

On Data-Based (Operations) Research, or Empirical Adventures in Call Centers, Hospitals, . . .

Avishai Mandelbaum, Technion IE&M (visiting **SAMSI**)

Jim Dai's Markov Lecture

INFORMS, October 2012

References: **TQM** (80's), **BPR** (90's), **CRM** (00's), **B[A+D]** (10')

Main Messages

1. **Simple Models** at the Service of **Complex Realities**.

ServNets = FNets, QNets, DNets, SimNets

2. **Data-Based** Research & Teaching: Fun, Must, Challenging

Technion SEELab = Online Open EDA Environment

3. (Human) Complexity + Data $\Rightarrow$ redefine the Role of Models

- **"All Models Born Equal"**

- "Confidence Interval": Saving Lives, Making Money, Playing Games

- Classical Research Paradigm: Medicine, Finance, My OR Childhood)

4. **Ultimate Goal:**

**Data-based creation, validation and application of ServNets,
automatically in real-time**

Address the Reproducibility & Proprietary crisis in scientific research

5. **Challenges**: Individuals ("old", young), Universities, Societies (INFORMS), Science (OR/OM)

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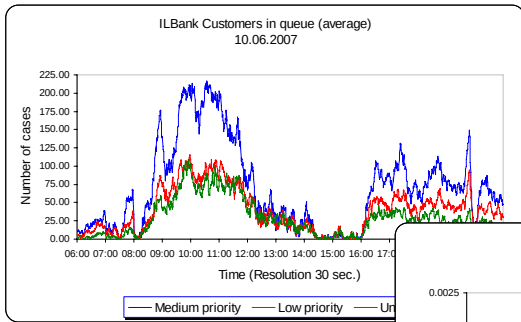
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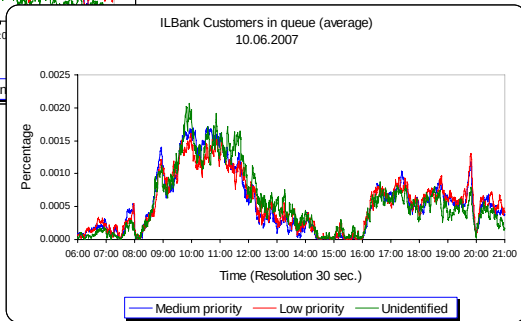
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Dynamics: Parsimonious Models (Congestion Laws)

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



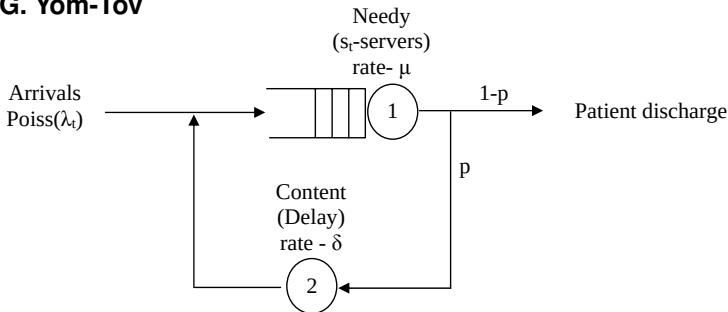
Queue "Shape"



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

The Basic Service-Network Model: Erlang-R

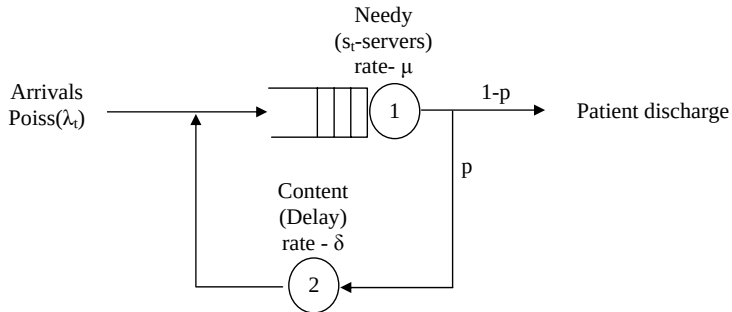
w/ G. Yom-Tov



Erlang-R (IE: Repairman Problem 50's; CS: Central-Server 60's) =
2-station "Jackson" Network = (M/M/S, M/M/ ∞) :

- ▶ λ_t – **Time-Varying** Arrival rate
- ▶ S_t – Number of **Servers** (Nurses / Physicians)
- ▶ μ – **Service** rate ($E[\text{Service}] = \frac{1}{\mu}$)
- ▶ p – **ReEntrant** (Feedback) fraction
- ▶ δ – **Content-to-Needy** rate ($E[\text{Content}] = \frac{1}{\delta}$)

Fluid Model $\leftrightarrow$ (Time-Varying) Erlang-R System



FNet of a 2-station "Jackson" Network:

$$\begin{aligned} \frac{d}{dt} q_t^1 &= \lambda_t - \mu \cdot (q_t^1 \wedge s_t) + \delta \cdot q_t^2, \\ \frac{d}{dt} q_t^2 &= p \cdot \mu \cdot (q_t^1 \wedge s_t) - \delta \cdot q_t^2. \end{aligned} \tag{1}$$

An Asymptotic Framework: Erlang-R in the ED

System = Emergency Department (eg. Rambam Hospital)

- ▶ **SimNet** = Customized ED-Simulator (Marmor & Sinreich)
- ▶ **QNet** = Erlang-R (time-varying 2-station Jackson; w/ **Yom-Tov**)
- ▶ **FNets** = 2-dim dynamical system (Massey & Whitt)
- ▶ **DNets** = 2-dim Markovian Service Net (w/ Massey and Reiman)

Prerequisite: Data

At the level of the **Individual Transaction**:

For each service transaction (during a phone-service in a call center, or a patient's visit in a hospital, or browsing in a website, or . . .), its **operational history** = time-stamps of events (events-log files).

Sources: **"Service-floor"** (vs. Industry-level, Surveys, . . .)

- ▶ **Administrative** (Court, via "paper analysis")
- ▶ **Face-to-Face** (Bank, via bar-code readers)
- ▶ **Telephone** (Call Centers, via ACD / CTI, IVR/VRU)
- ▶ **Hospitals** (Emergency Departments, via RFID, EPIC)
- ▶ **Internet** (Websites, via clickstreams)

Expanding:

Operational + Financial + Contents (Marketing, Clinical)

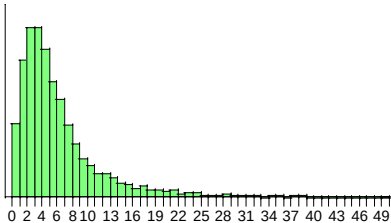
The Technion SEE Center / Laboratory

Data-Based Service Science / Engineering / Management

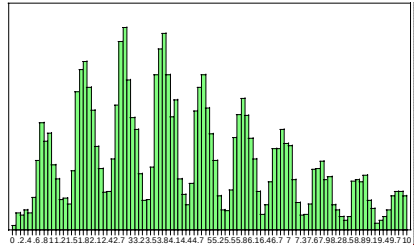


LogNormal & Beyond: Length-of-Stay in a Hospital

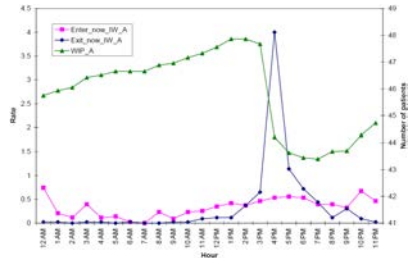
Israeli Hospital, in Days: LN



Israeli Hospital, in Hours: Mixture



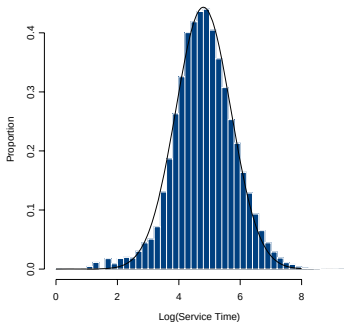
Explanation: Patients released around **3pm** (1pm in Singapore)



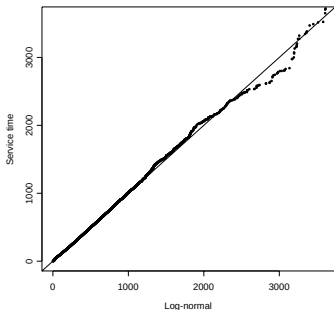
Durations: Phone Calls (2 Surprises)

Israeli Call Center, Nov–Dec, 1999

Log(Service Times)



LogNormal QQPlot



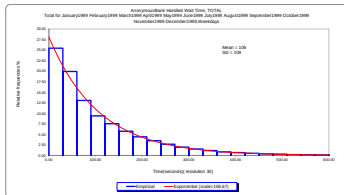
- ▶ **Practically Important:** (mean, std)(log) characterization
- ▶ **Theoretically Intriguing:** Why LogNormal ? Naturally multiplicative but, in fact, also **Infinitely-Divisible** (Generalized Gamma-Convolutions)

Durations: Waiting Times in a Call Center

⇒ Protocols

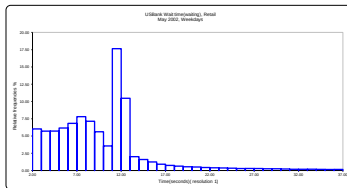
Exponential in Heavy-Traffic (min.)

Small Israeli Bank



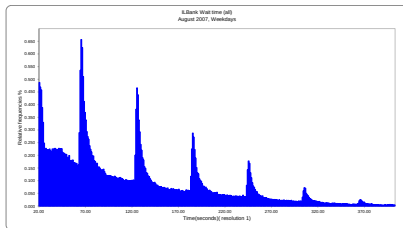
Routing via Thresholds (sec.)

Large U.S. Bank



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

Medium Israeli Bank



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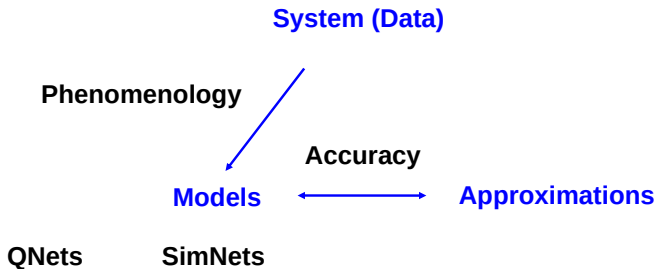
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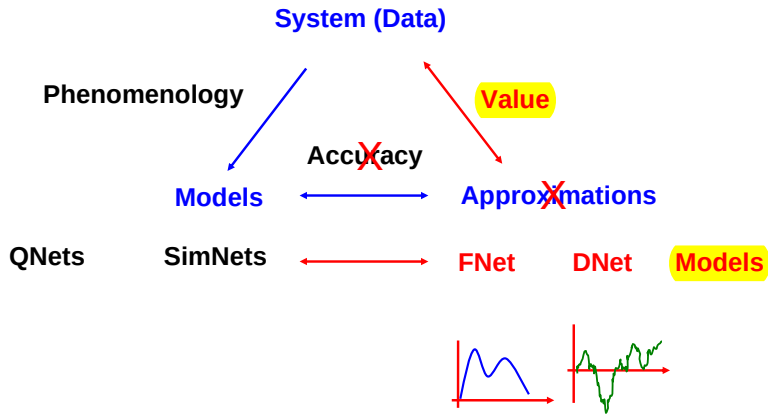
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Prevalent Asymptotic Approximations



Data-Based ~~Prevalent~~ Asymptotic ~~Approximations~~ Models



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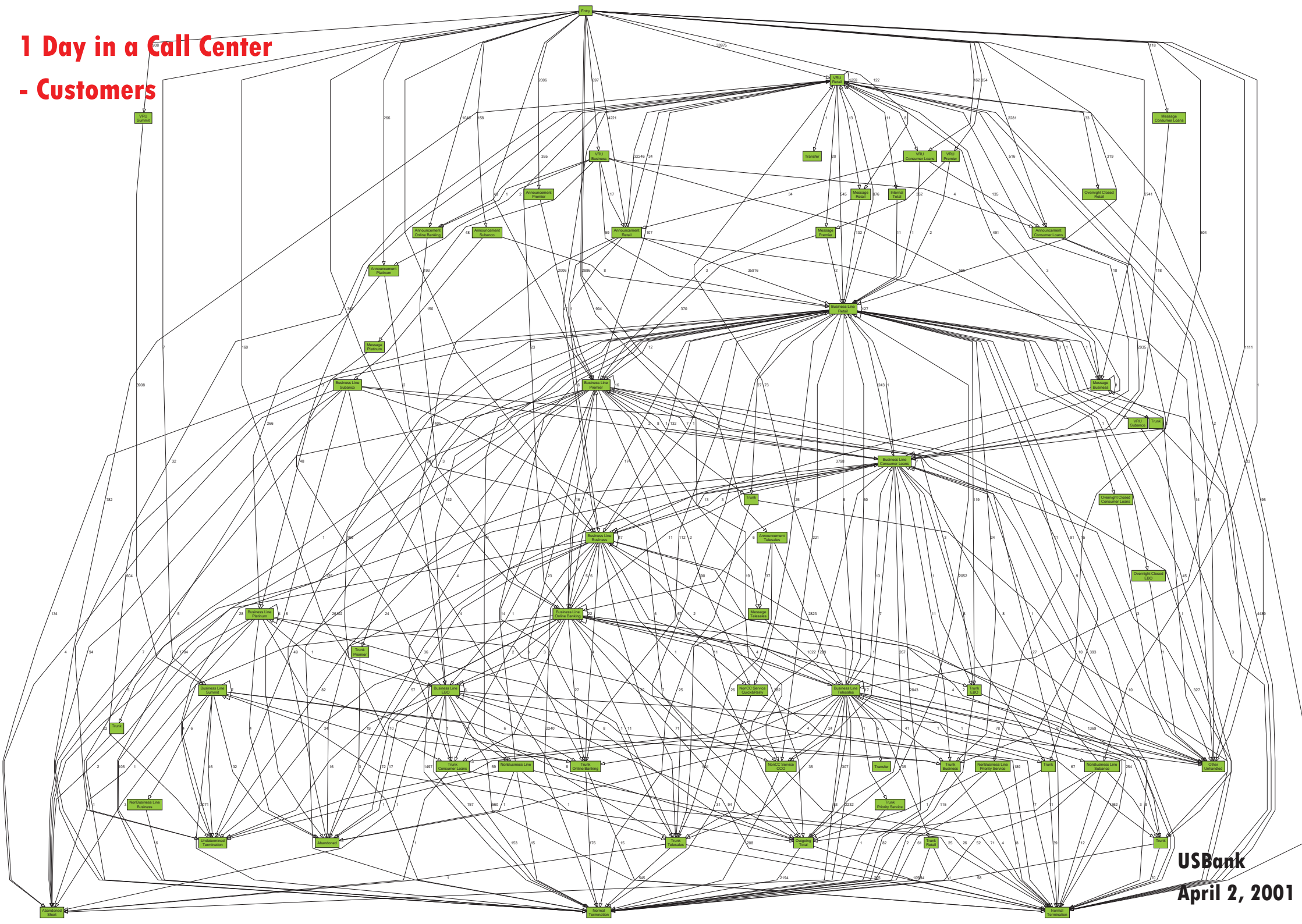
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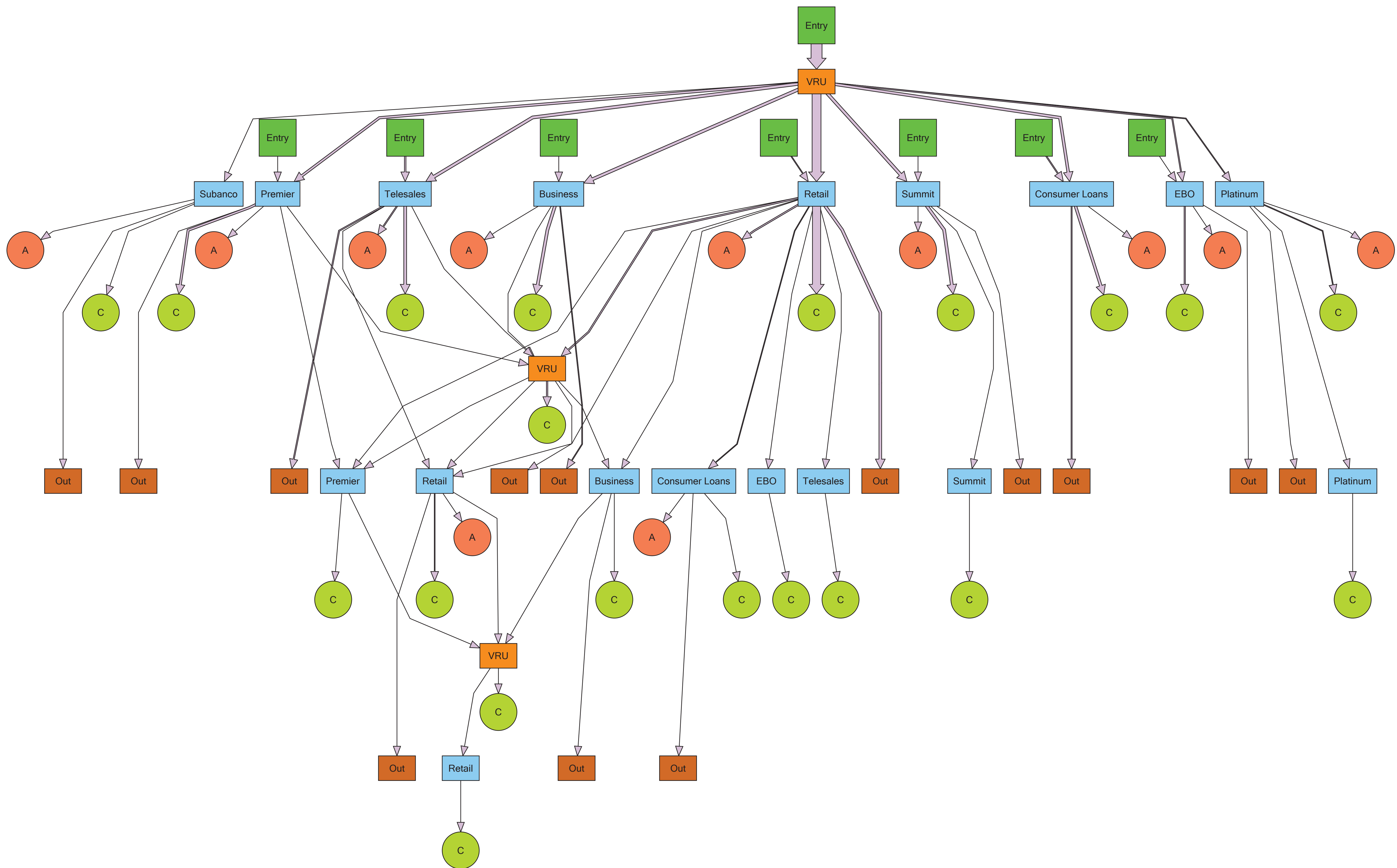
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1 Day in a Call Center - Customers

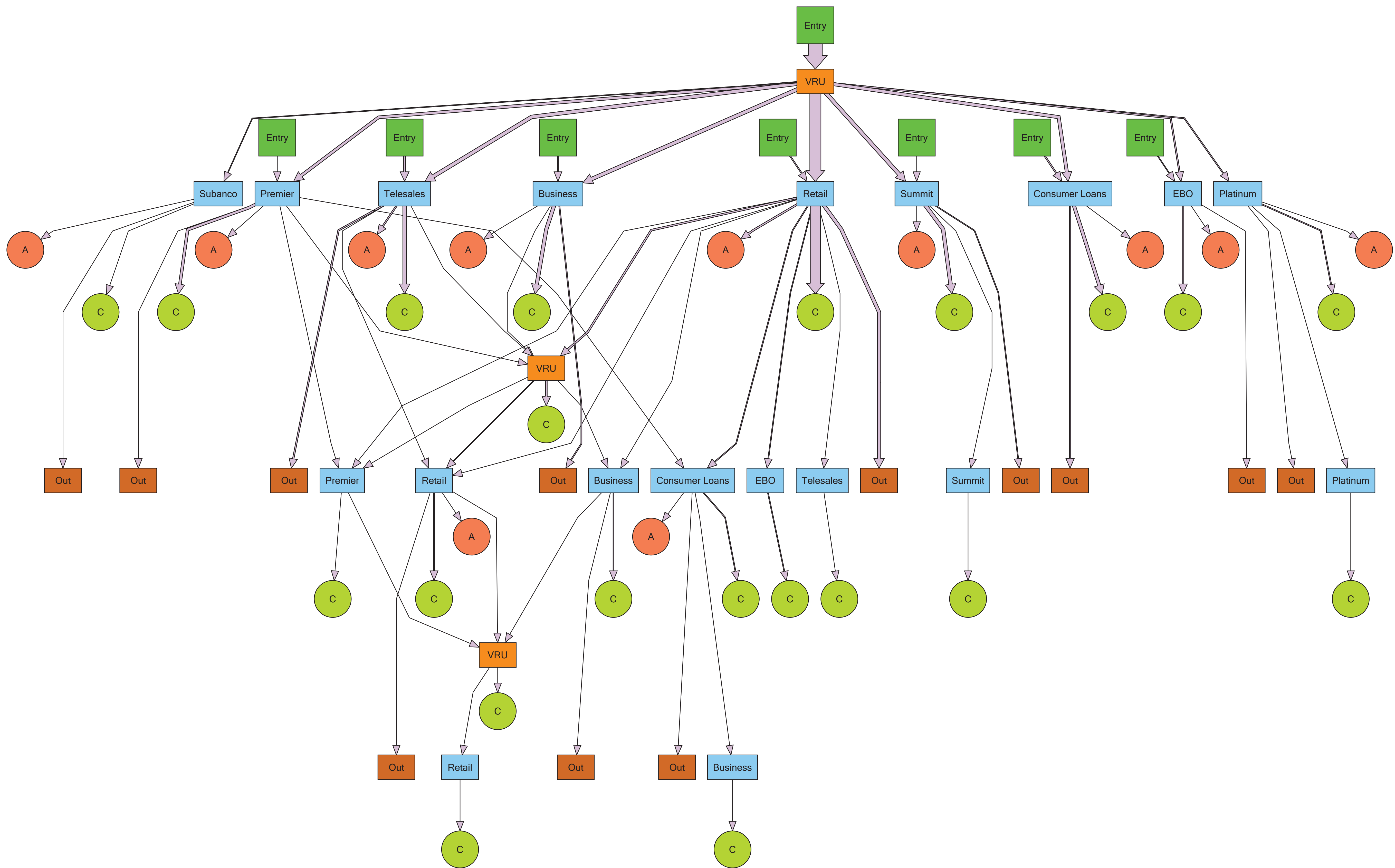


USBank
April 2, 2001



8 AM - 9 AM

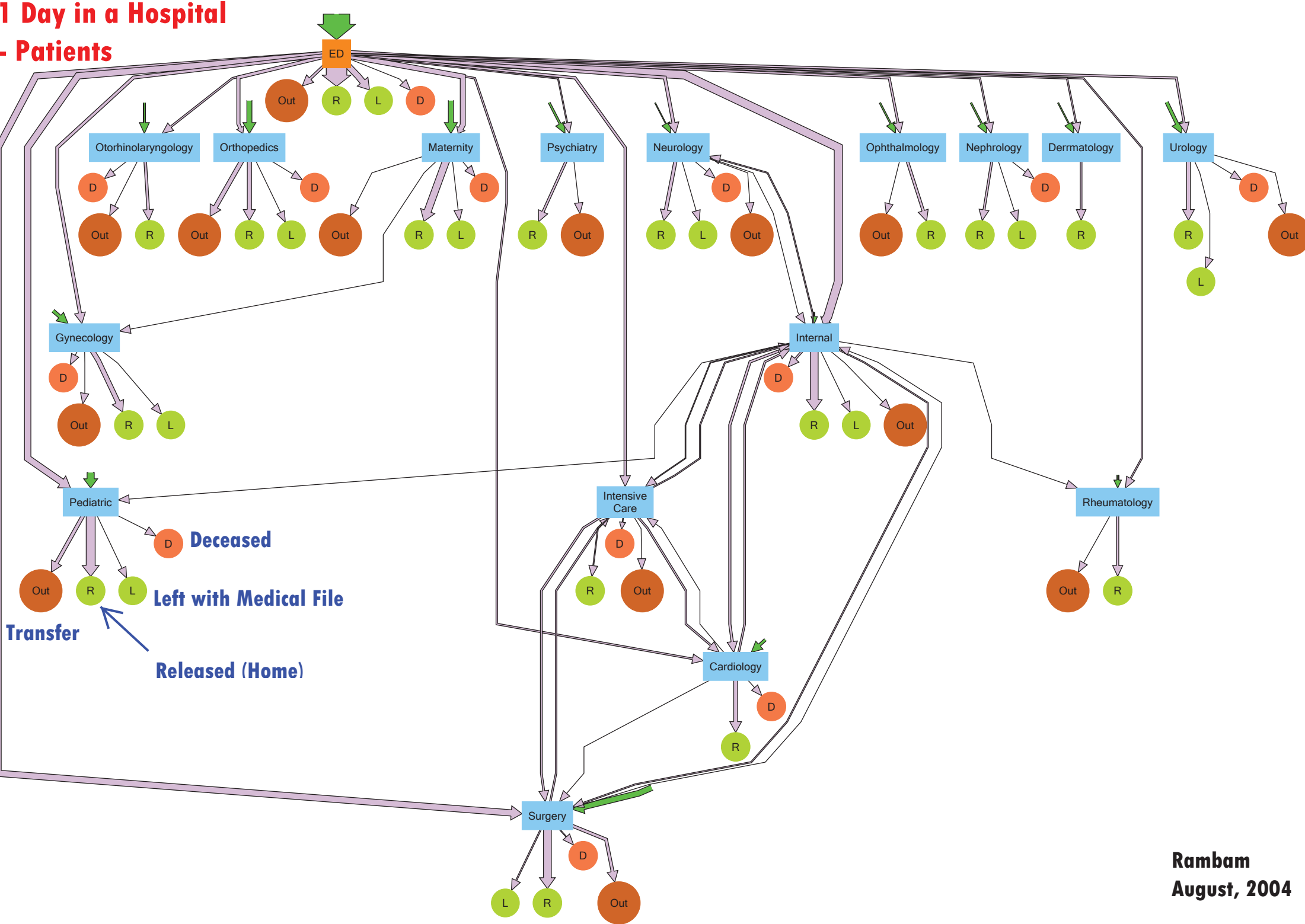




9 AM - 10 AM

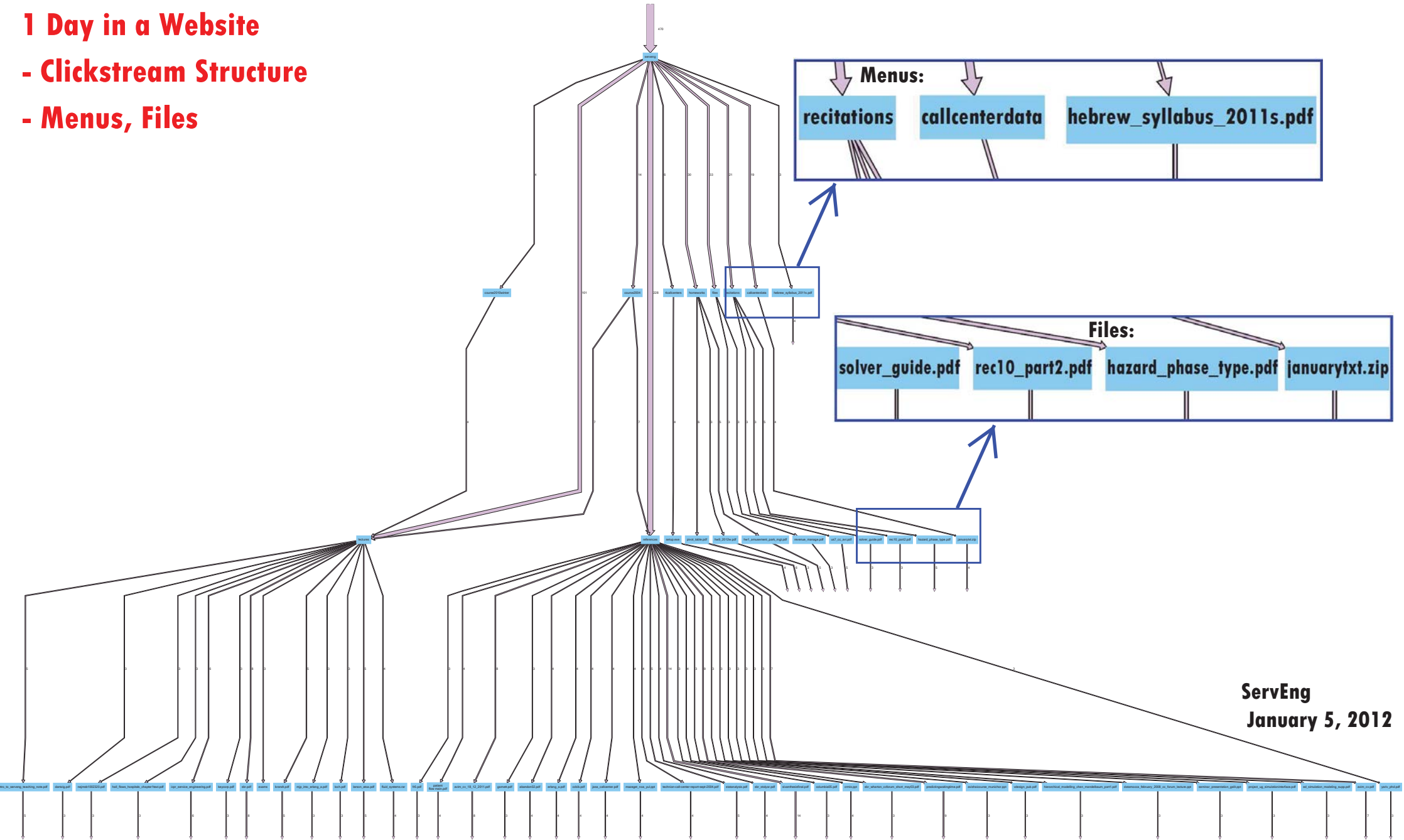


1 Day in a Hospital
- Patients



1 Day in a Website

- Clickstream Structure
- Menus, Files



Challenges and how to Address Them

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- ▶ **Universities**: **Research Labs**, offering universal access to data, ServNets and their analysis, directly or indirectly via simulation (Virtual Realities, Proprietary Barrier); already starting with "Big-Data" (eg. OMOP); eg. **SEELab**, helps the Young
- ▶ **Societies**: **Fund** these labs (neither basic-research nor applications), and publish empirical adventures, but condition on reproducibility; eg. Armony et al
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- ▶ **Data-based Research:** Tradition in Physics, Biology, Medicine, Economics, Psychology, Management
- ▶ **Why not in Service Science & Engineering ?**