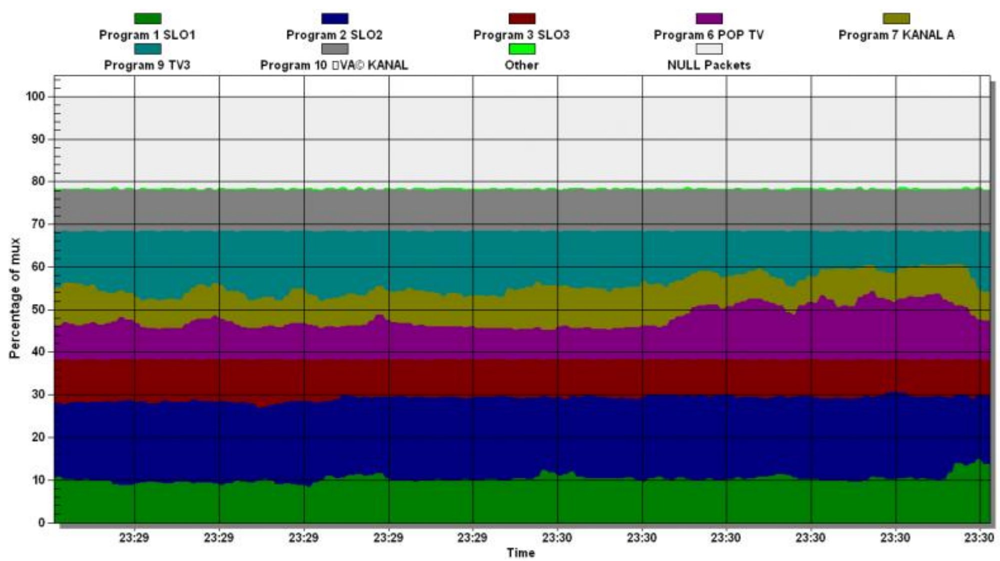
First published in "Nyt Tidsskrift for Matematik" B, Vol. 20 (1909), p. 33.

Although several points within the field of Telephony give rise to problems, the solution of which belongs under the Theory of Probabilities, the latter has not been utilized much in this domain, so far as can be seen. In this respect the Telephone Company of Copenhagen constitutes an exception as its managing director, Mr. *F. Johannsen*, through several years has applied the methods of the theory of probabilities to the solution of various problems of practical importance; also, he has incited others to work on investigations of similar character. As it is my belief that some point or other from this work may be of interest, and as a special knowledge of telephonic problems is not at all necessary for the understanding thereof, I shall give an account of it below.

And a very modern one…

- Digital TV uses MPEG coding of video which naturally leads to a variable data rate



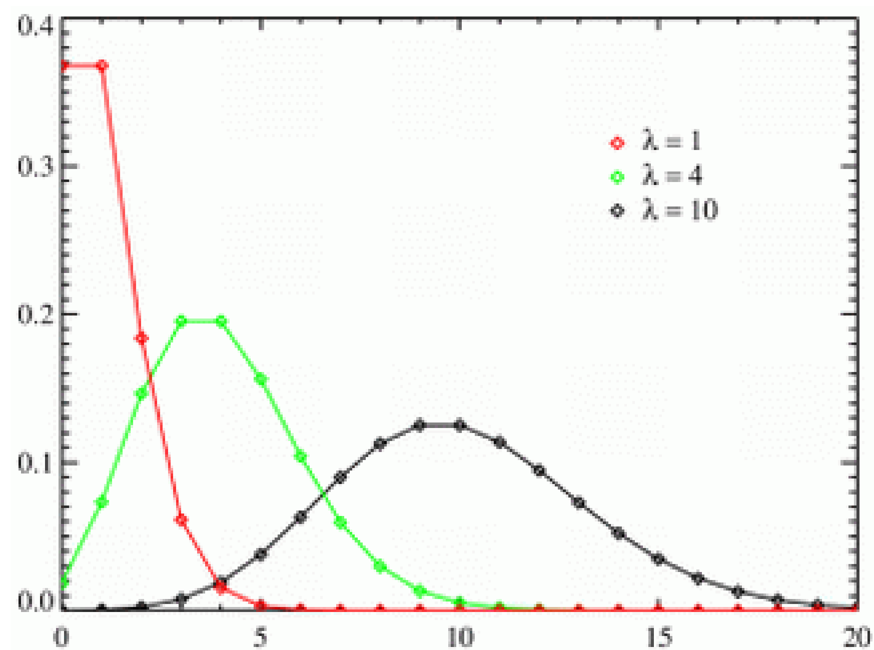


A simple stochastic processes

Poisson process:

If the expected number of occurrences in an interval is λ, then the probability that there are exactly k occurrences (k being a non-negative integer, k = 0, 1, 2, ...) is equal to:

$f\,(k;\,\lambda) = \lambda^k e^{-\lambda}\,/\,k!$



Poisson appears in strange places

Do Outbreaks of War Follow a Poisson-Process?

H. W. Houweling

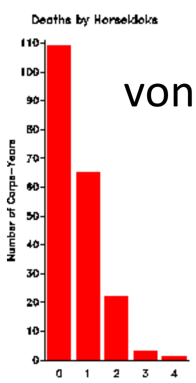
J. B. Kuné

University of Amsterdam

Abstract

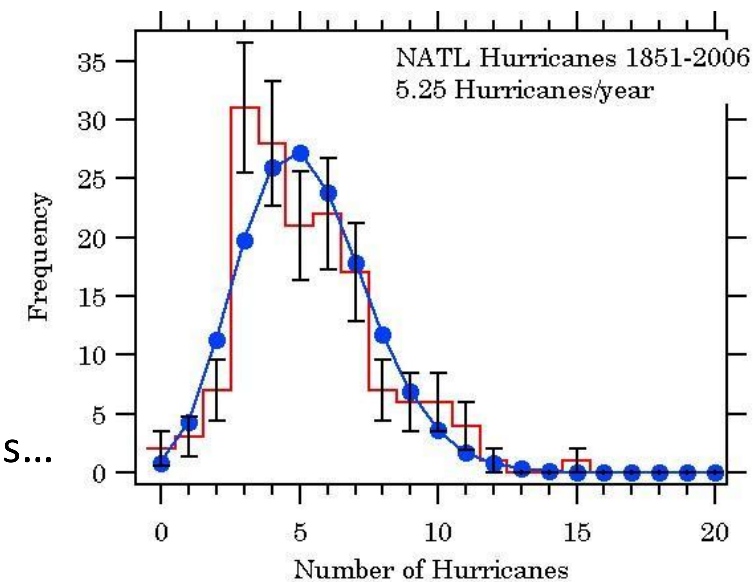
Richardson's finding that the distribution of war outbreaks in time conforms to the Poisson distribution has been repeated over and over again. In this article, we argue that the close correspondence between the two distributions does not imply that the mechanism generating the data is the Poisson process. Because the time sequence is broken down in Richardson's analysis, his finding does not imply that war outbreaks follow a distinct pattern in time. The Parzen test on arrival times revealed that war outbreaks are not generated by a Poisson random process.

Journal of Conflict Resolution, March 1984; vol. 28, 1: pp. 51-61.



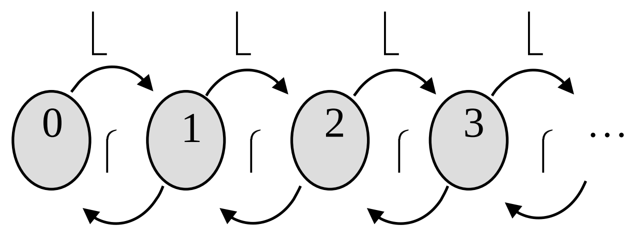
von Bortkiewicz (1898) - horse kick fatalities in the Prussian Cavalry

Paul Linsay (2006) – Atlantic hurricanes…



A simple queue

- M/M/1
  - Markov (poisson) arrivals
  - Markov (poisson) departures
  - 1 Server



λ = arrival rate
μ = departure rate

Define $\rho = \lambda/\mu$, the *traffic intensity* (what if $\rho \geq 1$?)

However if $\rho<1$, probability of j things in queue: $P_j = \rho^j(1 - \rho)$ for $j = 0,1,\ldots$

and average queue length: $L = \sum jP_j = \lambda/(\mu - \lambda)$

- Unfortunately real network traffic doesn't look like Poisson…. why?

CDMA

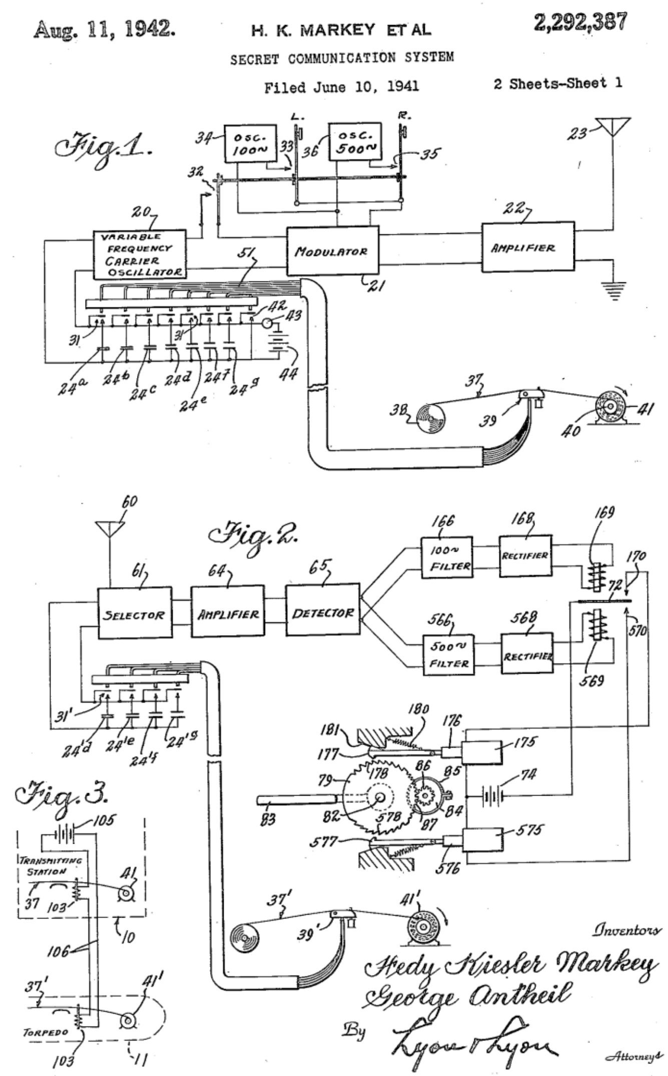
- Unique code assigned to each user
- Users share same frequency space
- Three types:
  - Frequency hopping
  - Time hopping
  - Direct Sequence

- Allows multiple users to “coexist” and transmit simultaneously with minimal interference
  - if codes are “orthogonal”
  - A large code can be selected at random and will probably be orthogional to any other random one!
- Can’t receive signal unless you know the code
- In fact hard to interfere if you don’t know the code

Frequency hoping

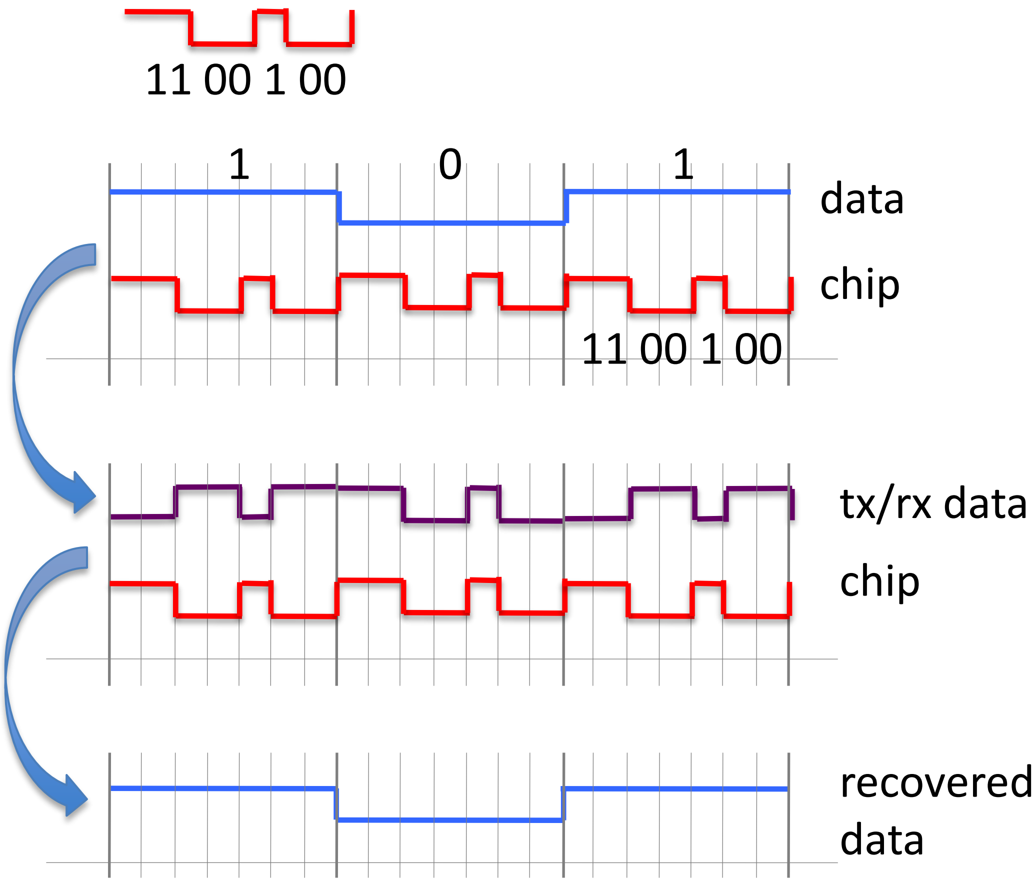
- Patent filed 1941 by
  - Hedy Keiser Markey & George Antheil
- Code on paper tape to select frequency
- Synchronise transmitter and receiver tapes…
- Designed for radio control torpedoes to prevent radio jamming

Hedy had a professional nname - Hedy Lamarr, star of stage and screen….



Direct Sequence CDMA

- Code is called
  "chip sequence"
- XOR data and chip sequence at transmitter
- XOR received data and chip sequence at receiver
- CDMA is the basis for:
  - 3G mobile telephony…
  - GNSS / GPS



Summary

- Reminder of various multiplexing techniques
- Description of STM, PTM, ATM
  - Role of statistical multiplexing
  - Problems then in queuing theory....
- CDMA