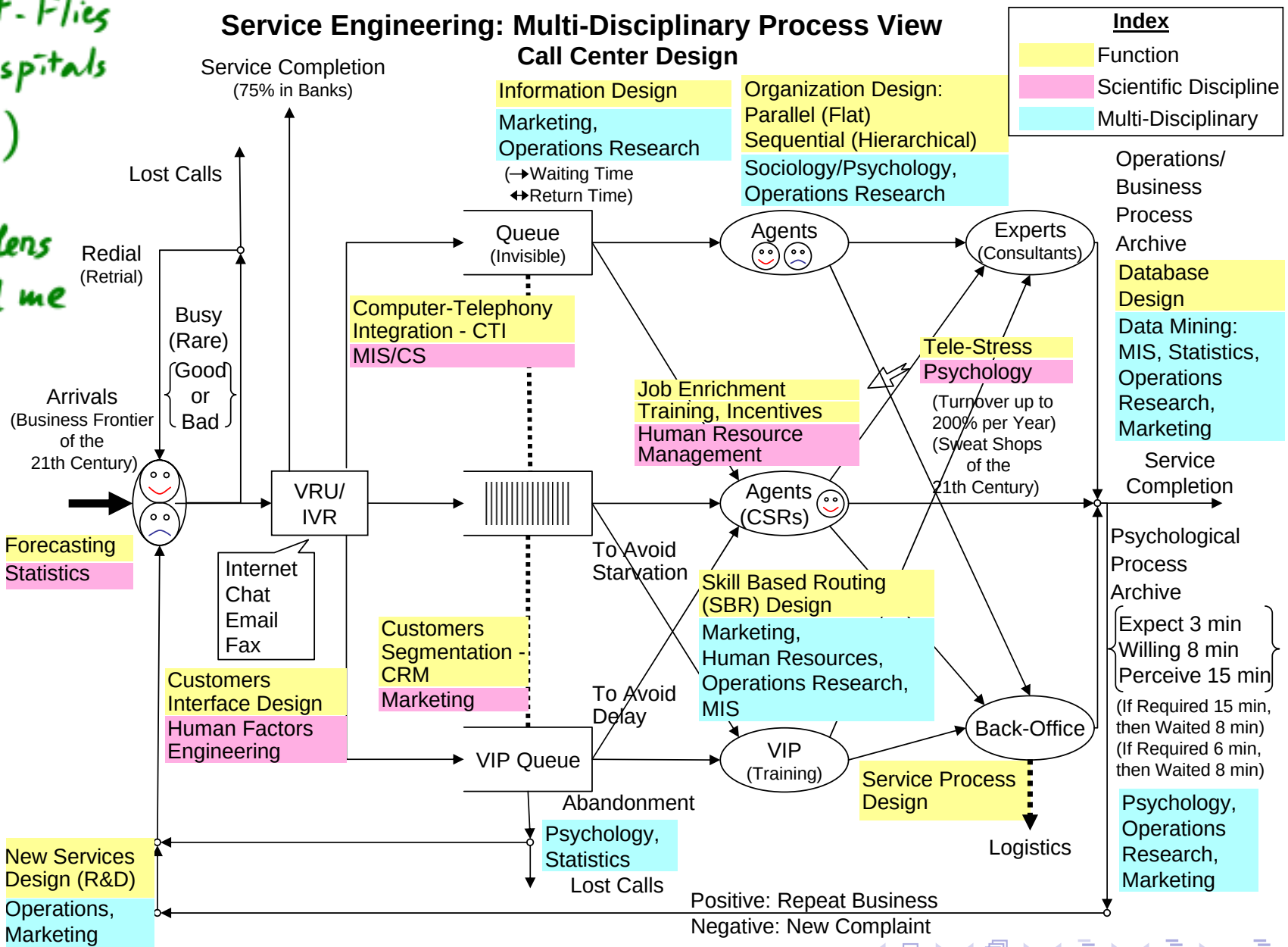
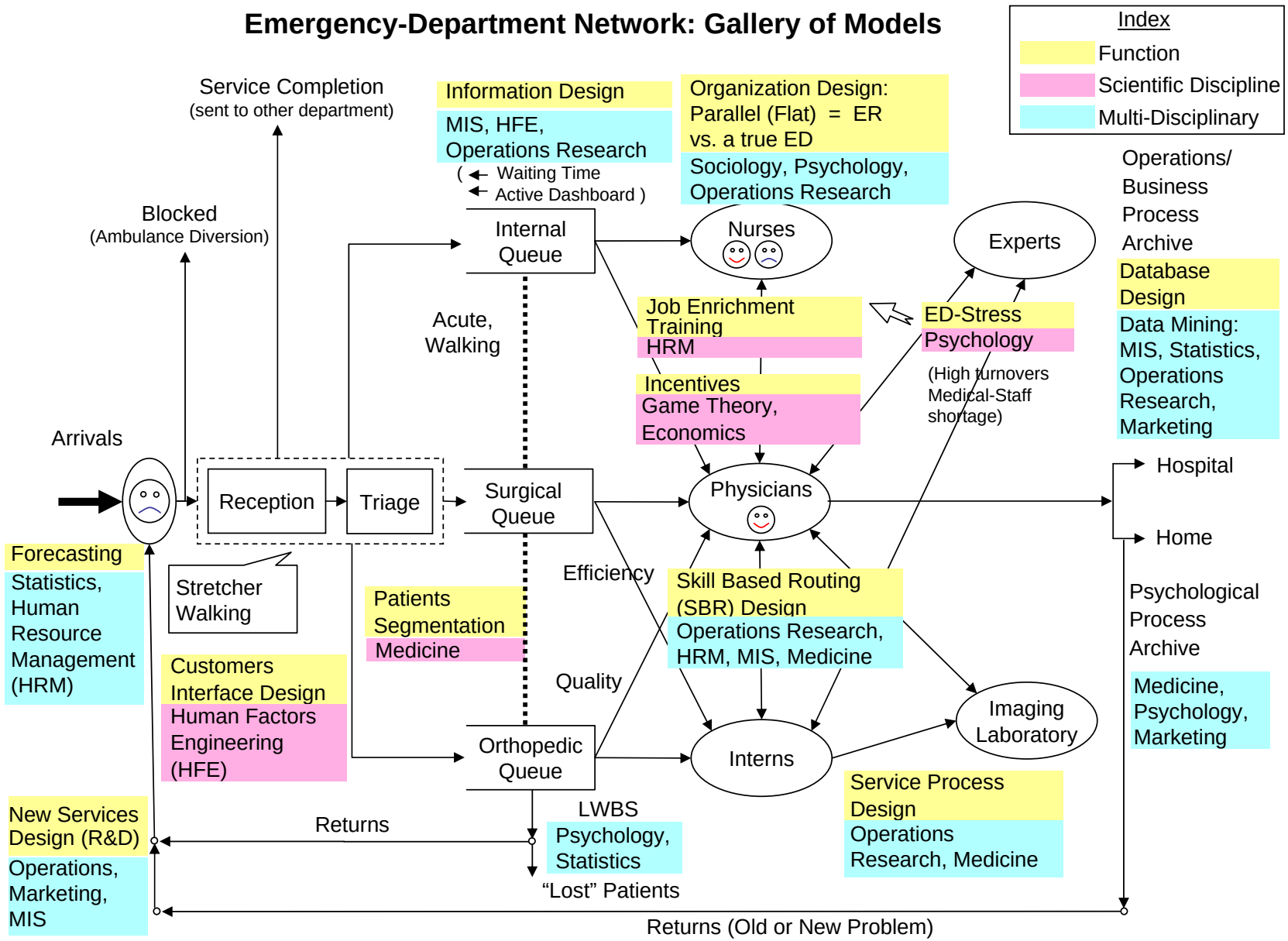
Call-Center: Multi-Disciplinary ServEng View

Fruit-Flies of Hospitals (EDs) ~ Flanders helped me

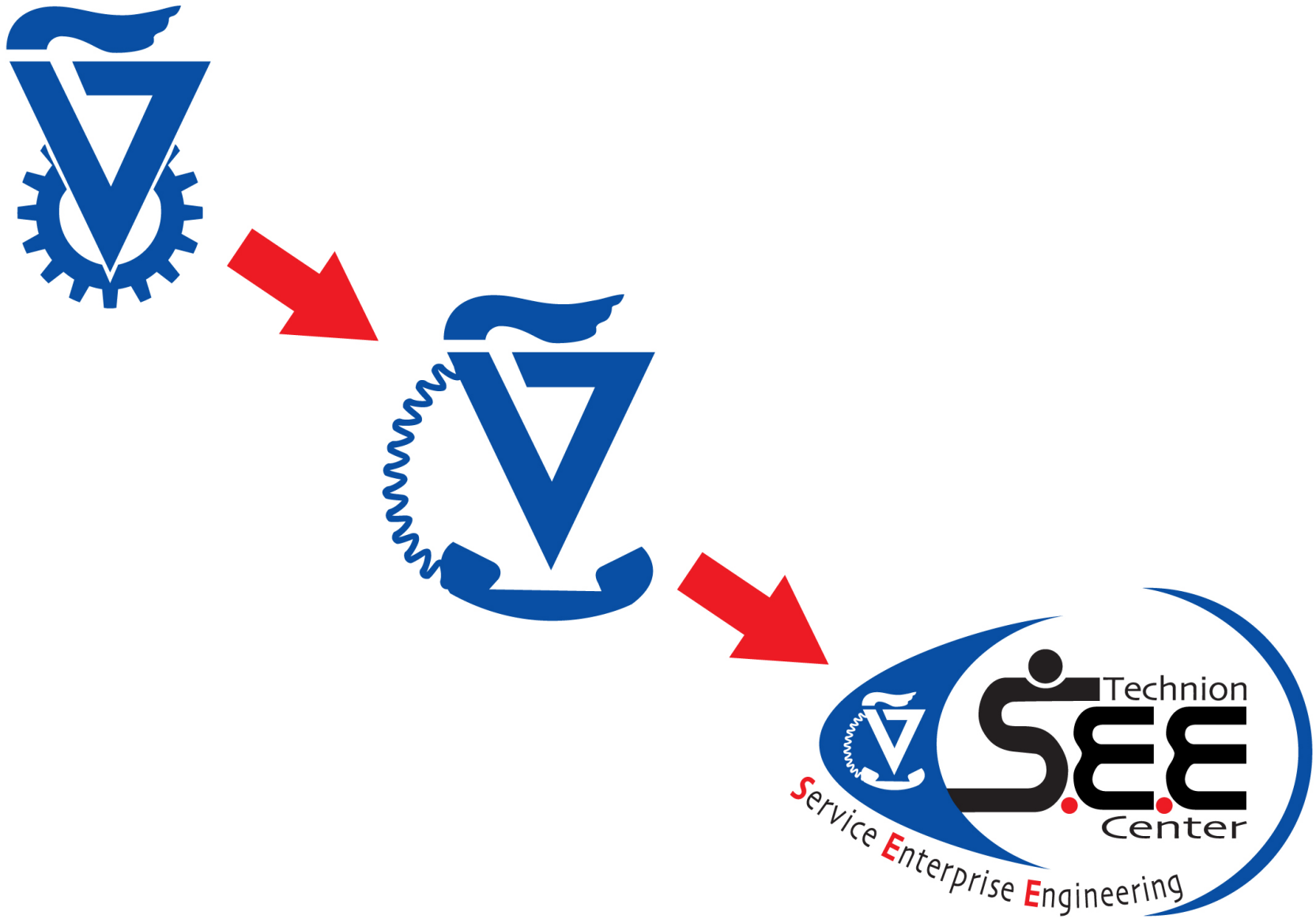


Emergency-Dept.: Multi-Disciplinary ServEng View



The Technion SEE Center / Laboratory

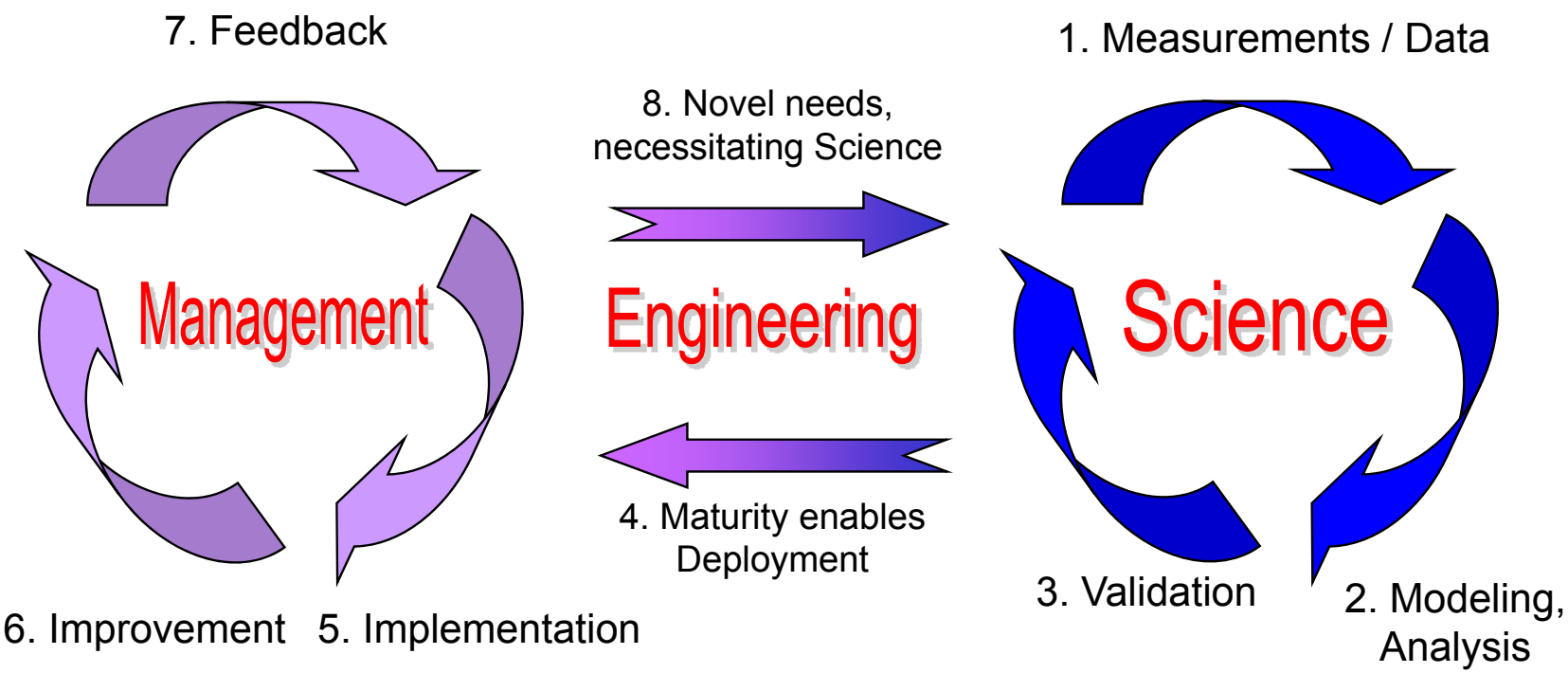
Data-Based Research & Teaching



Expanding the Scientific Paradigm

Service Engineering vs. **Industrial** Engineering

Human Complexity $\Rightarrow$ **Scientific Paradigm** (Physics ... Economics) and beyond (with IBM Research):



Started with Call Centers, Expanded to Hospitals

Call Centers - U.S. (Israel) Stat.

- $200 – $300 billion annual expenditures (0.5)
- 100,000 – 200,000 call centers (500)
- “Window" into the company, for better or worse
- Over 3 million agents = **2% – 4% workforce** (11K)

Healthcare - similar and unique challenges:

- Cost-figures far more staggering
- Risks much higher
- ED (initial focus) = hospital-window
- Over 3 million nurses

Technion SEELab: From SEEStat through SEEGraph to SEEmulations

- **SEEStat**: Software platform for EDA of Service Systems in real-time
  - e.g. Summary Stats, Smoothing, Mixtures, Survival
- **SEEGraph**: Pilot platform for creating process-maps in real-time (in-house development)
  - e.g. Call Centers, Internet Websites, Hospitals
- **SEEmulations**: Animating SEEGraphs (DISCO), getting tangibly close to the intermediate goal

Data History: Patient-Level ED Data

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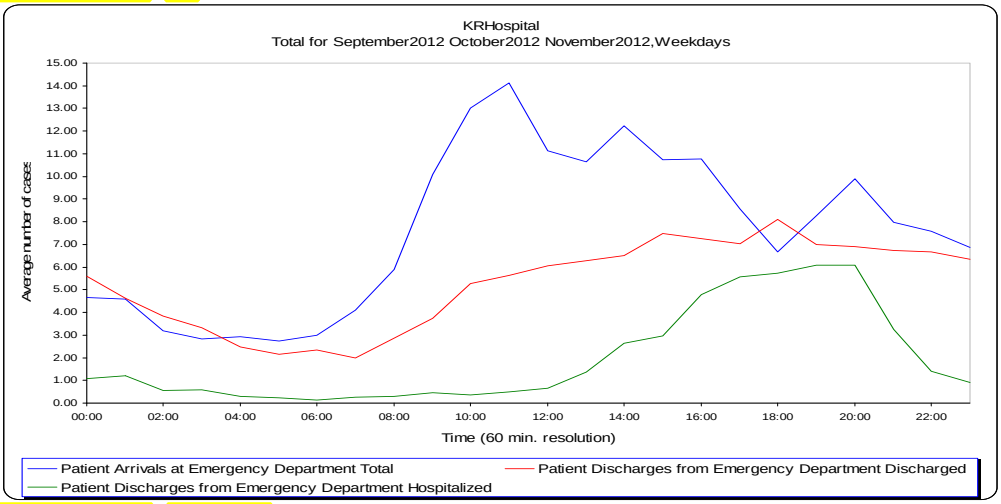
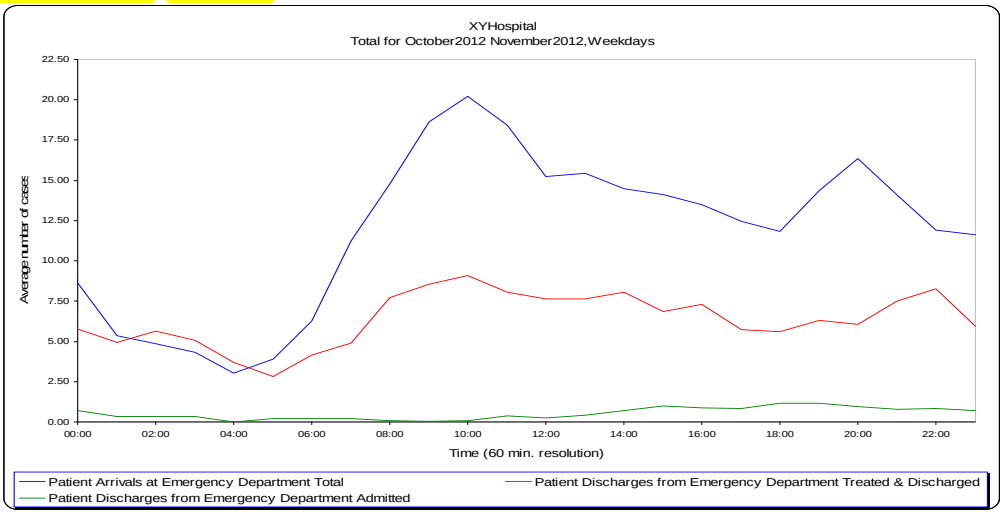
  - Demo **5**: **Dynamic Process Maps**, towards ED simulations

2. Arrivals to ED and Discharges from ED

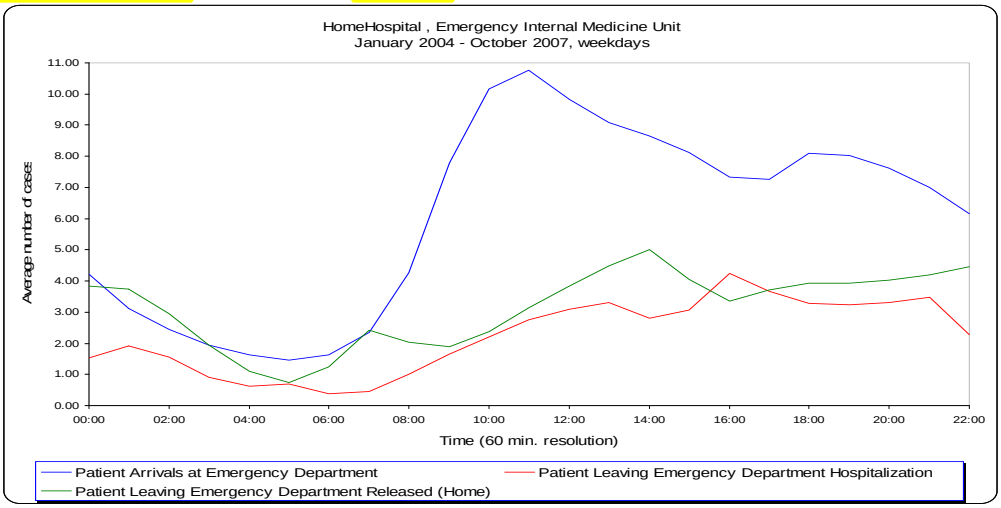
KRHospital, all ED patients



XYHospital, walking patients



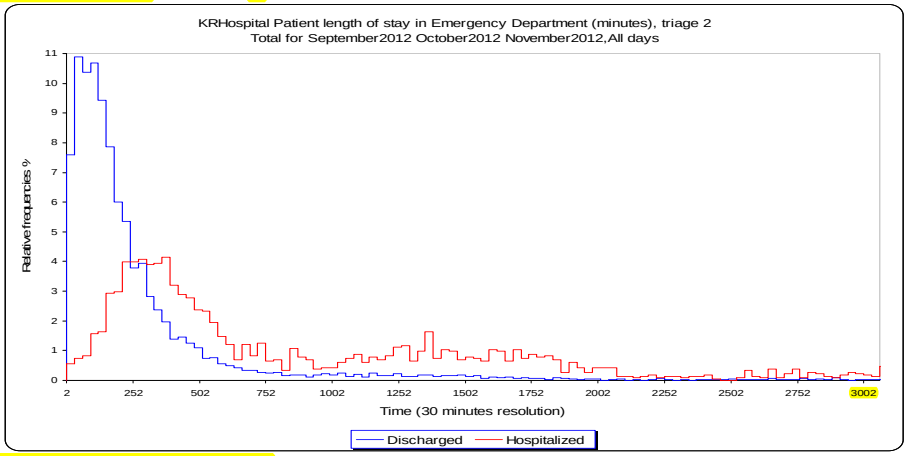
HomeHospital, Emergency Internal Medicine



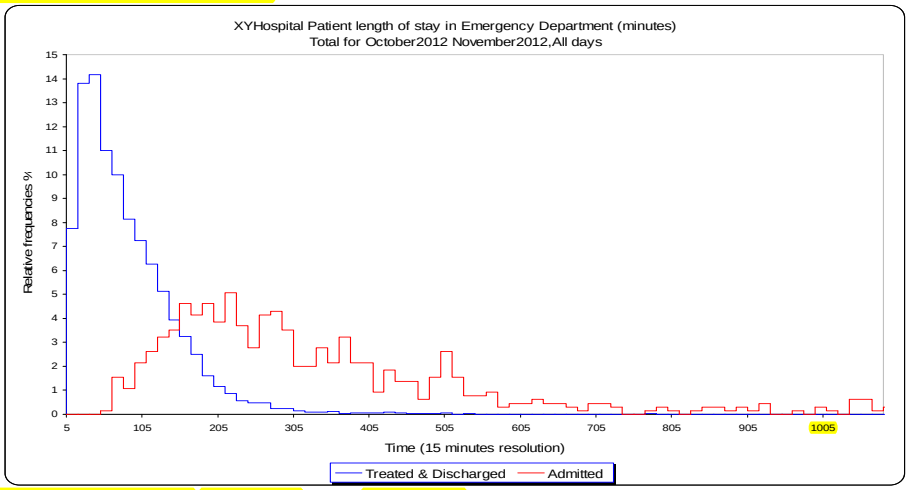
1. Patient length of stay in Emergency Department

1.1 Distribution by hospitalized and released (home) patients

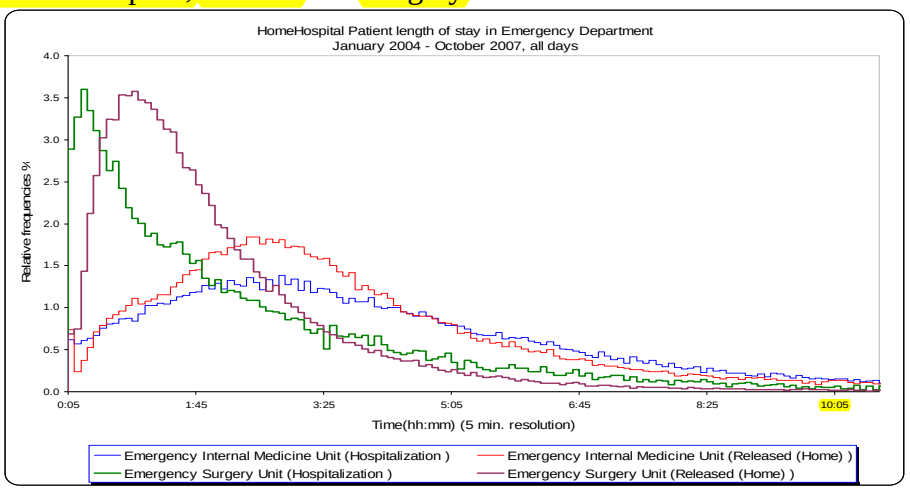
KRHospital, triage 2



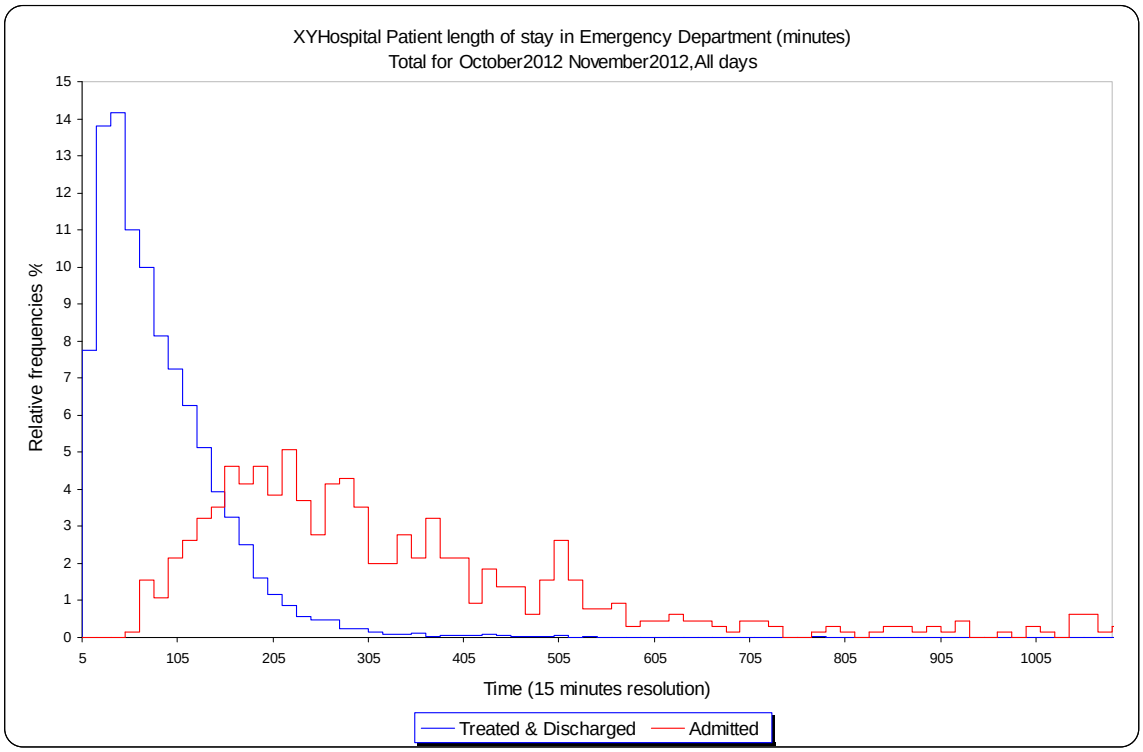
XYHospital, walking patients



HomeHospital, Internal and Surgery ED



XYHospital, walking patients



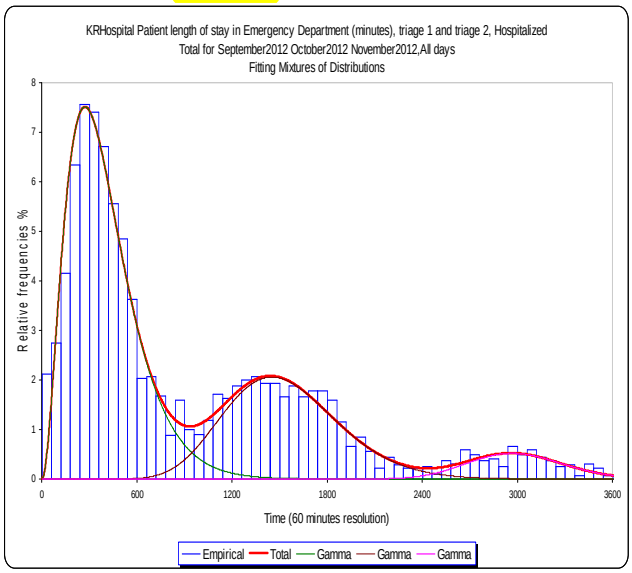
Statistics		
	Treated & Discharged	*Admitted*
N	7944	651
N(average per day)	152.7692308	12.51923077
Mean	85.62	387.44
Standard Deviation	68.68	327.95
Variance	4716.6	107552
Median	69	283
Minimum	5	63
Maximum	969	1960

Quantiles		
Quantile	*Treated & Discharged*	*Admitted*
99.5%	420.0	1787
99%	315.0	1731
97.45%	246.0	1508
95%	201.0	1121
90%	166.0	730
75% - Q3	116.0	448
50% - Median	69.0	283
25% - Q1	38.0	191
10%	22.0	133
2.5%	12.0	91
0.5%	8.0	68

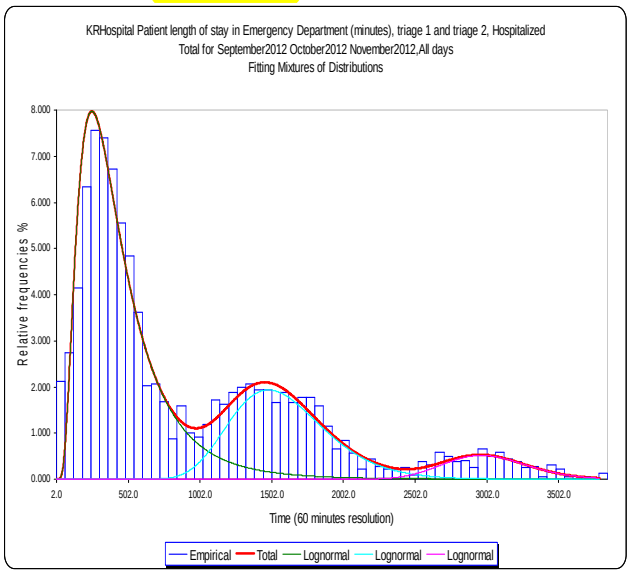
1.2 Fitting mixture of distributions

KRHospital: hospitalized patients, triage 1 and triage 2

Gamma distributions

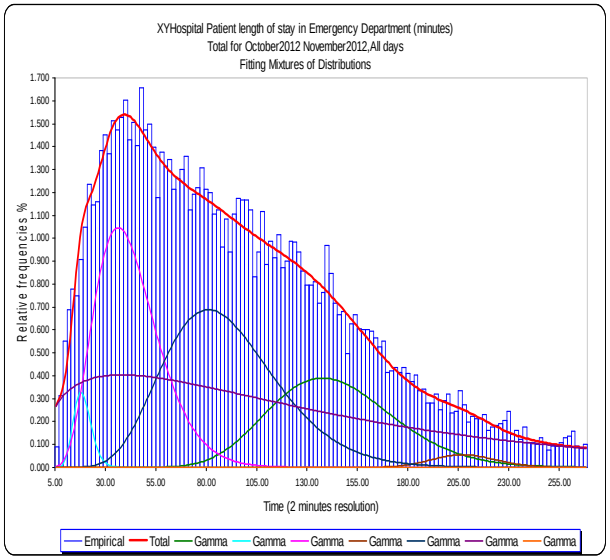


Lognormal distributions

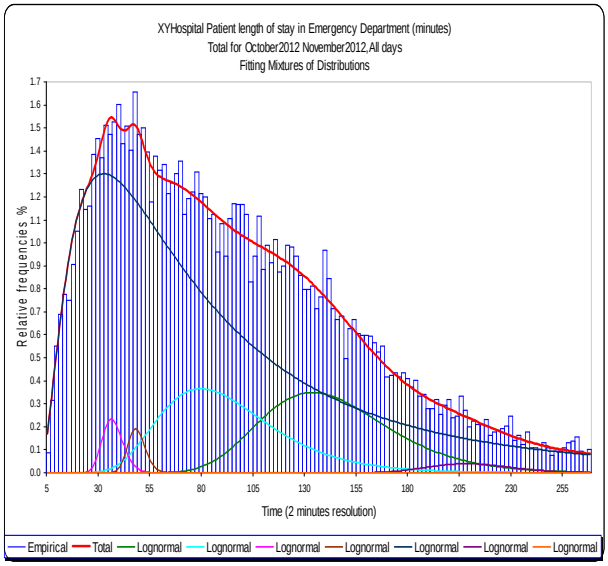


XYHospital: walking patients

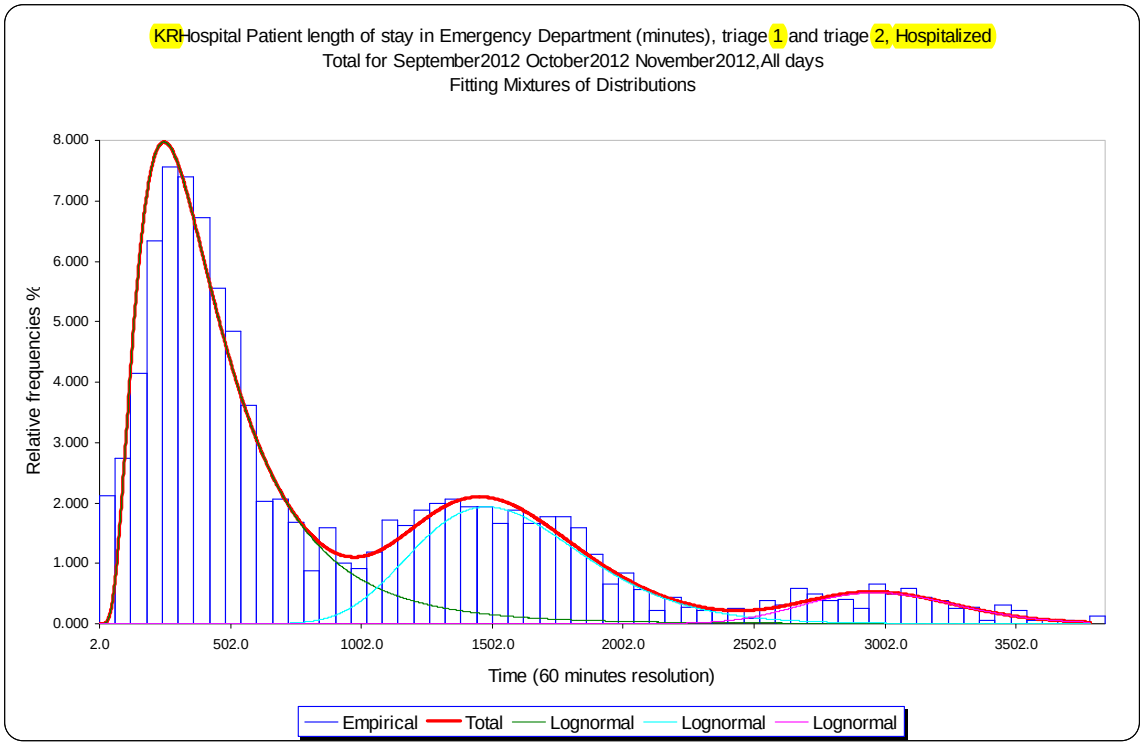
Gamma distributions



Lognormal distributions



Lognormal distributions



Statistics	
	Patient length of stay in Emergency Department (minutes)
N	3122
N(average per day)	41.07894737
Mean	926.53
Standard Deviation	809.57
Variance	655402
Median	562.5
Minimum	3
Maximum	3810

Parameter Estimates						
Components	*Mixing Proportions (%)*	*Location*	*Scale*	*Shape*	*Mean*	*Standard Deviation*
1. Lognormal	66.39		5.92	0.64	457.27	324.5128
2. Lognormal	27.16		7.35	0.22	1586.92	347.2102
3. Lognormal	6.45		8.00	0.10	3007.21	296.1252

Goodness-of-Fit Tests		
Tests	*Statistic*	*p Value*
Residuals Std	0.00753	
Kolmogorov-Smirnov	0.02523	0.0339
Cramer-von Mises	0.17690	0.3174
Andersen-Darling	7.92870	<.0001

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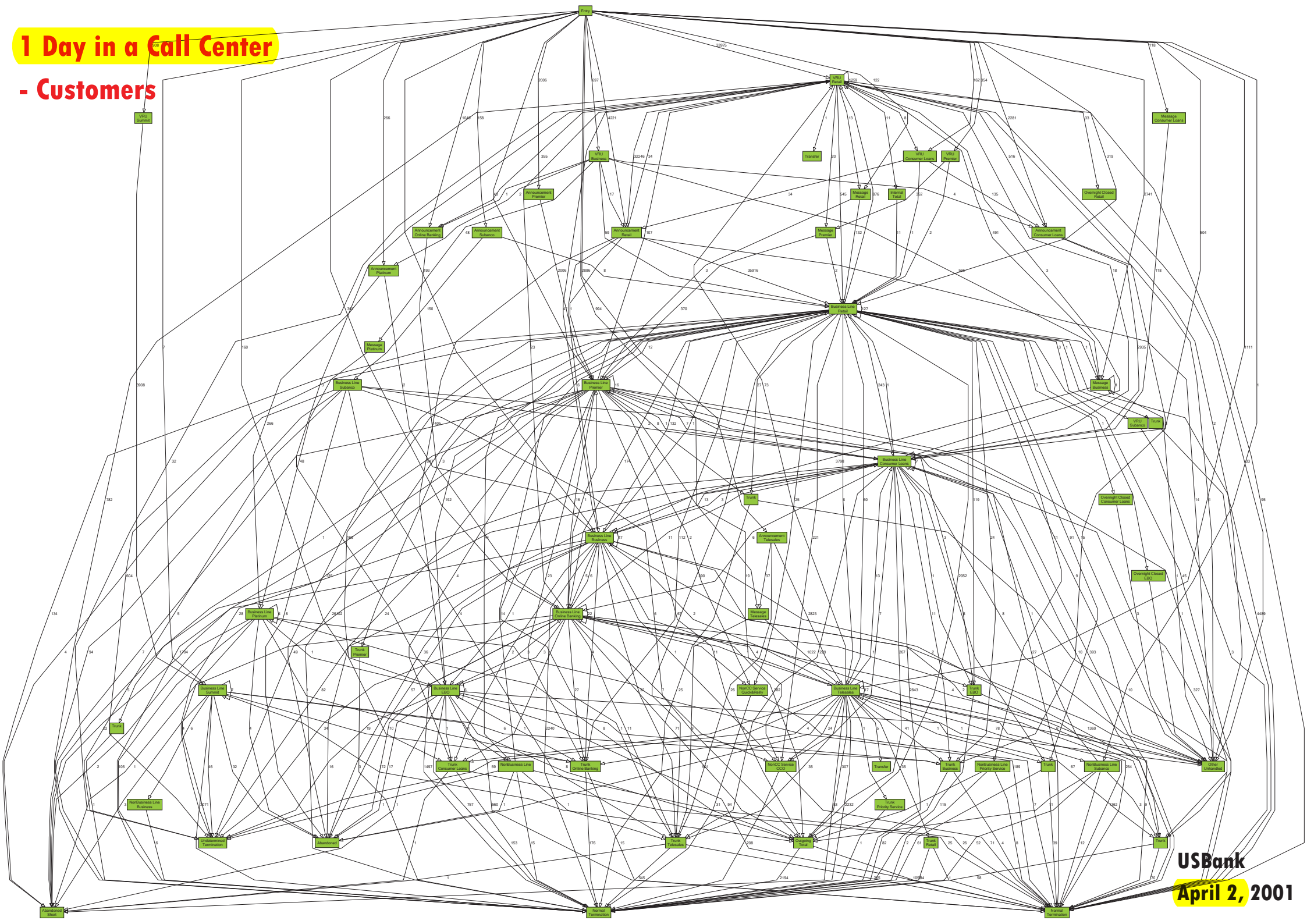
1 Day in a Call Center

- Customers

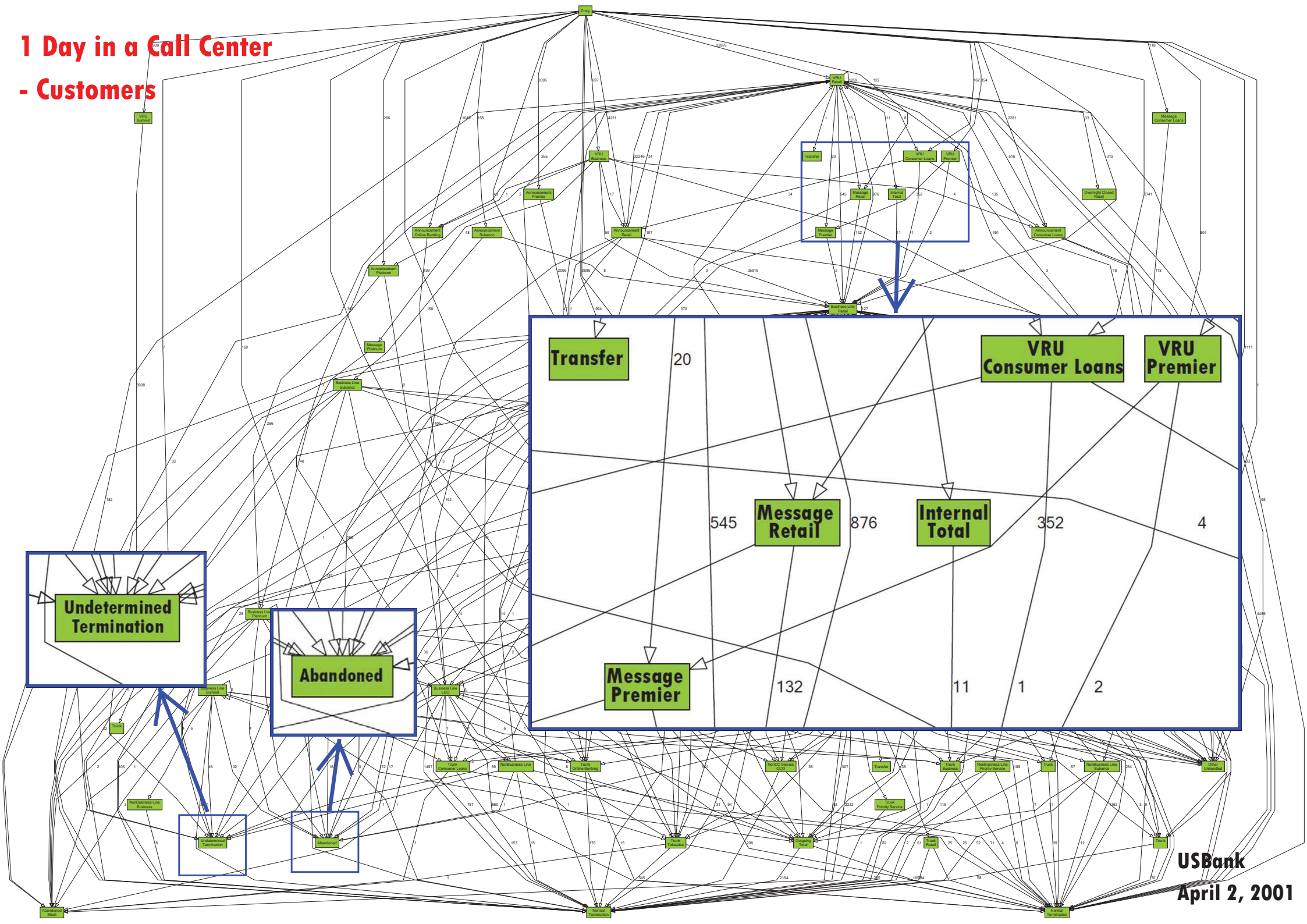


USBank

April 2, 2001

1 Day in a Call Center

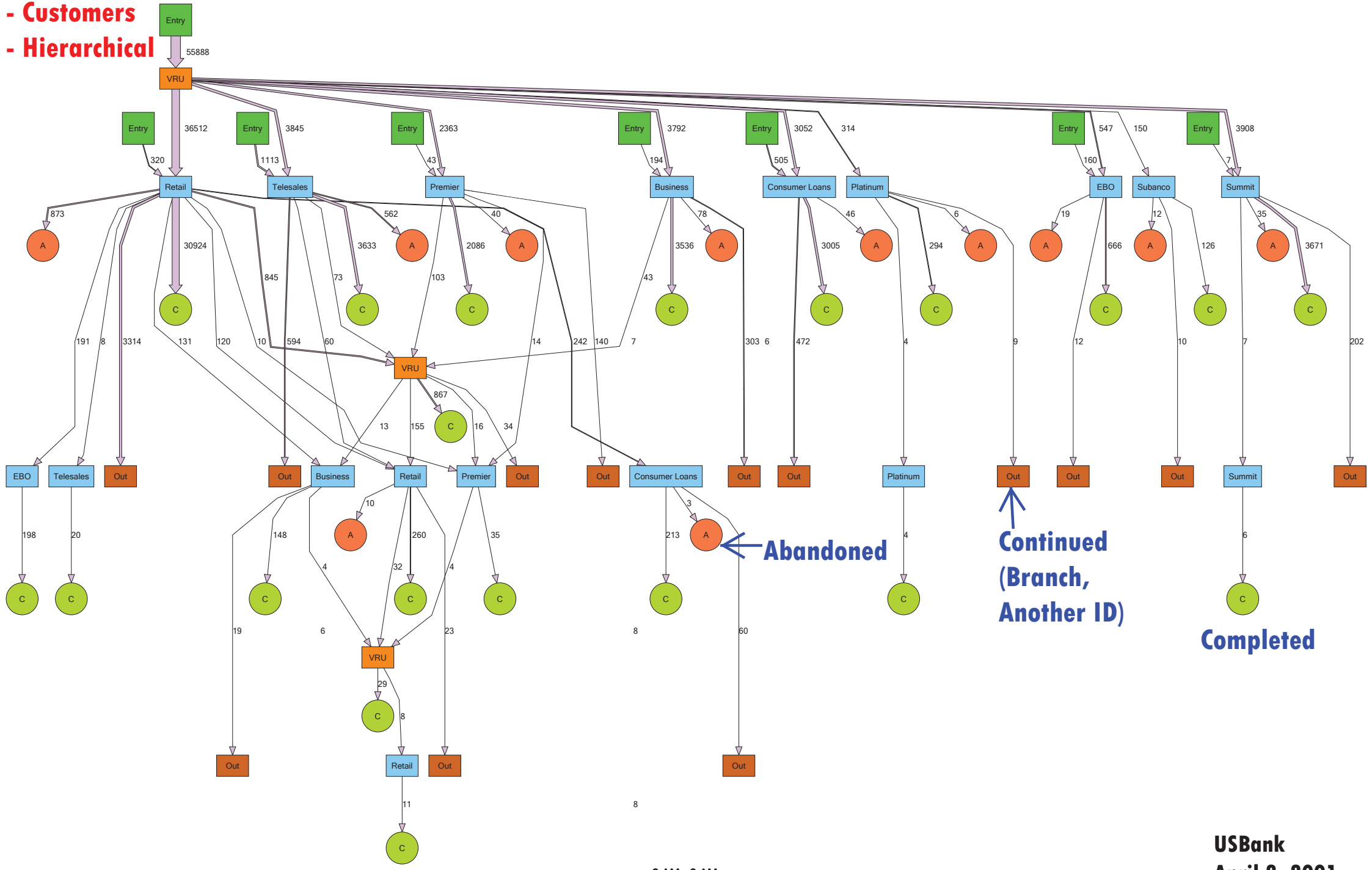
- Customers



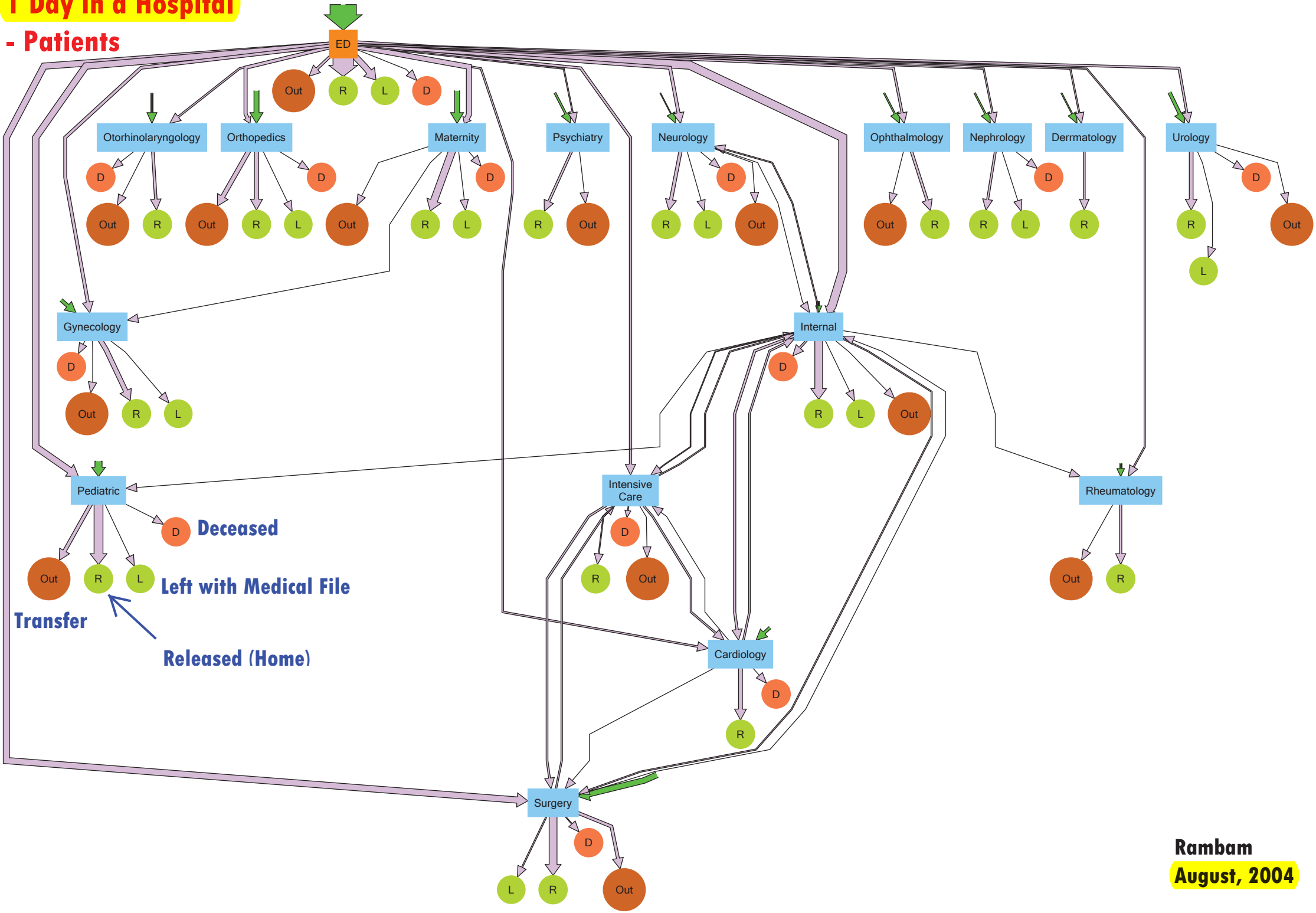
USBank

April 2, 2001

1 Hour in a Call Center
- Customers
- Hierarchical



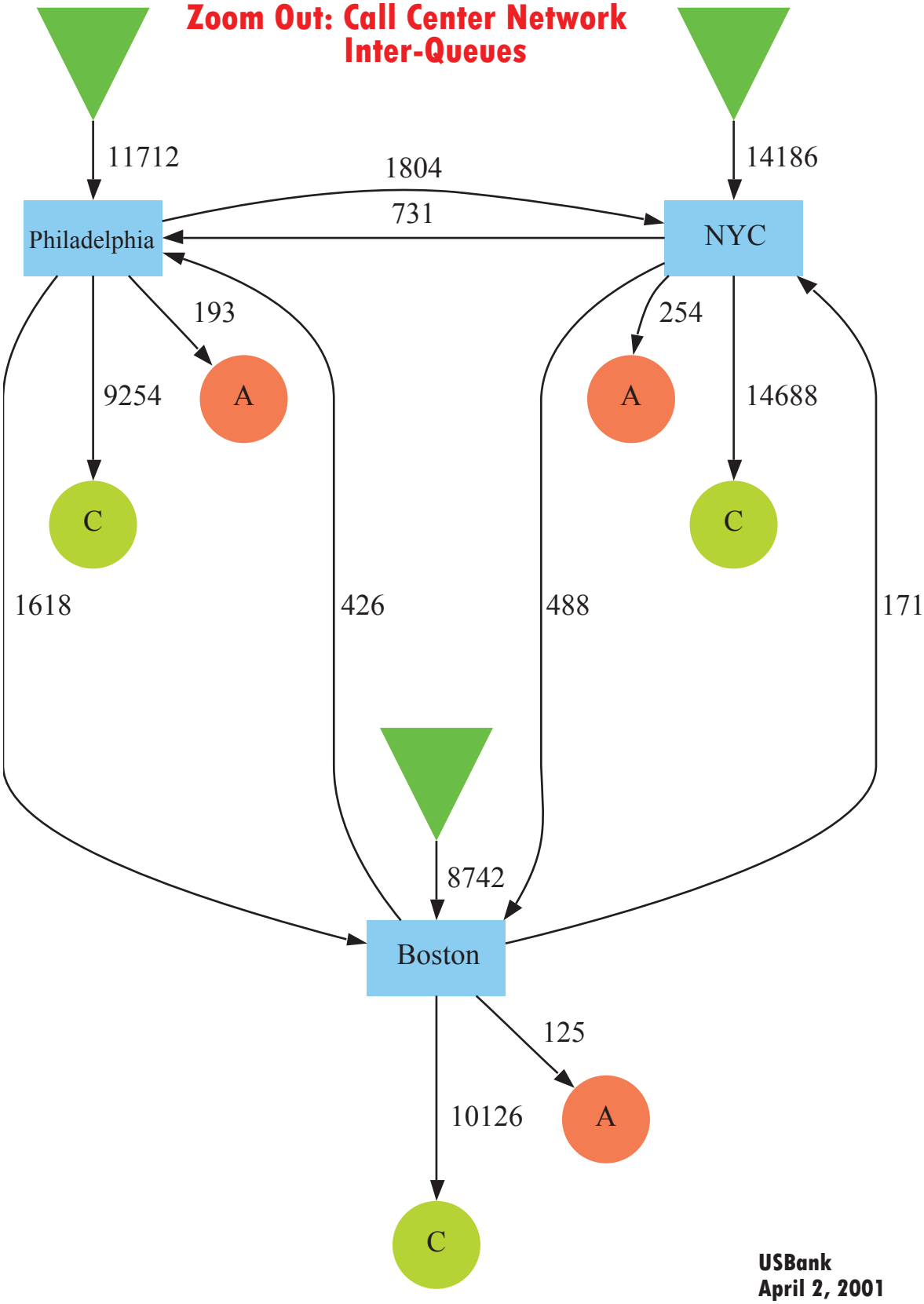
1 Day in a Hospital
- Patients



Rambam

August, 2004

Zoom Out: Call Center Network Inter-Queues



USBank
April 2, 2001

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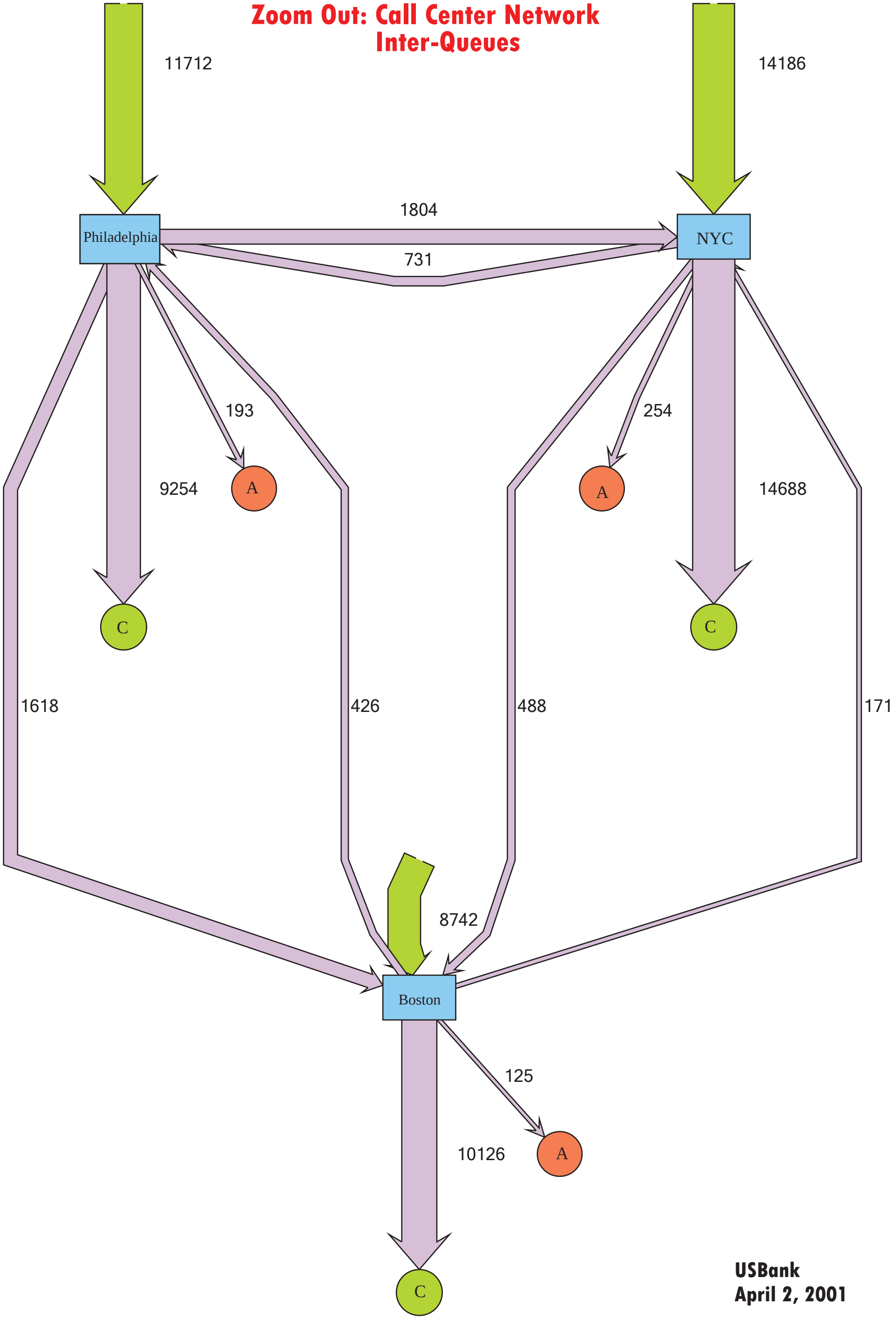
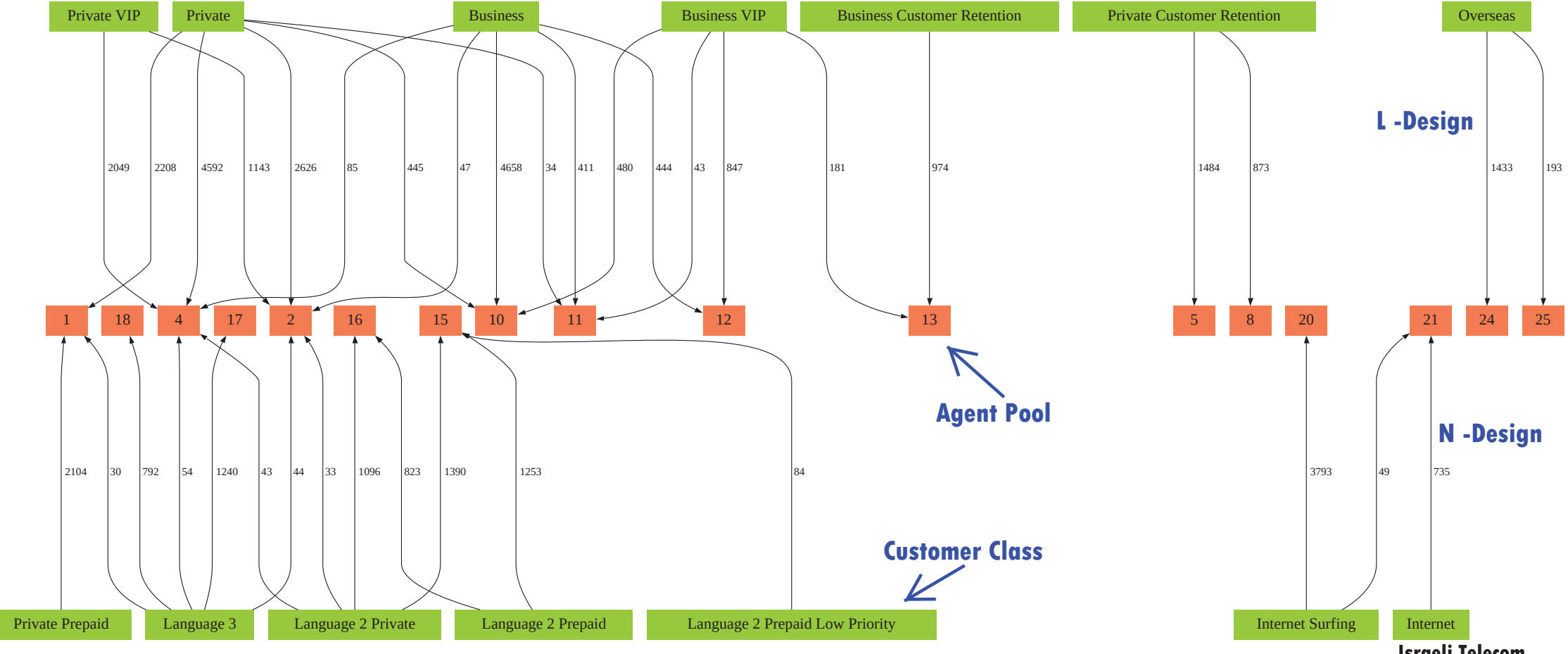


USBank
April 2, 2001

Zoom In: Skills - Based Routing (SBR)

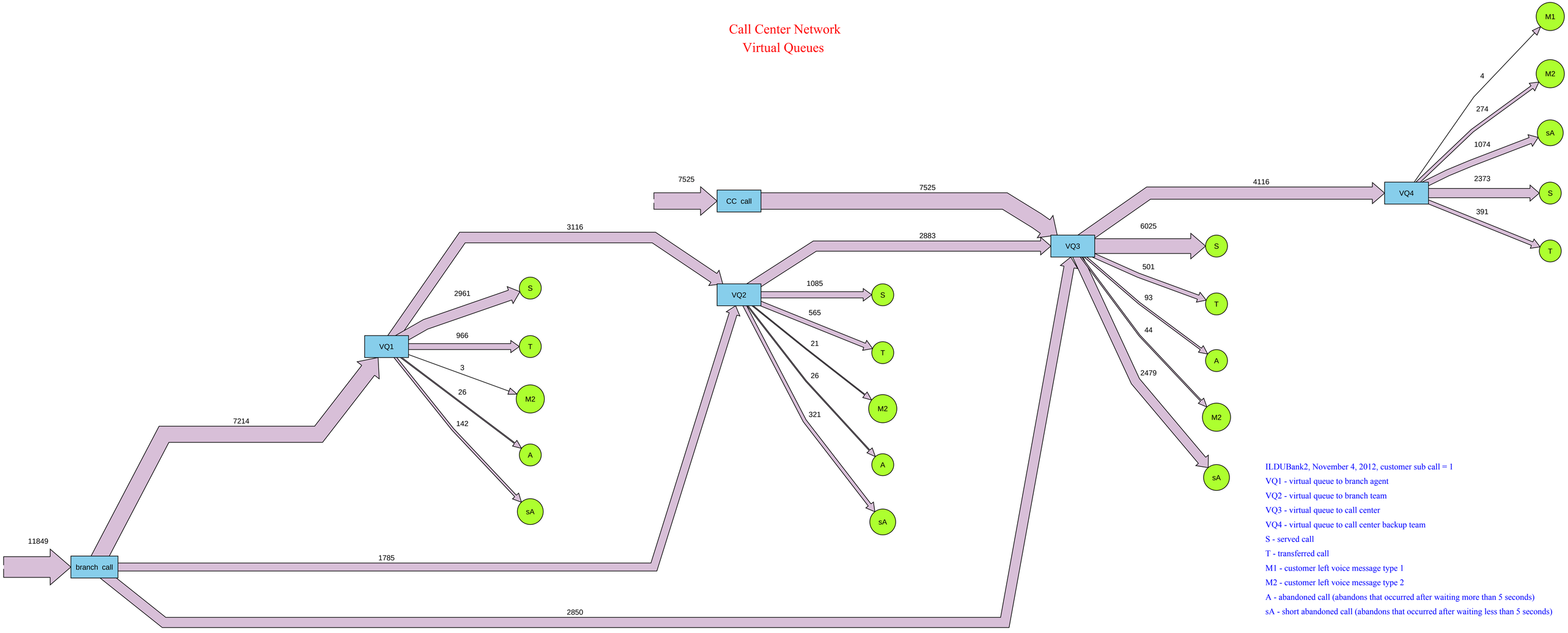
Network Structure (Protocol)



Connected Component

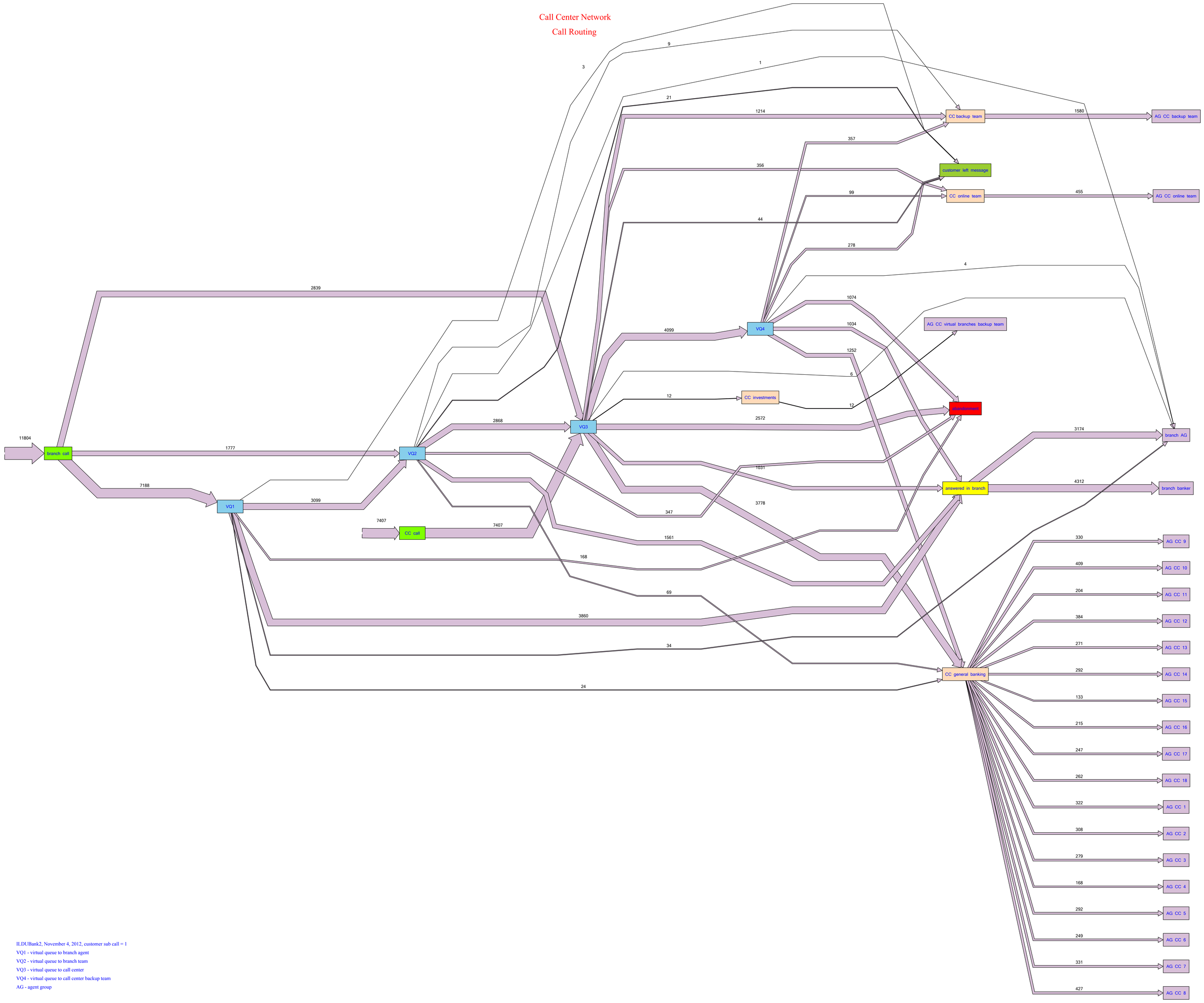
Israeli Telecom
February 10, 2008

Call Center Network
Virtual Queues



Call Center Network

Call Routing



ILDUBank2, November 4, 2012, customer sub call = 1

VQ1 - virtual queue to branch agent

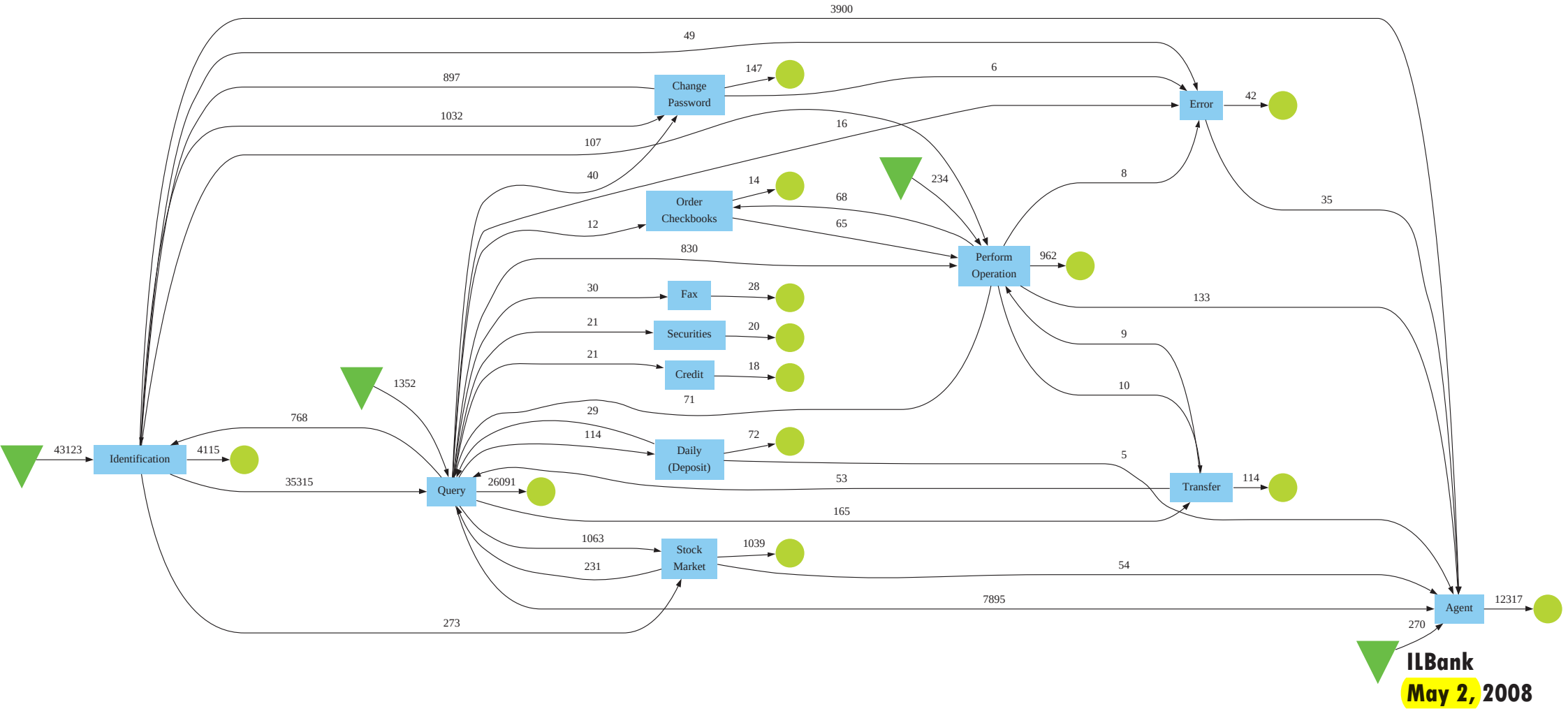
VQ2 - virtual queue to branch team

VQ3 - virtual queue to call center

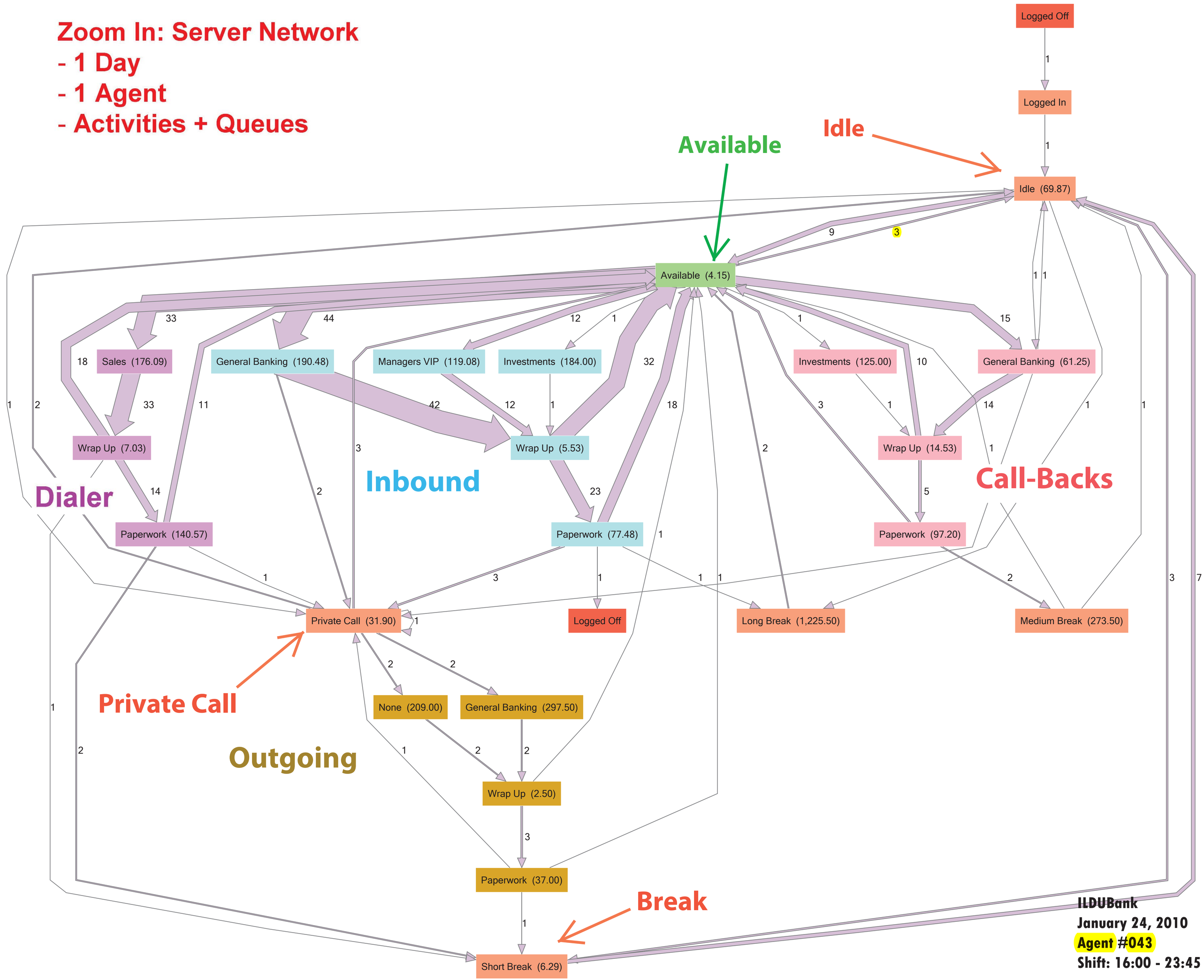
VQ4 - virtual queue to call center backup team

AG - agent group

Zoom In: Interactive Voice Response (IVR)

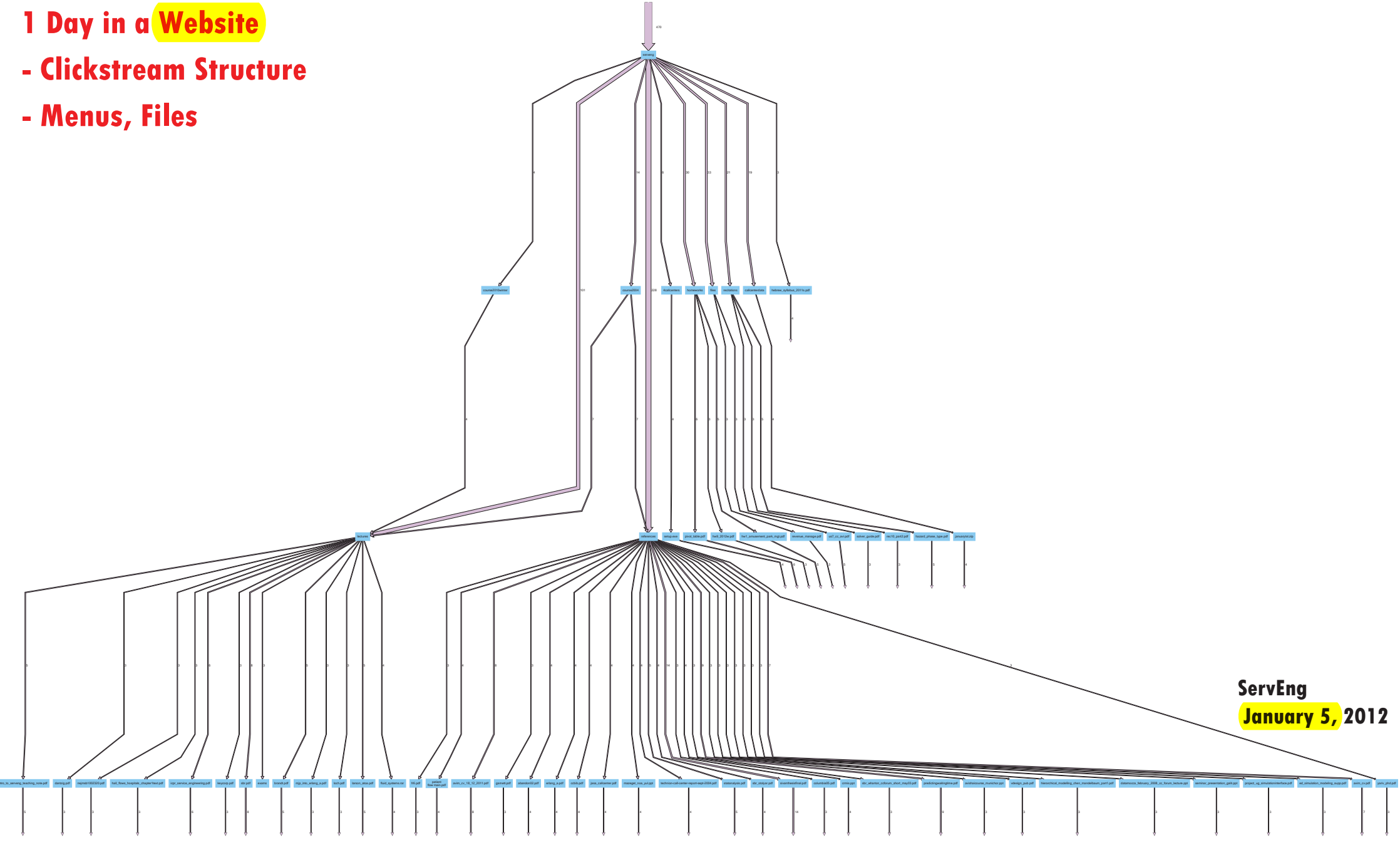


Zoom In: Server Network
- 1 Day
- 1 Agent
- Activities + Queues



1 Day in a Website

- Clickstream Structure
- Menus, Files



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ADULT ACUTE
G2850
G2852
G2854
G2856
G2858
G2860
G2860A
G2864
G2862
G2848
G2846
G2844
G2866
G2868
G2870
G2872
G2874
G2876
G2878
G2831A
G2831
G2832
G2839
G2839A
G2842
G2830
G2849
G2855
G2857
G2859
G2861
G2863
G2865
G2841
G2885
G2883
G2880
G2881
G2873
G2840
G2840A
G2822
G1810
G1812
G1811
G1800
G1809
G1808
G1806
G1807
G1805
G1803
G1768A
G1768
G1766
G1764
G1760
G3902
G3808
G3806
GSMH38
TRAUMA
G3802A
G3802G
G3802
G3802B
G3802F
G3802C
G3802E
G3802D
G3830
G3801
G3710H
G3710
G3710D
G3710F
G3710G
G3710C
G3710B
G3710A
G3710E
G3712
G3700
G2702A
G2702
G2898
G2802
G2894
G2892
G2804
G2806
G2808
G2814
G2888
G2821
G2812
G2819
PEDS
G2803
G2817
G2805
G2810
G2807
G2809
G2811
G2813
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G2800B
G2800C
G1757
G1755
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G2882
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G1710A
G1736
G1732
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G1707
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G1735
G1750
G1710
G1706
G1737
G1705
G1741
G1747
G1745
G1743
G1714
G1703
G1718
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G1751
G1729
GSMH36
G2703
GSMH33
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G1723
G1721
G1719
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G1715
G1713
G1711
G1702
G1720
G1700
FAMILY EXPRESS
G1700B

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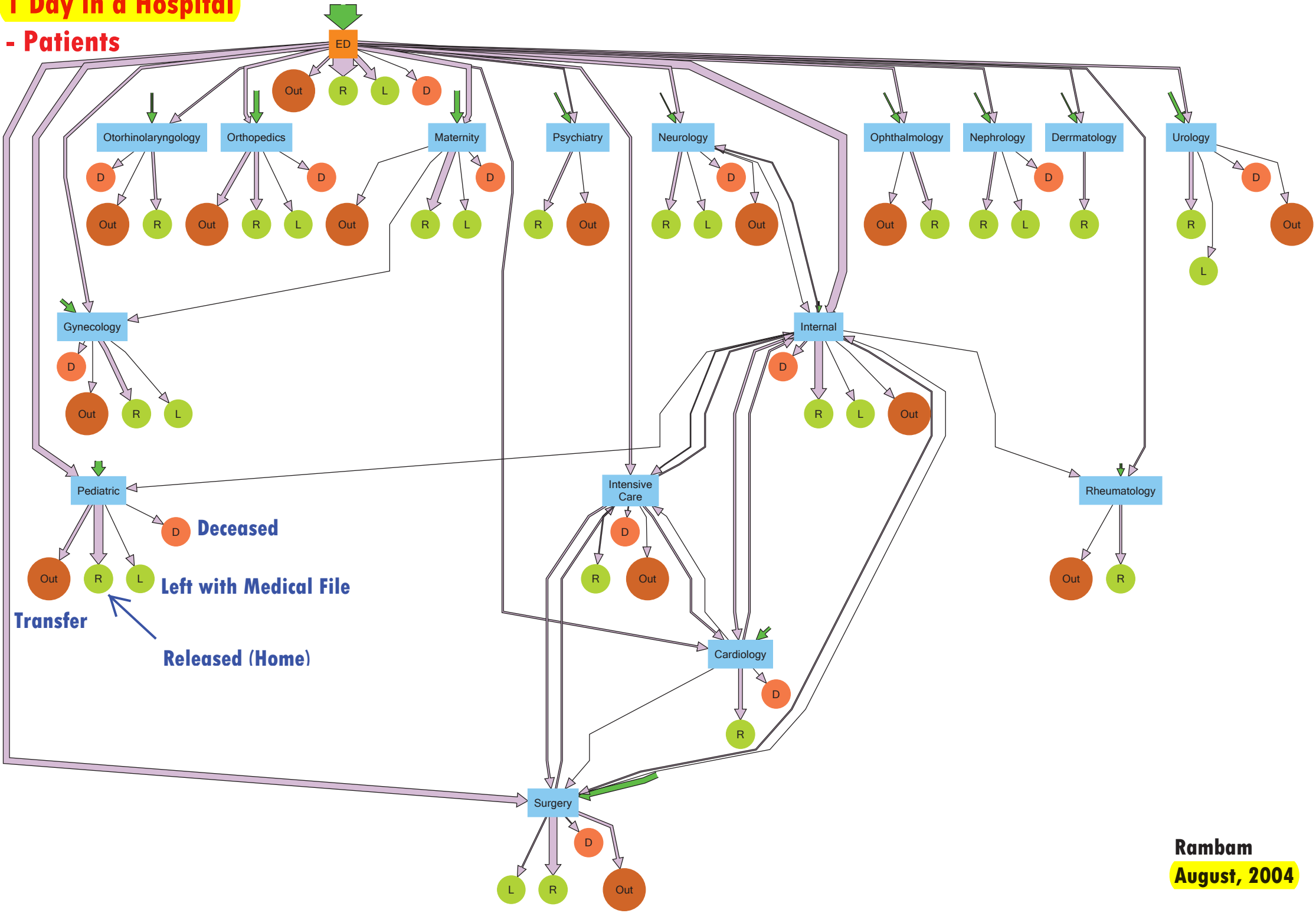
1 Day in a Hospital
- Patients

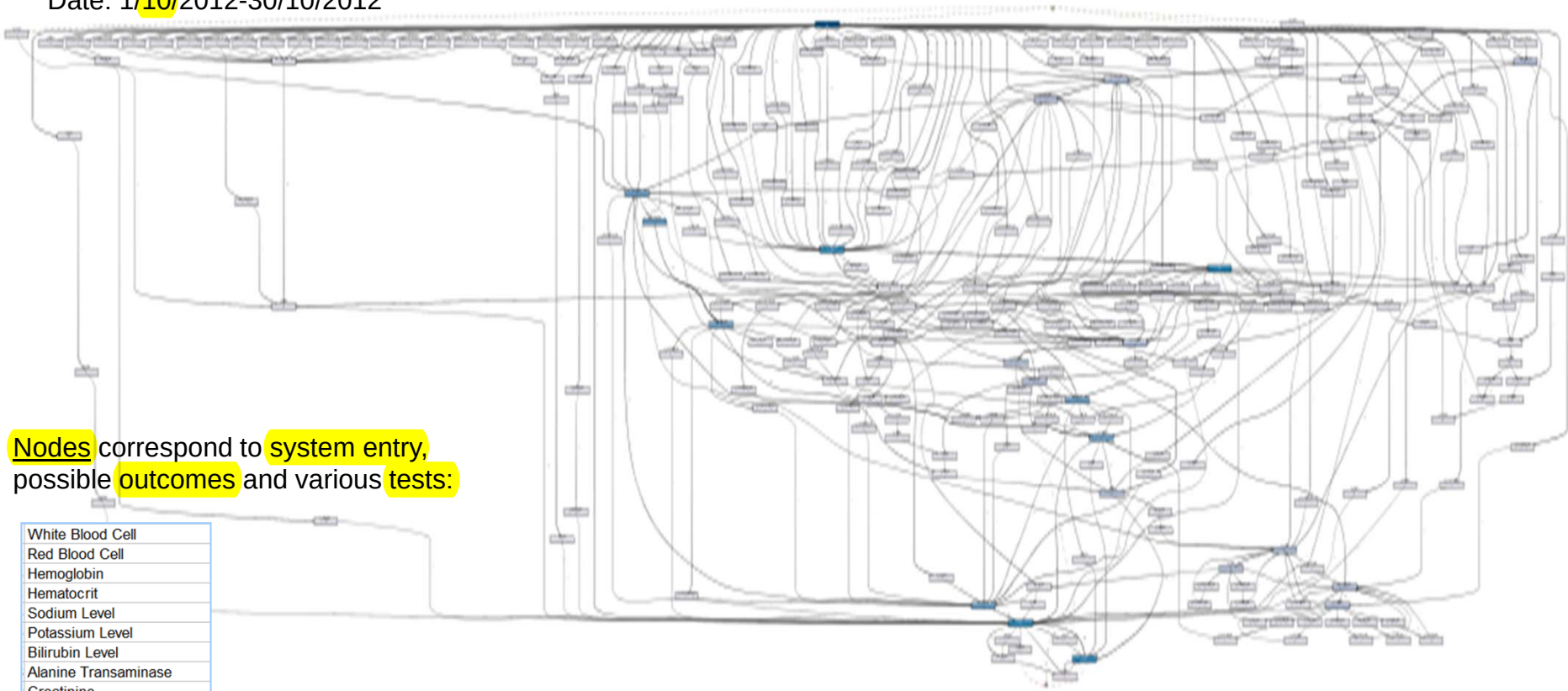


Rambam

August, 2004

SKHospital, all patients – Spaghetti Network

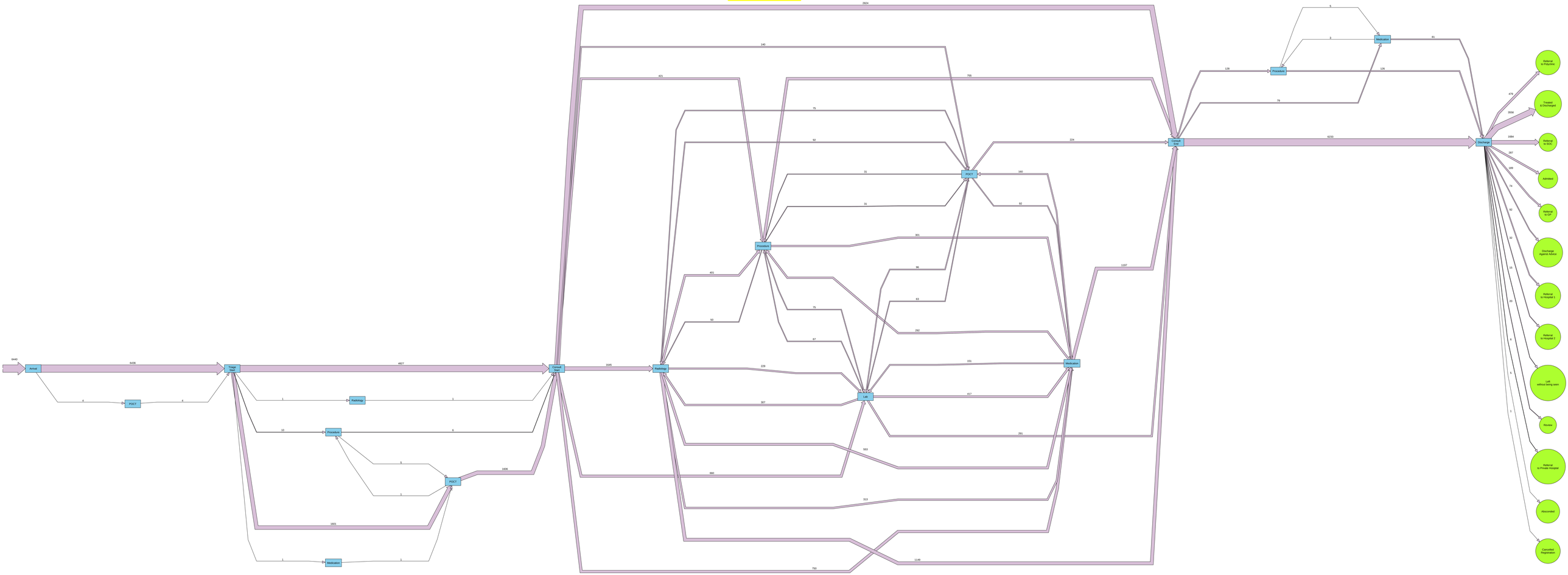
A flowchart of patients in a hospital.
Date: 1/10/2012-30/10/2012

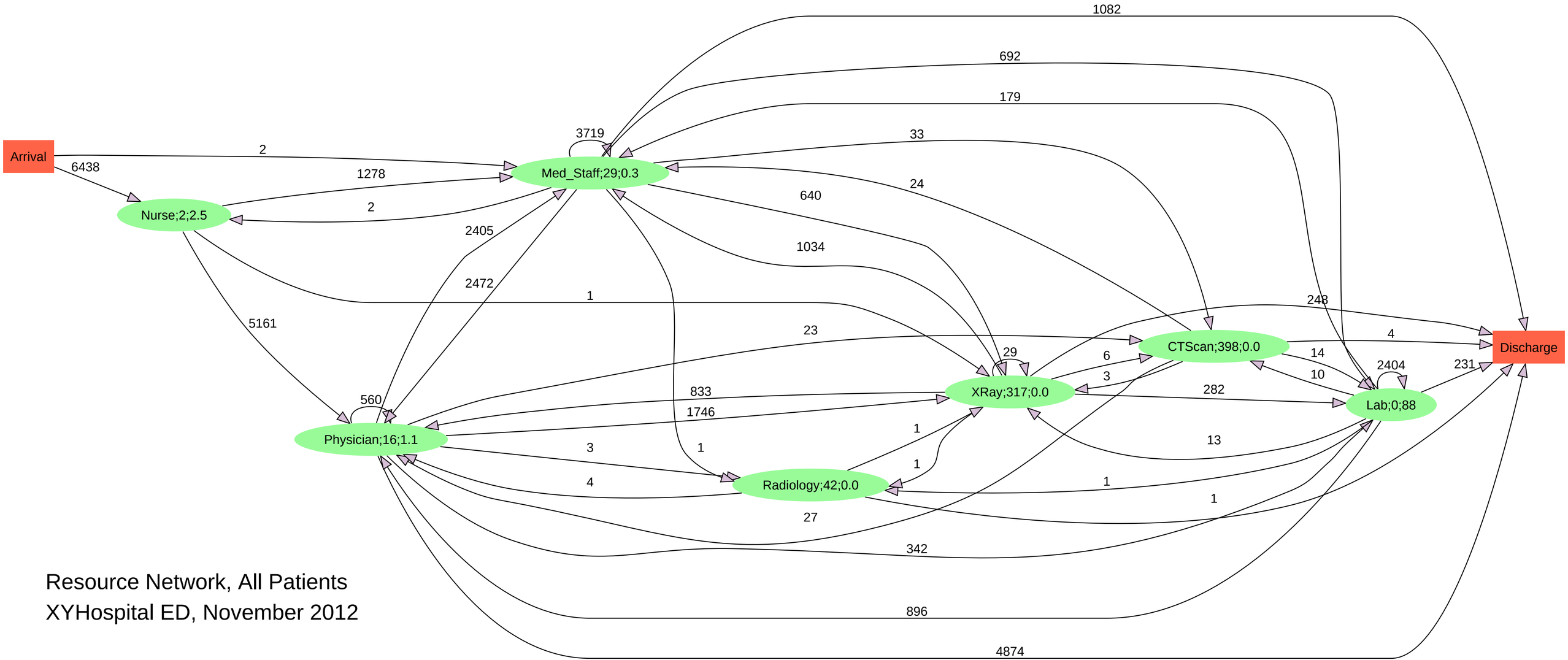


Nodes correspond to system entry, possible outcomes and various tests:

White Blood Cell
Red Blood Cell
Hemoglobin
Hematocrit
Sodium Level
Potassium Level
Bilirubin Level
Alanine Transaminase
Creatinine
D-Dimer

Patients flow (XYHospital)
November 2012





Resource Network, All Patients
XYHospital ED, November 2012

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Operationally,
CC ≈ ED
in many ways
(but not all)

Service Engineering: Multi-Disciplinary Process View

Call Center Design

Index
- Function
- Scientific Discipline
- Multi-Disciplinary

Service Completion
(75% in Banks)

Information Design
Marketing, Operations Research
(← Waiting Time
↔ Return Time)

Organization Design:
Parallel (Flat)
Sequential (Hierarchical)
Sociology, Psychology, Operations Research

Operations/ Business Process Archive
Database Design
Data Mining: MIS, Statistics, Operations Research, Marketing

Lost Calls

Redial
(Retrial)

Busy
(Rare)
Good or Bad

Arrivals
(Business Frontier of the 21th Century)

Queue
(Invisible)

Agents

Experts

Job Enrichment Training
HRM

Tele-Stress
Psychology
(Turnover up to 200% per Year)
(Sweat Shops of the 21th Century)

Computer-Telephony Integration - CTI
MIS/CS

Incentives
Game Theory, Economics

Service Completion

VRU/ IVR

Agents (CSRs)

Internet
Chat
Email
Fax

Forecasting
Statistics, Human Resource Management (HRM)

Efficiency

Skill Based Routing (SBR) Design
Marketing, HRM, Operations Research, MIS

Psychological Process Archive
Expect 3 min
Willing 8 min
Perceive 15 min
(If Required 15 min, then Waited 8 min)
(If Required 6 min, then Waited 8 min)

Customers Segmentation - CRM
Marketing

Quality

Customers Interface Design
Human Factors Engineering

VIP Queue

VIP
(Training)

Back-Office

Service Process Design
Operations Research, Economics, HRM

Logistics

Psychology, Operations Research, Marketing

Abandonment
Psychology, Statistics
Lost Calls

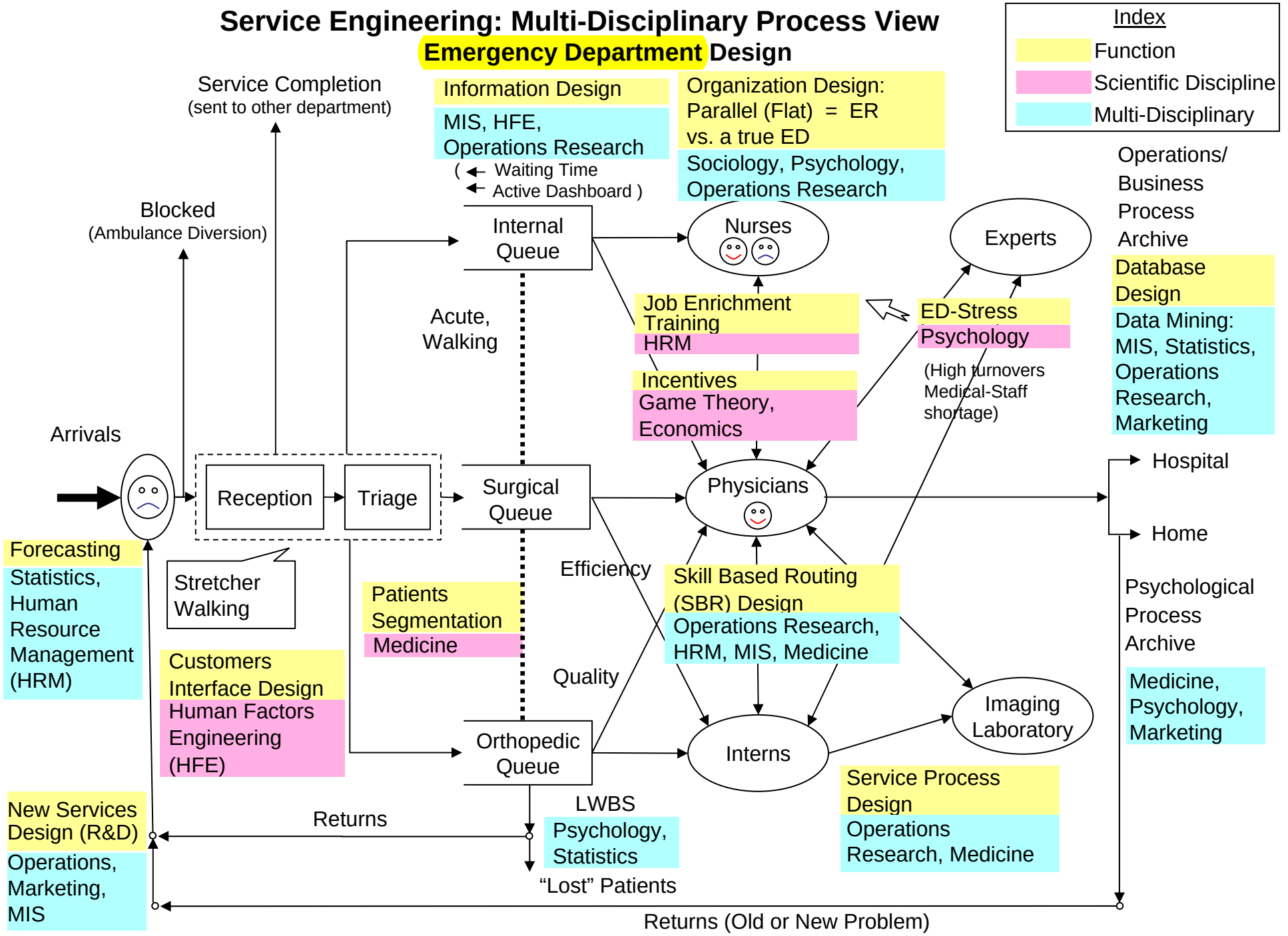
Redial

New Services Design (R&D)
Operations, Marketing, MIS

Positive: Repeat Business
Negative: New Complaint

Service Engineering: Multi-Disciplinary Process View

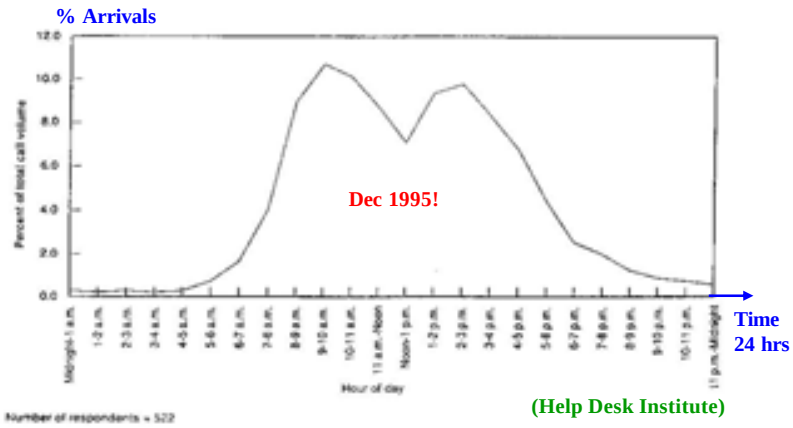
Emergency Department Design



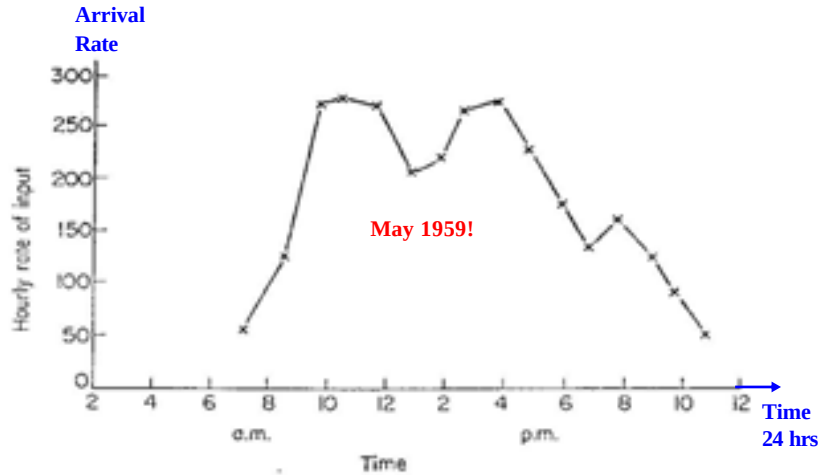
Dynamics: Time-Varying Arrival-Rates

2 Daily Peaks

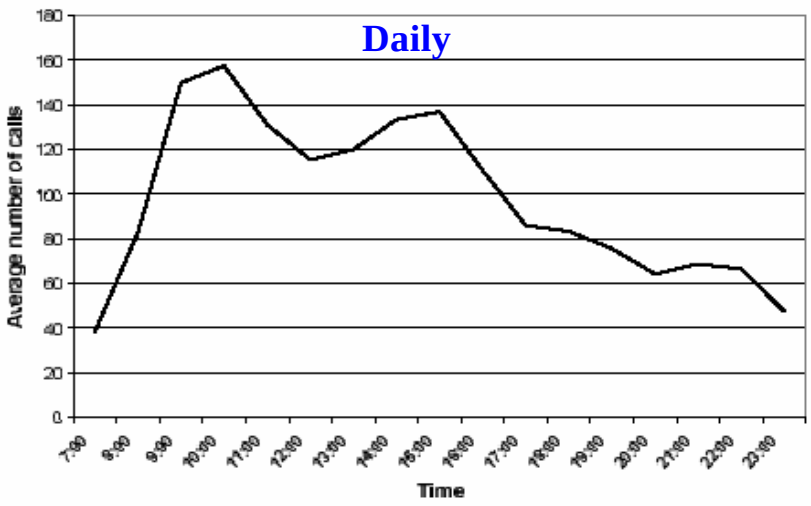
CC: Dec. **1995**, (USA, 700 Helpdesks)



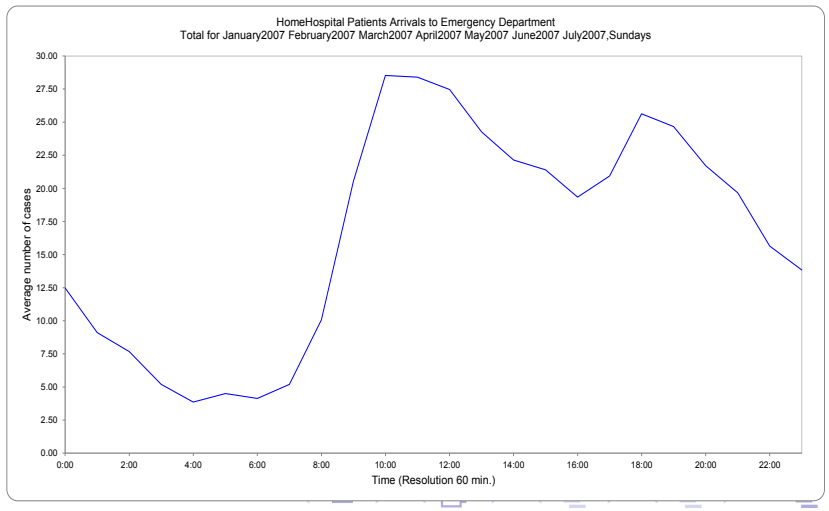
CC: May **1959** (England)



CC: Nov. 1999 (Israel)



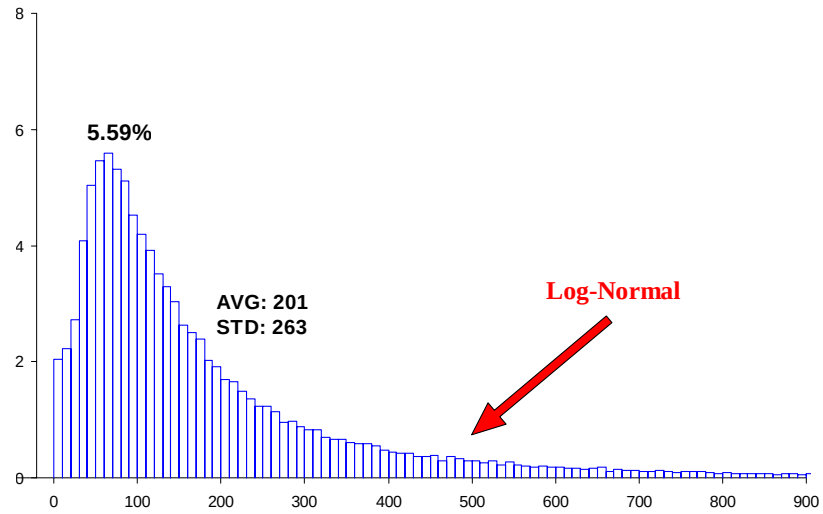
ED: Jan.–July 2007 (Israel)



Beyond Averages: The Human Factor

Histogram of Service-Time in an Israeli Call Center, 1999

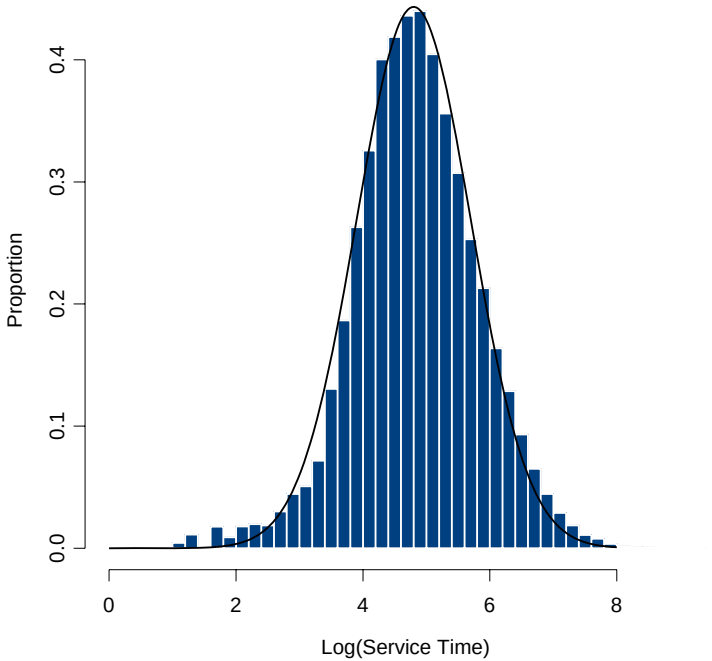
November-December



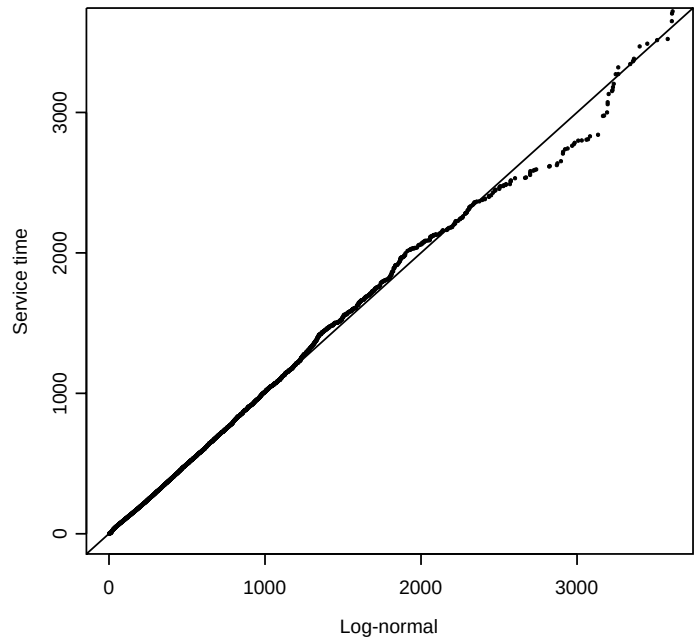
Durations: Phone Calls (2 Surprises)

Israeli Call Center, Nov–Dec, 1999

Log(Service Times)



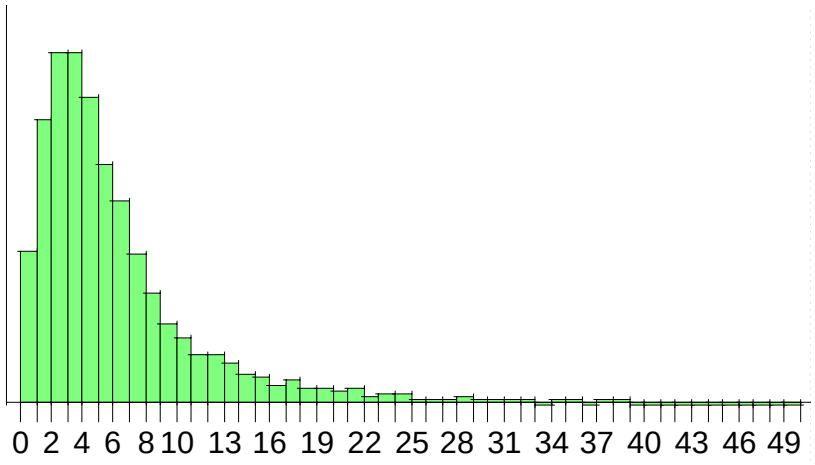
LogNormal QQPlot



- **Practically Important**: (mean, std)(log) characterization
- **Theoretically Intriguing**: Why LogNormal ? Naturally multiplicative but, in fact, also **Infinitely-Divisible** (Generalized Gamma-Convolutions)

LogNormal & Beyond: Length-of-Stay in a Hospital

Israeli Hospital, in Days: LN

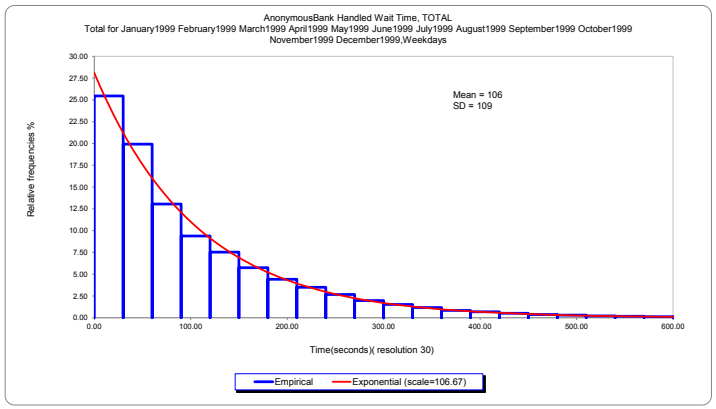


Durations: Waiting Times in a Call Center

$\Rightarrow$ Protocols

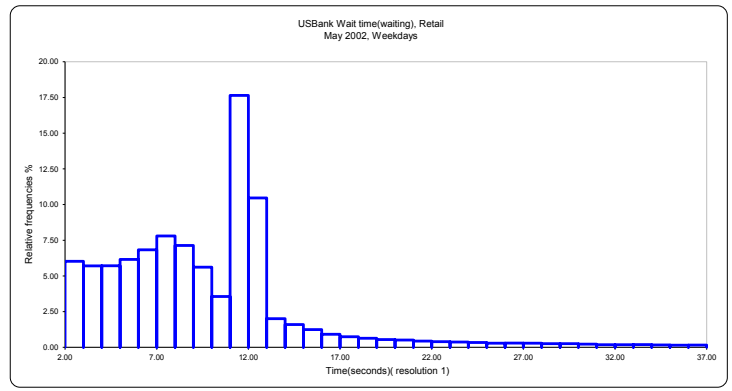
Exponential in Heavy-Traffic (min.)

Small Israeli Bank



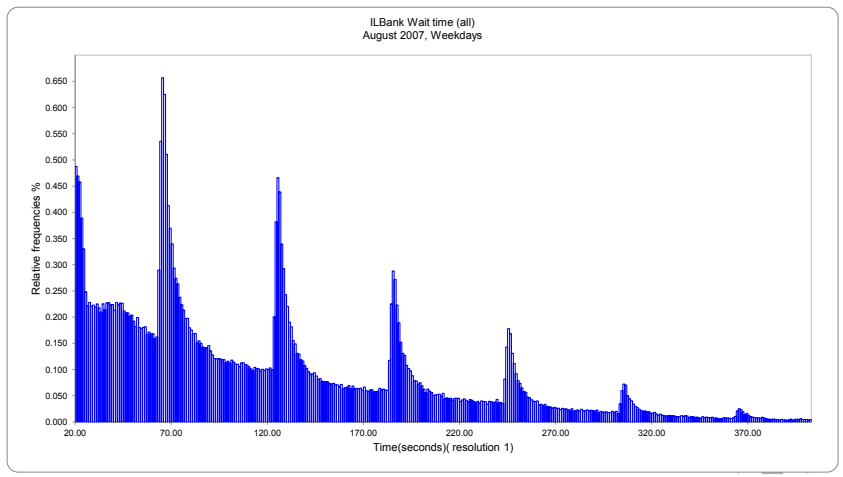
Routing via Thresholds (sec.)

Large U.S. Bank



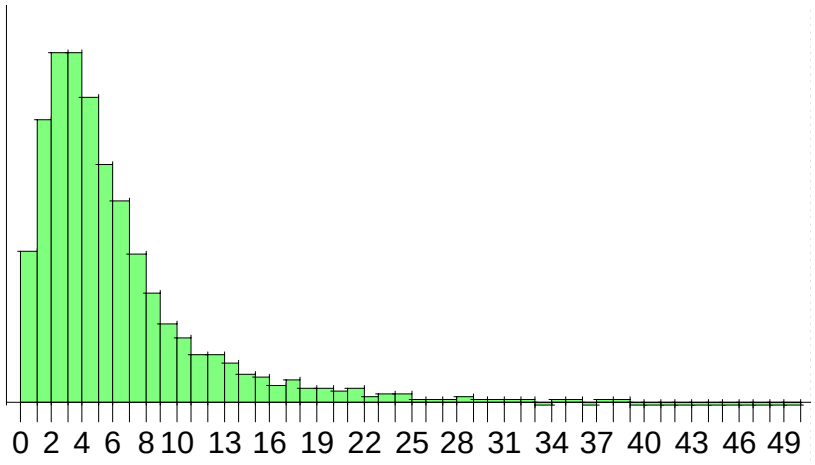
Scheduling Priorities (sec.) [compare Hospital LOS (hours)]

Medium Israeli Bank

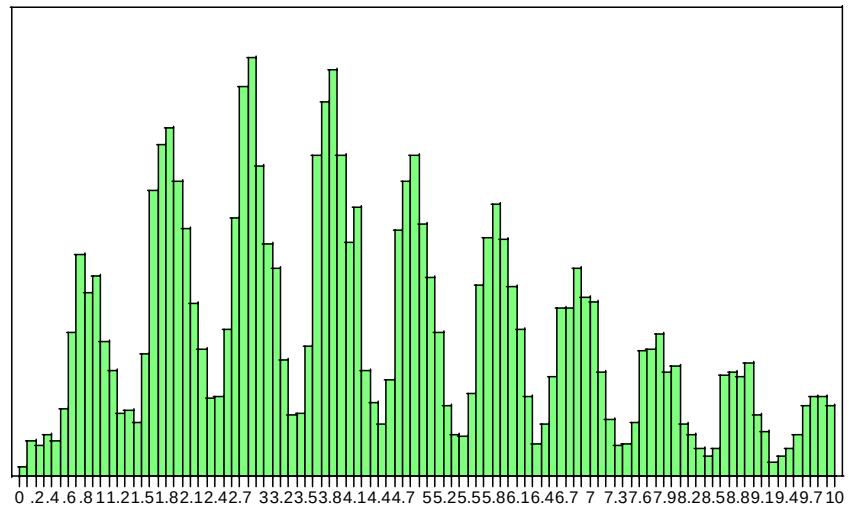


LogNormal & Beyond: Length-of-Stay in a Hospital

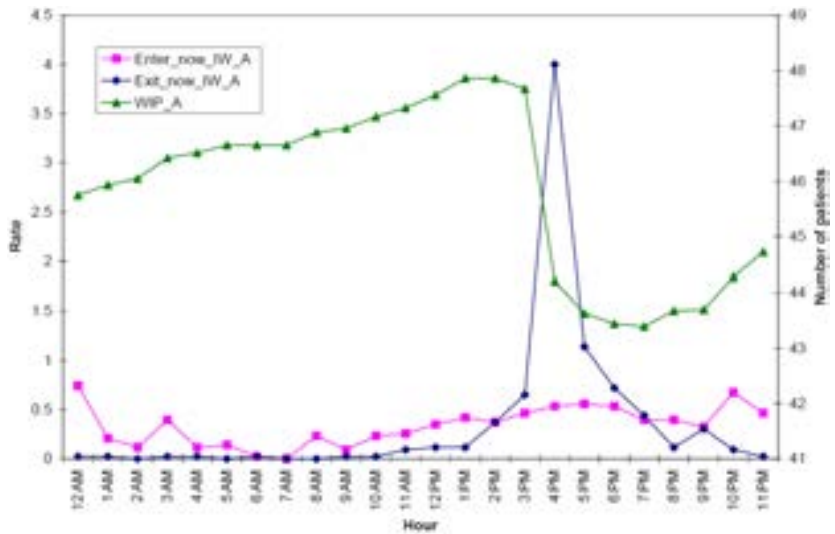
Israeli Hospital, in Days: LN



In Hours: 2 Time Scales, Mixture



Explanation: Patients released around **3pm** (2-3 in Singapore, 2-4 in UNC Hospital)



Why Bother ?

- Hourly Scale: Staffing,. . .
- Daily: Flow / Bed Control,. . .

Skills-Based Routing in Call Centers

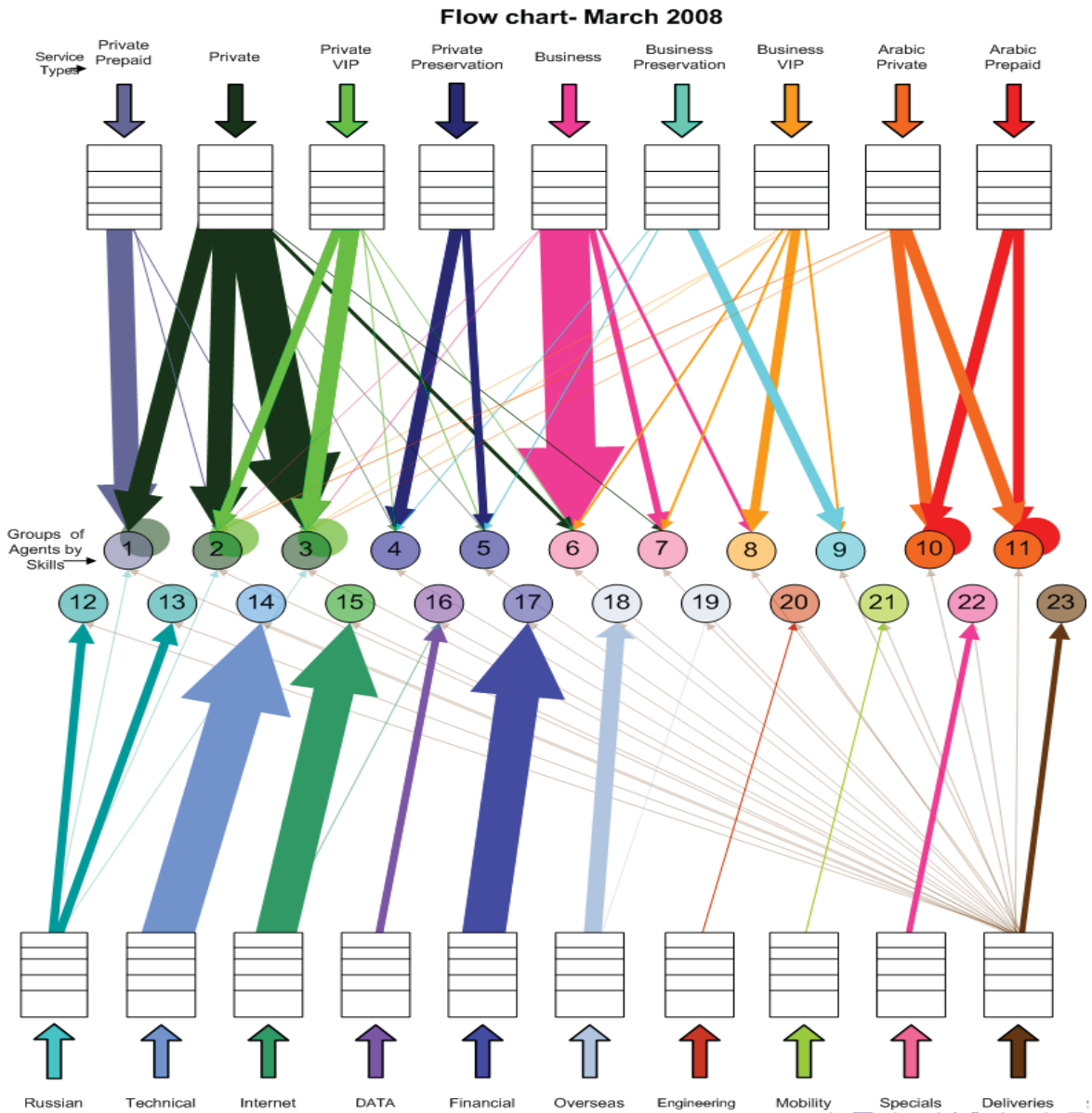
EDA and OR, with I. Gurvich and P. Lieberman

Mktg. ⇒

OR ⇒

HRM ⇒

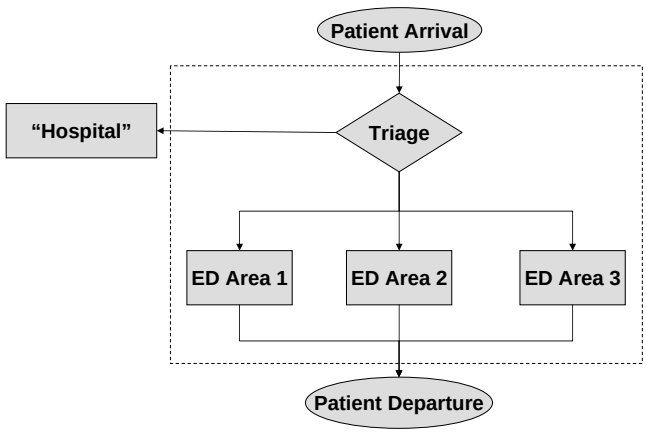
MIS ⇒



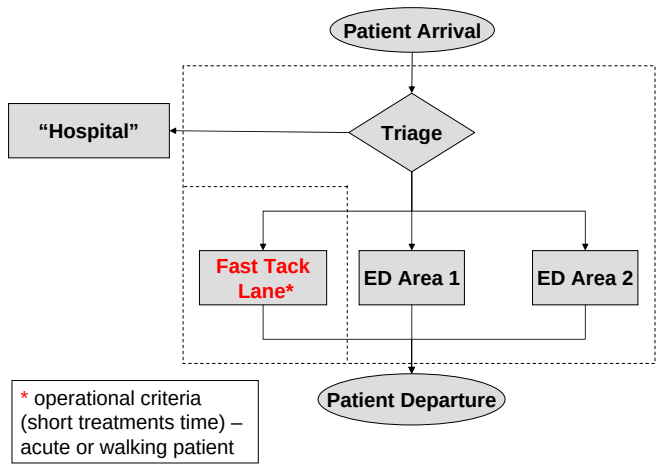
ED Design, with B. Golany and Y. Marmor (PhD)

Routing: Triage (Clinical), Fast-Track (Operational), . . . (via DEA)

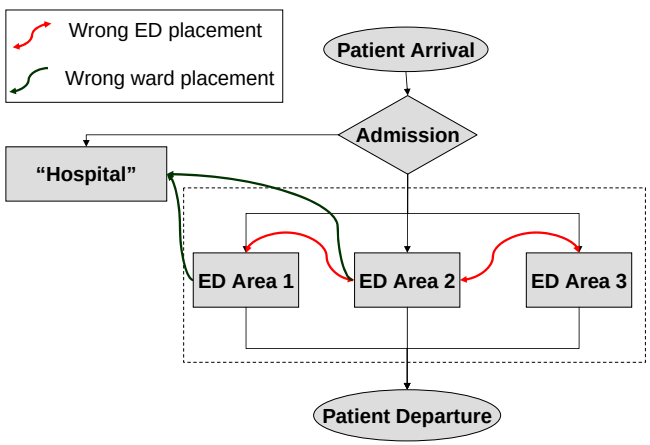
e.g. Fast Track most suitable when elderly dominate



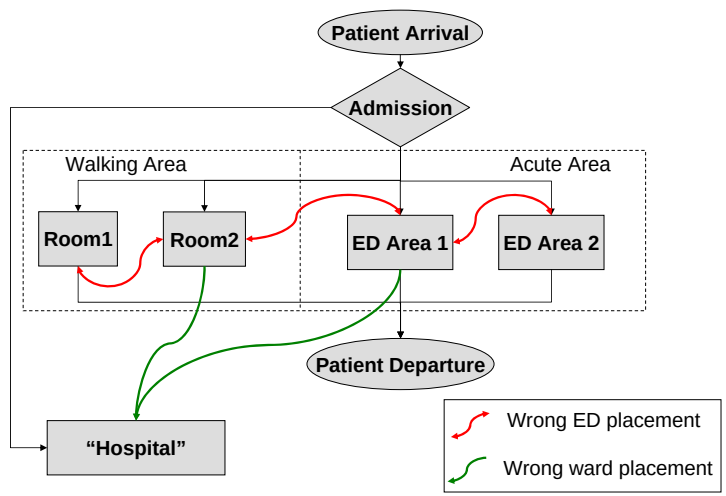
(a) Triage Model



(b) Fast-Track Model



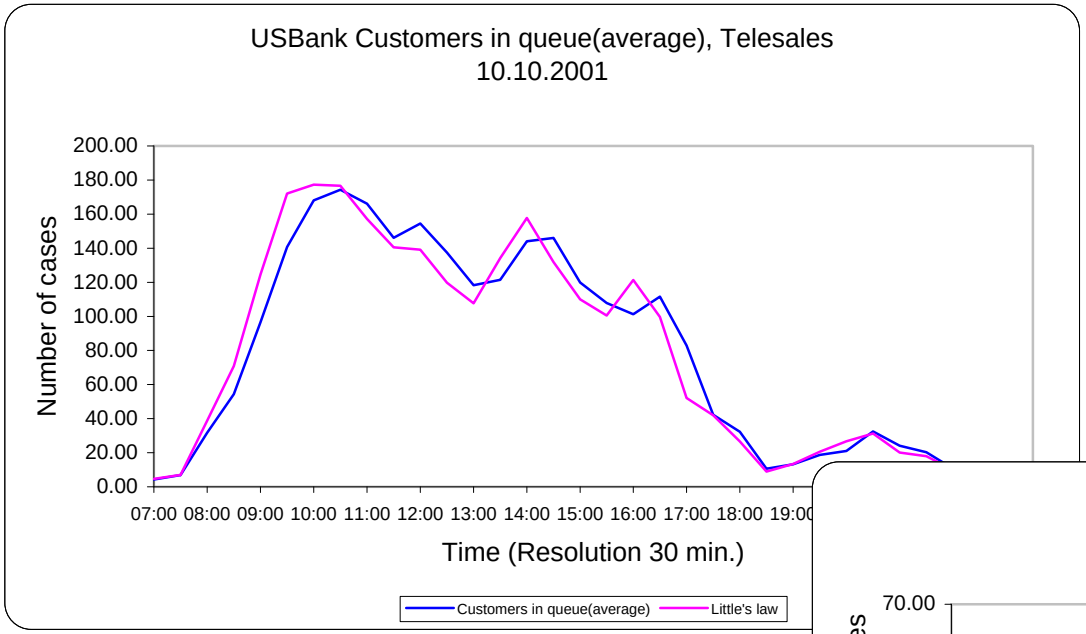
(c) Illness-based Model

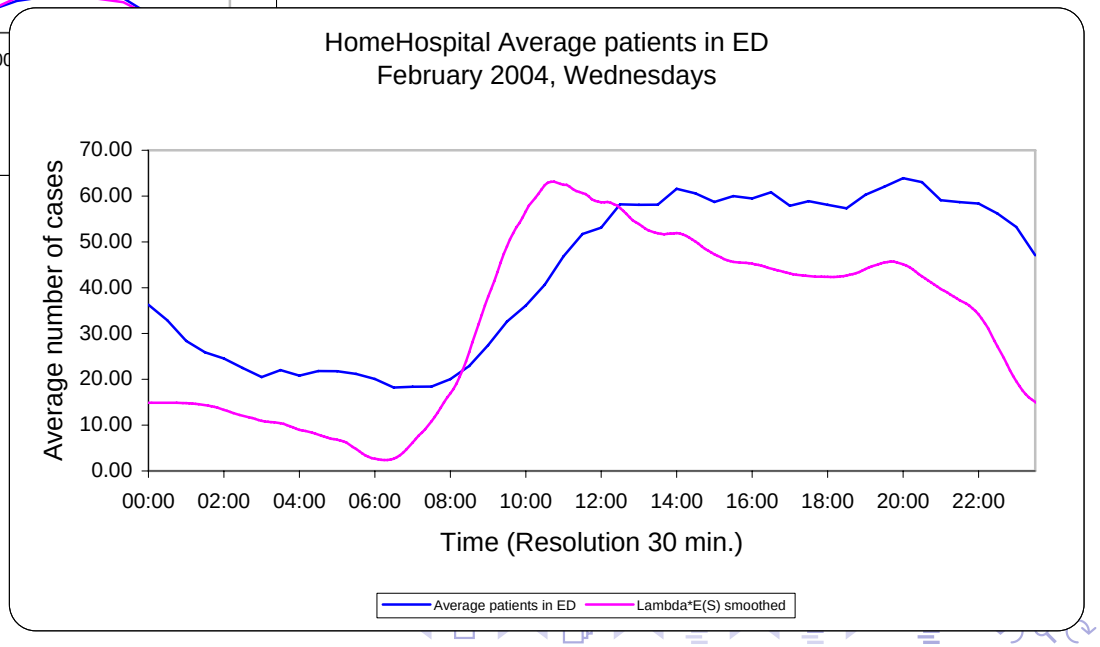


(d) Walking-Acute Model

Little's Law: Call Center ≠ Emergency Department

Time-Gap: **# in System** lags behind **Piecewise-Little** ($L = \lambda \times W$)





$\Rightarrow$ **Time-Varying Little's Law**

$$EL(t) = \tilde{\lambda}(t) \times EW,$$

(Later)

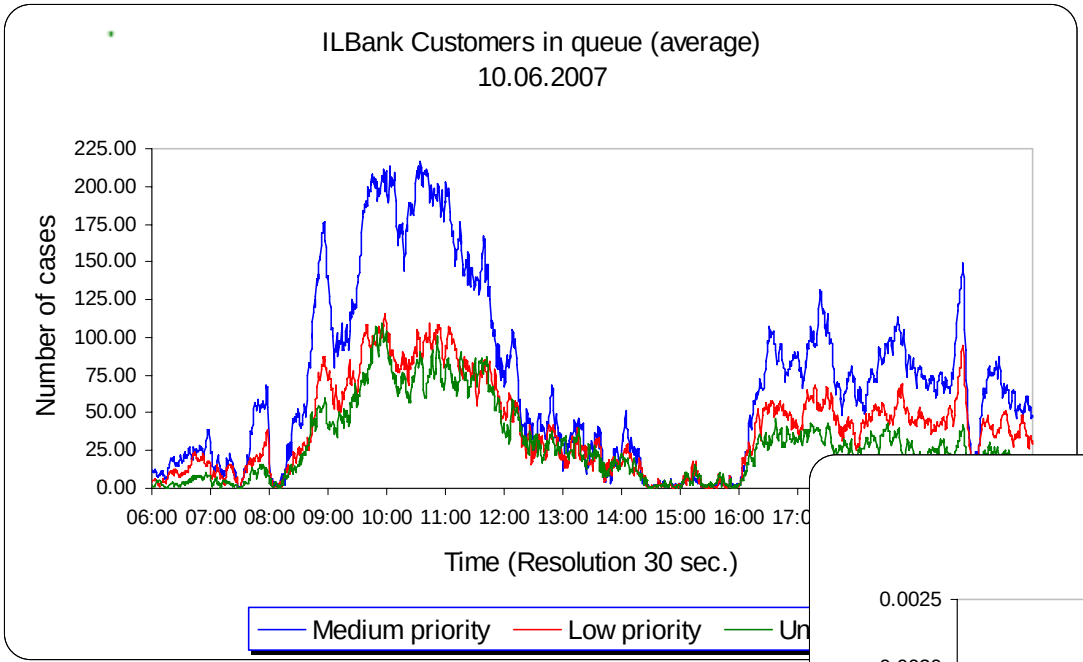
$$\tilde{\lambda}(t) = E\lambda(t - W_e).$$

(Bertsimas & Mourtzinou;
Fralix, Riano, Serfozo; ...)

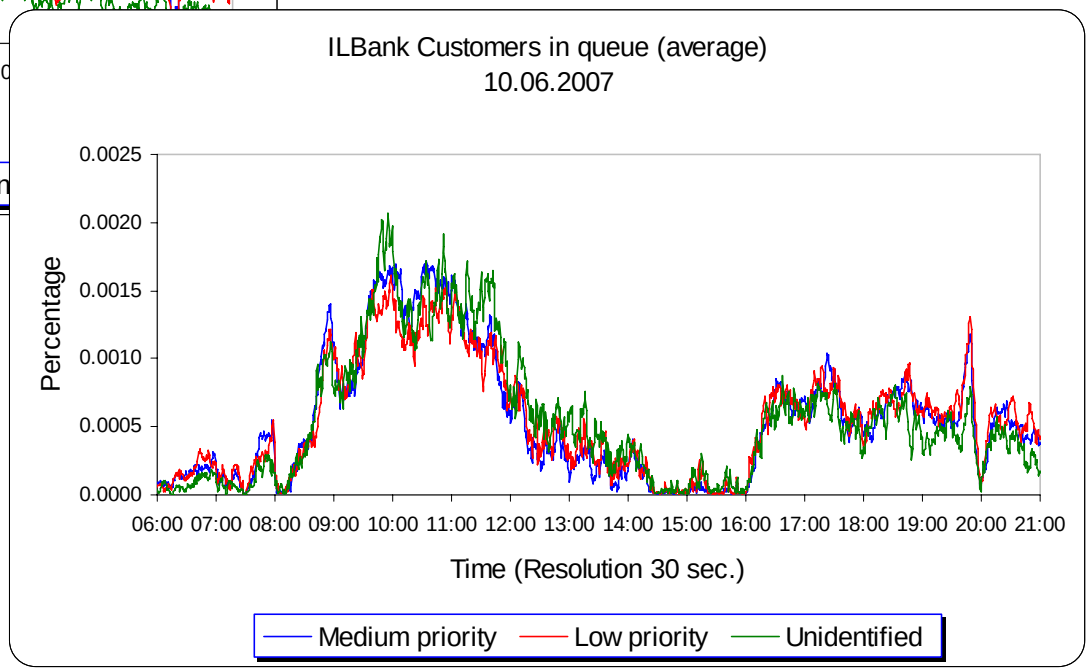
Why Hope for Simple Models ?

Dynamics: Parsimonious Models (Congestion Laws)

3 Queue-Lengths at 30 sec. resolution (ILBank, 10/6/2007)



Queue "Shape"



- Area normalized to 100%
- **State-Space Collapse**