



UNIVERSITY OF DEBRECEN
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Teaching Queueing Theory Based on Information and Communication Technologies

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**Modern Challenges and Achievements of Information and
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Outline

- Origin of Queueing Theory
- Classifications of Queueing Systems
- Software Support
- QSA, Queueing Systems Assistance
- References

Origin of Queueing Theory



Agner Krarup Erlang, 1878-1929

- "The Theory of Probabilities and Telephone Conversations", Nyt Tidsskrift for Matematik B, vol 20, 1909.
- "Solution of some Problems in the Theory of Probabilities of Significance in Automatic Telephone Exchanges", Elektroteknikeren, vol 13, 1917.
- "The life and works of A.K. Erlang", E. Brockmeyer, H.L. Halstrom and Arns Jensen, Copenhagen: The Copenhagen Telephone Company, 1948.

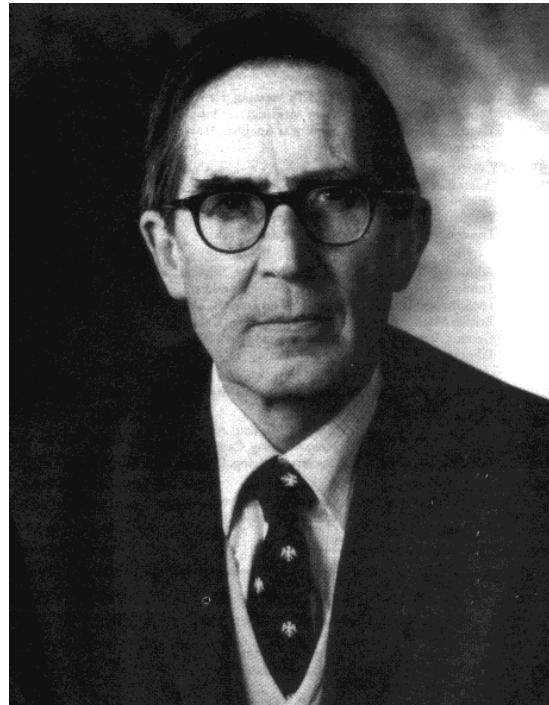
Queueing Theory Homepage

<http://web2.uwindsor.ca/math/hlynka/queue.html>

Applications

- Telephony, Call Centers
- Manufacturing
- Inventories
- Dams
- Supermarkets
- Computer and Communication Systems
- Sensor Networks, IoT
- Infocommunication Networks, Clouds
- Hospitals
- Many others

Kendall's Notation



David G. Kendall, 1918-2007

$A/B/c/K/m/Z$

Performance Metrics

- Utilizations
- Mean Number of Customers in the System / Queue
- Mean Response / Waiting Time
- Mean Busy Period Length of the Server
- Distribution of Response / Waiting Time
- Distribution of the Busy Period
- Distribution of Number of Customers Served during a Busy Period
- Distribution of Number of Retrials until Service Completion

Solution Methodologies

- Analytical
- Numerical
- Asymptotic
- Simulation
- Tool Supported Solutions

Tool Supported Modeling

- University of Dortmund: *HIT, HiQPN, APNN*
<http://ls4-www.informatik.uni-dortmund.de/tools.html/>
- University of Illinois at Urbana-Champaign: *MÖBIUS*
<http://www.mobius.uiuc.edu/>
- University of Erlangen: *PEPSY, MOSEL*
<http://www4.informatik.uni-erlangen.de/Projects/MOSEL/>
- University of Oxford: *PRISM*
<http://www.prismmodelchecker.org/>

Software and Information

<http://web2.uwindsor.ca/math/hlynka/qsoft.html>

<http://mason.gmu.edu/~jshortle/QtPlus-4-0.zip>

QSA (Queueing Systems Assistance)

<https://qsa.inf.unideb.hu>

Lecture Notes

https://irh.inf.unideb.hu/~jsztrik/education/16/SOR_Main_Angol.pdf

https://irh.inf.unideb.hu/~jsztrik/education/16/Queueing_Problems_Solutions_2021_Sztrik.pdf

Introduction of QSA and Case Studies

Example 1

Customers arrive to a 2 server system according to a Poisson process with rate 3. The service times are exponentially distributed with parameter 2.

Find the minimum capacity of the system for which the probability of blocking is less than 0.01 and the probability that the waiting time exceeds 1.8 minutes is less than 0.05.

Case Studies

Example 2

We have a finite-source system with 50 sources, the request generation times are exponentially distributed with rate 0.5. The service times are exponentially distributed for all the 5 servers with intensity 2.

Find the minimum capacity of the system for which the probability of blocking is less than 0.01 and the probability that the waiting time exceeds 3.5 minutes is less than 0.05.







Case Studies

Example 3






Let us see an M/M/1 system with arrival intensity 1 and the following costs, cost of service per server per unit time $C_S = 2$, cost of waiting in the system per customer per unit time $C_W = 2$, cost of idleness per server per unit time $C_I = 10$, cost of service rate per server per unit time $C_{SR} = 10$, reward per customer per unit time $R = 5$.

Find the optimal value for the service intensity which minimize the expected total cost per unit time with linear objective function.






Bibliography on Queueing

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Bibliography on Applications

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-  JAIN, R. *The Art of Computer Systems Performance Analysis*, John Wiley Sons, 1991
-  NELSON, R. *Probability, Stochastic Processes, and Queueing Theory, The Mathematics of Computer Performance Modeling*, Springer, 1995
-  TRIVEDI, K. *Probability and Statistics with Reliability, Queueing, and Computer Science Applications*, John Wiley Sons, 2002

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-  BEGAIN, K., BOLCH, G., HEROLD, H. *Practical Performance Modeling, Application of the MOSEL Language*, John Wiley Sons, 2001
-  CAI, L., SHEN, X., MARK, J.W. *Multimedia Services in Wireless Internet, Modeling and Analysis*, John Wiley Sons, 2009
-  GEBALI, F. *Analysis of Computer and Communication Networks*, Springer, 2008
-  KOUVATSOS, D. *Network Performance Engineering, A Handbook on Convergent Multi-Service Networks and Next Generation Internet*, Springer, 2011
-  MISIS, J., MISIC, V.B. *Performance Modeling and Analysis of Bluetooth Networks: Polling, Scheduling and Traffic Control*, Auerbach Publications, 2006

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for Your
Attention*