Simulation Based Investigation of Conservation Laws in Queueing Networks

Research Focus Period-Summer 2016 Presentation

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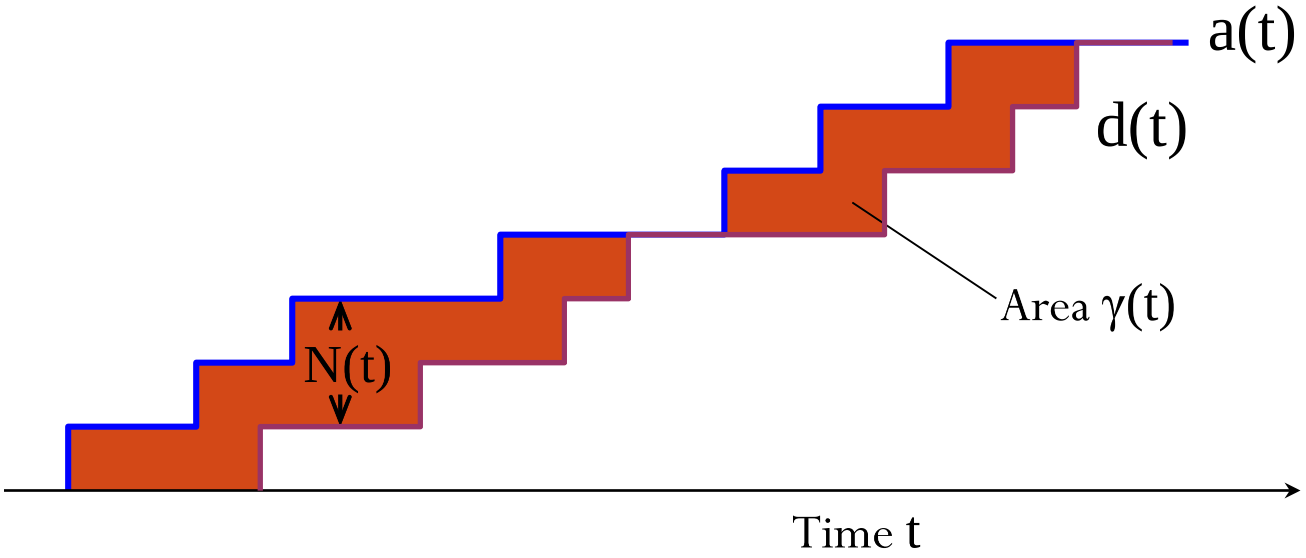
INTRODUCTION

- A queuing discipline is nothing more than a means for choosing which customer in the queue is to be serviced next
- The selection may be based on;
  1. Some measure related to relative arrival times for those customers in the queue e.g. First Come First Serve (FCFS), Last Come First Serve (LCFS)
  2. Some measure of the service time required e.g. Shortest Job First (SJF), Longest Job First (LJF)
  3. Some function of group membership e.g. Head of the line (HOL) system
- The third one is usually referred to as priority queueing discipline

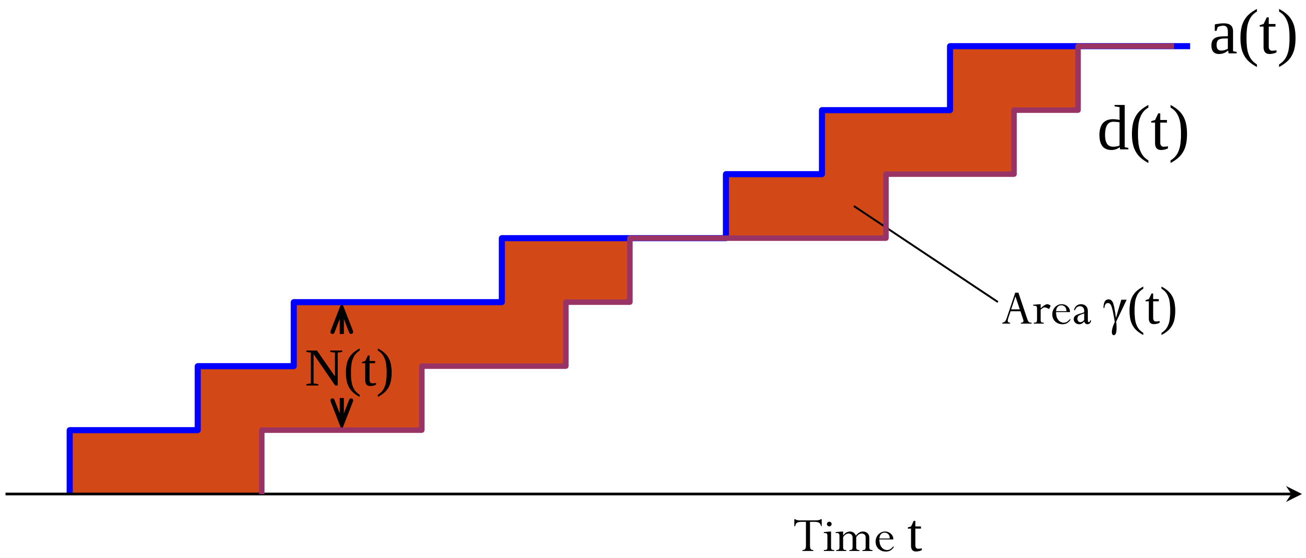
LITTLE'S LAW

- a(t): the process that counts the number of arrivals up to t.
- d(t): the process that counts the number of departures up to t.
- $N(t) = a(t) - d(t)$



- Average arrival rate (up to t) $\lambda_t = a(t)/t$
- Average time each customer spends in the system $T_t = \gamma(t)/a(t)$
- Average number in the system $N_t = \gamma(t)/t$

LITTLE'S LAW



$$N_t = \lambda_t T_t$$

- Taking the limit as t goes to infinity

$$E[N] = \lambda E[T]$$

Expected number of customers in the system

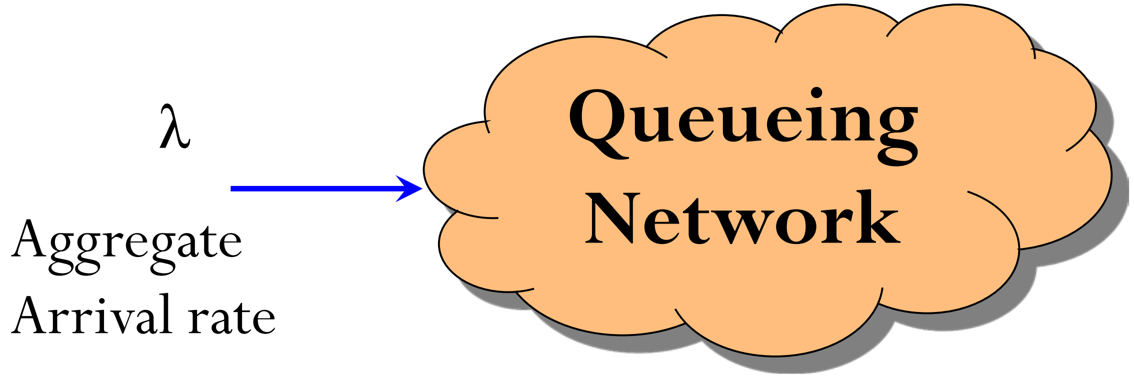
Expected time in the system

Arrival rate **IN** the system

GENERALITY OF LITTLE'S LAW

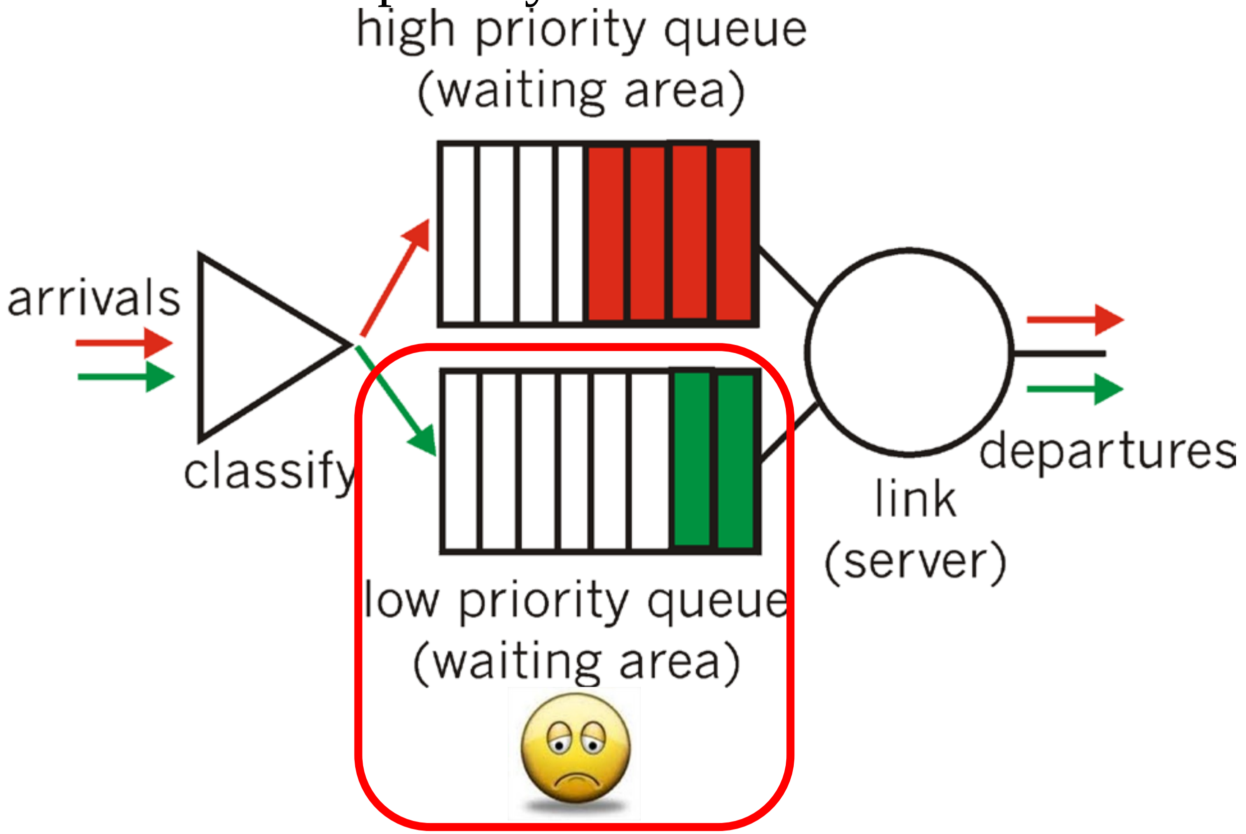
$$E[N] = \lambda E[T]$$

- Little's Law is a pretty general result
- It does not depend on the arrival process distribution
- It does not depend on the service process distribution
- It does not depend on the number of servers and buffers in the system



PRIORITY QUEUEING

- A priority queue is a collection of zero or more items, associated with each item is a priority



- Note that in a priority queue “FIRST COME FIRST SERVE" does not apply in general

EFFECTS OF PRIORITIZATION

- "You don't get something for nothing"
- Preferential treatment given to one class of customers is afforded at the expense of the other customers
- Following approaches can be used to estimate the effect of prioritization on other customers (semiconductor fab lots in my case!)
  1. Use of little's law corollary
  2. Use of conservation laws

COROLLARY OF LITTLE'S LAW

- For each arrival process g:
  - Denote by P_g the number of stages of production
  - Denote by λ_g the throughput rate for lots from g
- Let Λ_g= aggregate rate at which stages of production are completed

$$= \lambda_g P_g$$

- Little's Law: $\lambda_g = N_g / CT_g$
  - N_g is mean number of g lots
  - CT_g is mean cycle time for a g lot
- Aggregate rate of completion of stages of production

$$\Lambda_g = P_g N_g / CT_g$$

COROLLARY OF LITTLE'S LAW

- Employ this approach for
  - CTg by application to the fabricator
  - $\eta_g(l)$ by application to each toolset
- Determine the consequences of prioritization
  - $P_1 = P_2 = 300$ stages
  - $N_1 = 100$ lots, $N_2 = 400$ lots
  - Cycle time targets: $CT^T{}_1 = 20$ days, $CT^T{}_2 = 50$ days
  - Lots from arrival process 1 are for preferred customers
  - To ensure CT for preferred customer lots:
    - Devote Λ_1 = (300 stages)(100 lots)/(20 days) = 1500 lot*stages/day
  - The remaining $\Lambda_c - \Lambda_1$ aggregate throughput is devoted group 2 lots
    - Let $CT_2 = \epsilon * CT^T{}_2$
    - Then

$$\varepsilon = \frac{P_2 N_2 / CT_2^T}{\Lambda_c - P_1 N_1 / CT_1^T}$$

CONSERVATION LAWS

- Following conservation laws can also help us to calculate the effect of prioritization on other lots in some specific cases
  1. The M/G/1 Conservation Law
  2. The G/G/1 Conservation Law

THE M/G/1 CONSERVATION LAW

$$\sum_{\rho=1}^{P} \rho_p W_p = \begin{Bmatrix} \dfrac{\rho W_0}{1-\rho} & \rho < 1 \\ \infty & \rho \geq 1 \end{Bmatrix}$$

Where

- $\rho = {}^{\lambda}/_{\mu}$ is the utilization
- W_p= Weighted sum of the waiting times
- W_0= Residual life of the customer found in service upon an arrival's entry

THE G/G/1 CONSERVATION LAW

$$\sum_{\rho=1}^{P} \rho_p W_p = \bar{U} - Wo$$

Where

- $\rho = {}^{\lambda}/_{\mu}$ is the utilization
- W_p= Weighted sum of the waiting times
- $\bar{U}$ = Unfinished work
- W_0= Residual life of the customer found in service upon an arrival's entry

SIMULATION MODEL BASED ON MIMAC DATASETS

MIMAC Data Sets

- Measurement and Improvement of MAnufacturing Capacity (MIMAC) was a joint effort between Joint European Submicron Silicon (JESSI) and SEMATECH
- The primary objective of MIMAC was to identify and measure the effects and interactions of major factors that cause loss in fab capacity
- They developed some datasets based on almost real fab data to model fab and study the behavior of different interactions

MIMAC DATA SET CHARACTERISTICS

	Data Set 1		Data Set 7
# of Process Flows Modeled	2		1
# of Tool Groups	83		24
Average Downtime per Tool	10.20%		7.92%
# of Operator Groups	32		0
Is Rework Modeled?	Yes		No
Are Setups Modeled?	Yes		No
Process Flow Steps	232 for process flow 1	273 for process flow 2	172

SIMULATION MODEL BASED ON MIMAC DATASETS

- MIMAC data set 1 and 7 are being used to develop a model to compare the estimation of prioritization effect calculation on following two cases;
  1. Prioritization effect within one product class
  2. Prioritization effect with two product classes (No prioritization within the same product class!)

SIMULATION MODEL

- Input Files for Data Set 7
  1. options.def
  2. order.txt

LOT	PART	PIECES	START	REPEAT	RUNITS	RPT#	DUE	TRACE
SET_7_R-D-WAFER	L_SET_7_R-D-WAFER	24	03/01/04 08:00:00	42.3729	hr	1500		

  3. route.txt

ROUTE	STEP	STNFAM	PTIME	PTUNITS	PTPER	SETUP	STIME	STUNITS
route_b	001_DEPOSITION	CLEAN_DEPOSITION	1.55	hr	per_lot			
	002_DEPOSITION	TMGOX_DEPOSITION	4.98	hr	per_lot			
	003_LITHOGRAPHY	PHPPS_LITHOGRAPHY	4.23	hr	per_lot			
	004_LITHOGRAPHY	PHGCA_LITHOGRAPHY	7.82	hr	per_lot			
	005_RESIST_STRIP	PHPLO_RESIST_STRIP	1.09	hr	per_lot			
	006_LITHOGRAPHY	PHHB_LITHOGRAPHY	0.87	hr	per_lot			
	007_ETCHING	PLM7_ETCHING	5.41	hr	per_lot			
	008_ETCHING	PHWET_ETCHING	1.04	hr	per_lot			
	009_RESIST_STRIP	PHPLO_RESIST_STRIP	1.09	hr	per_lot			
	010_ETCHING	PHWET_ETCHING	1.04	hr	per_lot			
	011_LITHOGRAPHY	PHFI_LITHOGRAPHY	1.56	hr	per_lot			
	012_LITHOGRAPHY	PHPPS_LITHOGRAPHY	4.23	hr	per_lot			

SIMULATION MODEL

- Input Files for Data Set 7
  4. station.txt

STNFAM	STN	RULE	TRACE	FWLRANK	RWLRANK	STNQTY	DOWN	DWNUNT	DWNUNU	PROCEFF	LDIST
CLEAN_DEPOSITION	CLEAN_DEPOSITION	rule_FIRST				2	for	2.22	hr	0.9473684	exponential
TMGOX_DEPOSITION	TMGOX_DEPOSITION	rule_FIRST				2	for	10	hr	0.9010978	exponential
TMNOX_DEPOSITION	TMNOX_DEPOSITION	rule_FIRST				2	for	5.21	hr	0.9539956	exponential
TMFOX_DEPOSITION	TMFOX_DEPOSITION	rule_FIRST				1	for	12.56	hr	0.8789281	exponential
TU_11_DEPOSITION	TU_11_DEPOSITION	rule_FIRST				1	for	6.99	hr	0.9304823	exponential
TU_43_DEPOSITION	TU_43_DEPOSITION	rule_FIRST				1	for	5.21	hr	0.9539956	exponential
TU_72_DEPOSITION	TU_72_DEPOSITION	rule_FIRST				1	for	4.38	hr	0.738975	exponential
TU_73_DEPOSITION	TU_73_DEPOSITION	rule_FIRST				1	for	3.43	hr	0.7405446	exponential
TU_74_DEPOSITION	TU_74_DEPOSITION	rule_FIRST				1	for	3.74	hr	0.6468366	exponential
PLM5L_DEPOSITION	PLM5L_DEPOSITION	rule_FIRST				1	for	12.71	hr	0.7325899	exponential
PLM5U_DEPOSITION	PLM5U_DEPOSITION	rule_FIRST				1	for	19.78	hr	0.6244541	exponential
SPUT_DEPOSITION	SPUT_DEPOSITION	rule_FIRST				1	for	9.43	hr	0.8700565	exponential
PHPPS_LITHOGRAPHY	PHPPS_LITHOGRAPHY	rule_FIRST				4	for	1.15	hr	0.9485919	exponential
PHGCA_LITHOGRAPHY	PHGCA_LITHOGRAPHY	rule_FIRST				3	for	4.81	hr	0.7789522	exponential
PHHB_LITHOGRAPHY	PHHB_LITHOGRAPHY	rule_FIRST				1	for	12.8	hr	0.9669421	exponential
PHBI_LITHOGRAPHY	PHBI_LITHOGRAPHY	rule_FIRST				2	for	12.8	hr	0.9669421	exponential
PHFI_LITHOGRAPHY	PHFI_LITHOGRAPHY	rule_FIRST				1	for	1.57	hr	0.9868289	exponential
PHJPS_LITHOGRAPHY	PHJPS_LITHOGRAPHY	rule_FIRST				1	for	1.57	hr	0.9868289	exponential
PLM6_ETCHING	PLM6_ETCHING	rule_FIRST				2	for	17.42	hr	0.6244071	exponential
PLM7_ETCHING	PLM7_ETCHING	rule_FIRST				1	for	9.49	hr	0.7405686	exponential
PLM8_ETCHING	PLM8_ETCHING	rule_FIRST				2	for	9.49	hr	0.7405686	exponential
PHWET_ETCHING	PHWET_ETCHING	rule_FIRST				2	for	1.08	hr	0.9909183	exponential
PHPLO_RESIST_STRIP	PHPLO_RESIST_STRIP	rule_FIRST				2	for	1.08	hr	0.9909183	exponential
IMP_ION_IMPLANT	IMP_ION_IMPLANT	rule_FIRST				2	for	12.86	hr	0.7669445	exponential

SIMULATION MODEL

- Input Files for Data Set 7

5. part.txt

PART	ROUTE
L_SET_7_R-D-WAFER	route_b

6. perf.rdf
   - File containing output parameters


Thank
You!!!