Dynamic Provisioning of Multi-tier Internet Applications

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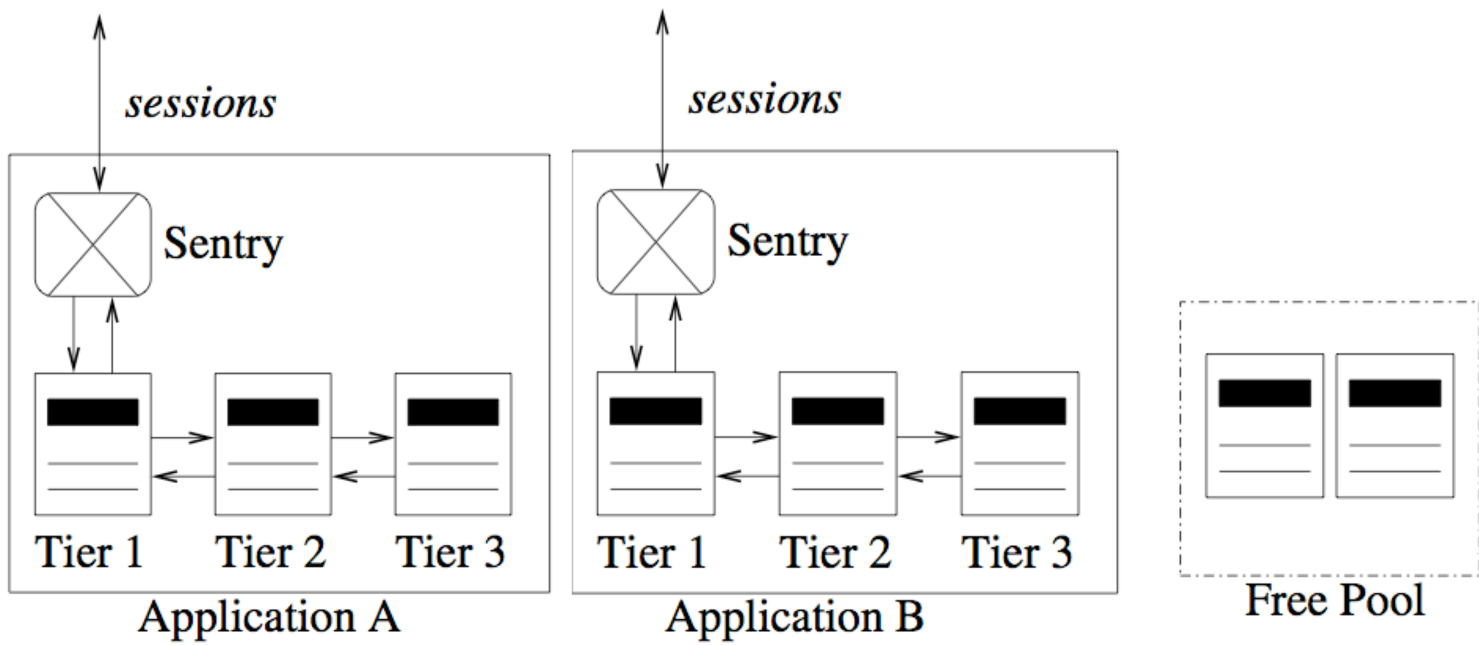
Outline

- The problem
- Baseline approaches
- Dynamic provisioning of n-tier systems
- Experimental evaluation
- Discussion

The Problem

- Dynamically provision ***servers*** among n-tier applications to meet ***response time*** requirements

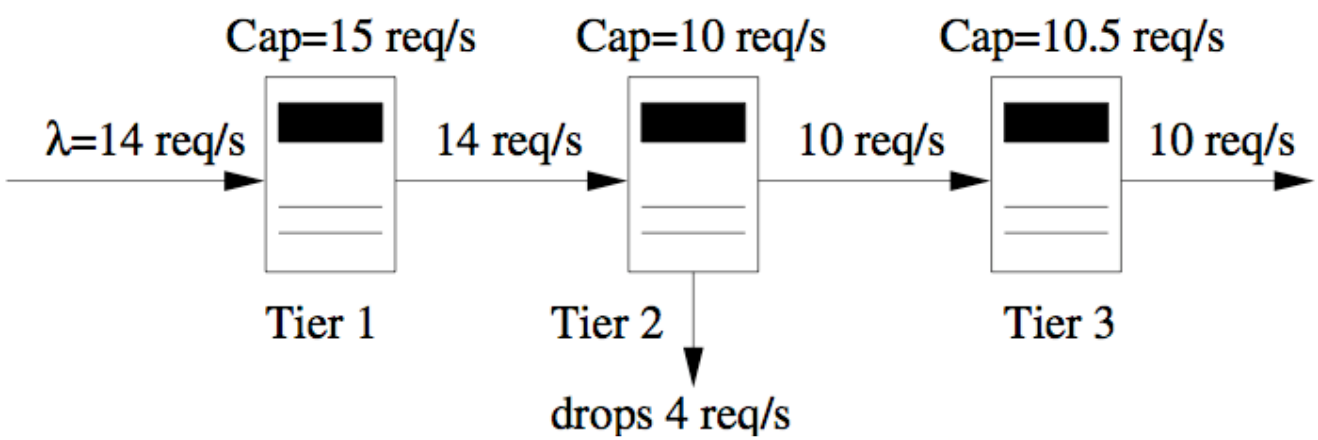


Baseline Approaches

- Idea: Use single tier provisioning approaches on the n-tier system
  - Scale individual tiers separately
  - Treat all n-tiers as a black box and scale together

Baseline: scale individual tiers

- Identify bottleneck tier and increase provisions to that tier



Baseline: scale individual tiers

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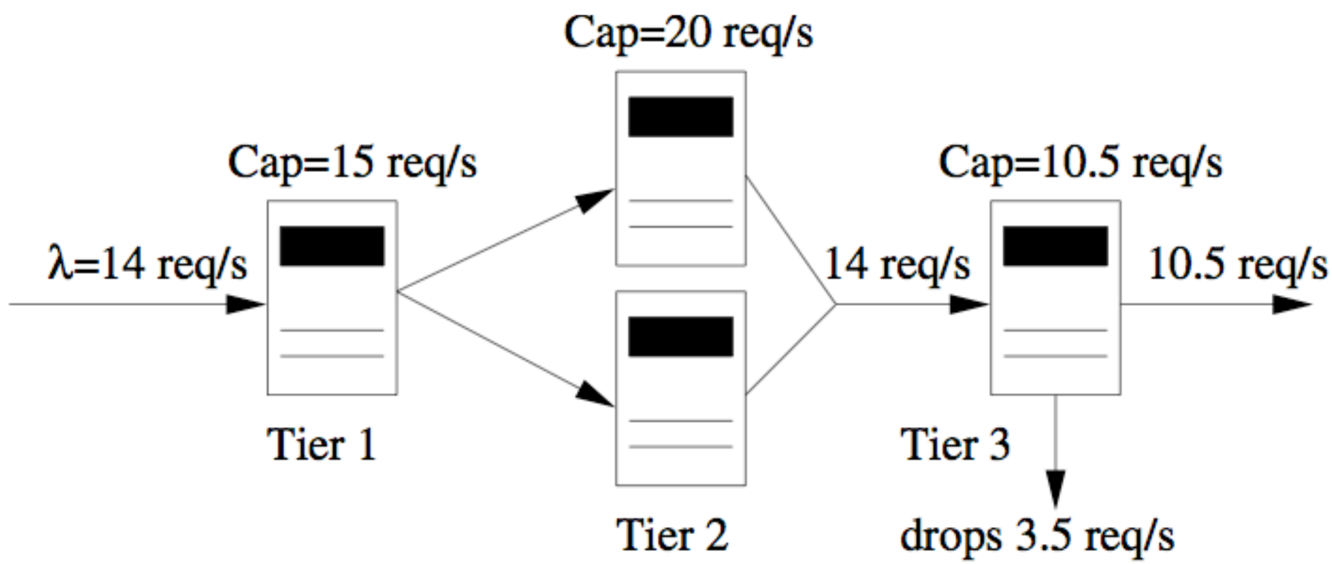
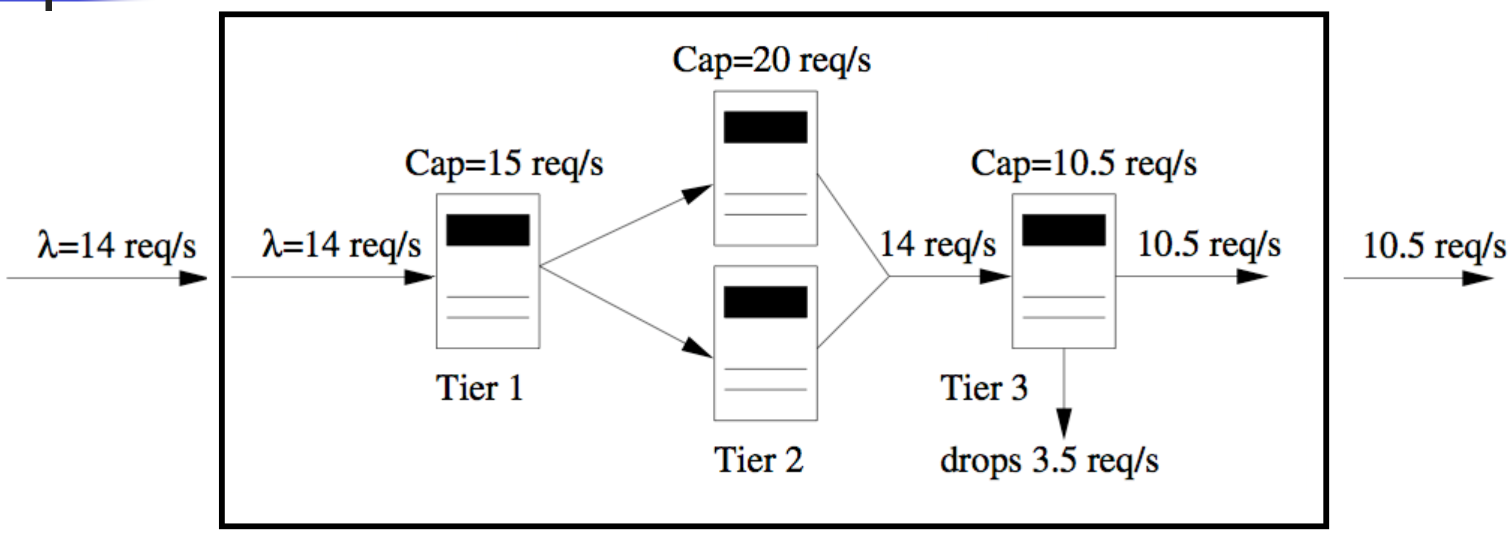


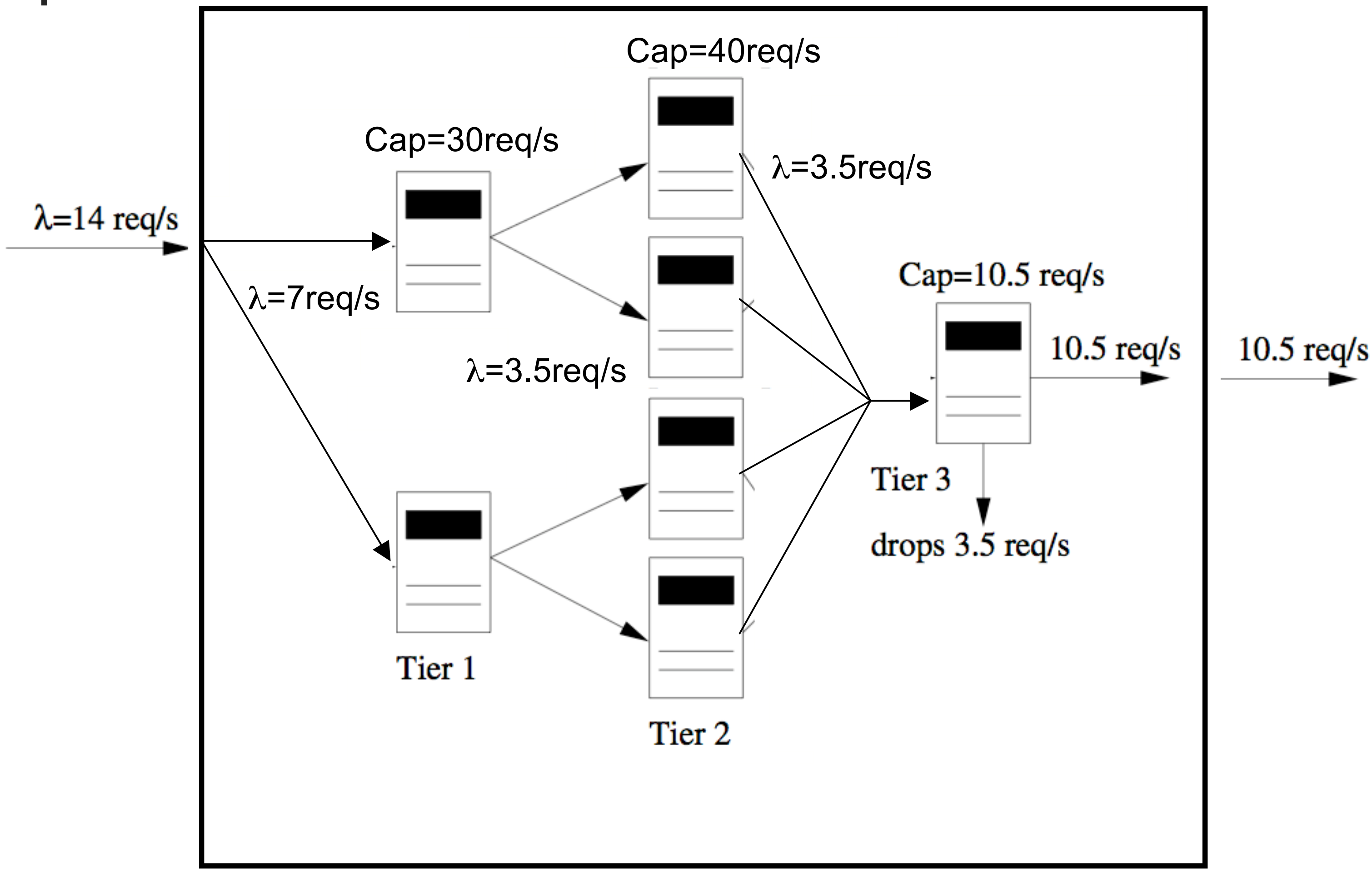
Baseline: Black-box

- Treat the entire system as a black-box and provision when end-to-end response time is below target
  - How many servers do we add?
  - At which tier(s) do we add servers?
  - Not knowing which tier is the bottleneck can cause problems, what if the bottleneck tier isn't replicable?

Baseline: Black-box



Baseline: Black-box



Provisioning for n-tiers

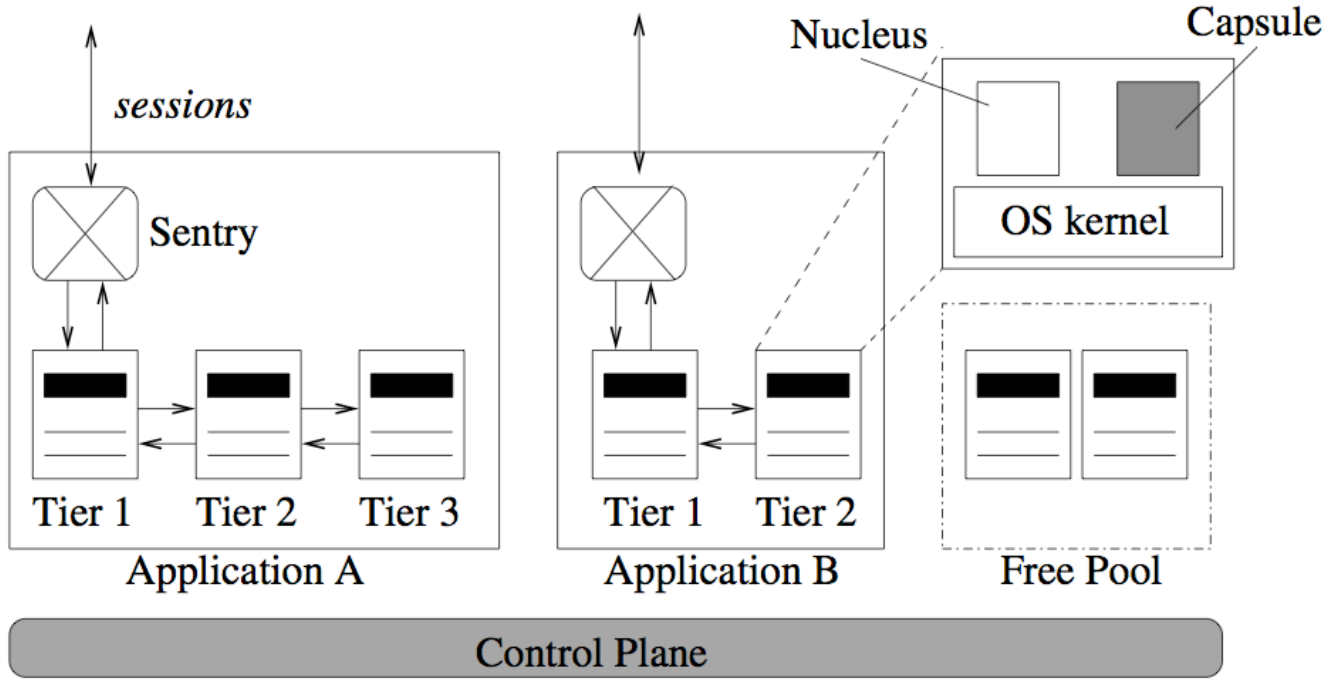
- Collectively model the effects of all tiers
- 3 major components:
  - Admission Control
  - Predictive Provisioning
  - Reactive Provisioning

Provisioning for n-tiers

- One time admission decision per session
- Response time guarantees (SLA)
- Tier-aware
  - Number of tiers, current capacities, constraints on replication
  - (Assume load balancer exists per tier)

Design

- Nucleus (monitor)
- Capsule (Application)
- Sentry (admission controller)
- Control Plane (provisions servers)



Provisioning Algorithm

- Input
  - Incoming request rate to the system
  - Service demand of request
- Output
  - Number of servers needed at each tier to handle the total demand on the system
- 2 questions to answer
  - ***How much*** to provision and ***when***?

How much?

- First, determine the capacity of an individual server (request rate)
  - Treat each server as a G/G/1 queue

$$\lambda_i \geq \left[s_i + \frac{\sigma_a^2 + \sigma_b^2}{2 \cdot (d_i - s_i)} \right]^{-1}$$

How much?

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$$\lambda_i \geq \left[s_i + \frac{\sigma_a^2 + \sigma_b^2}{2 \cdot (d_i - s_i)} \right]^{-1}$$

- Then, compute the number of servers need at each tier (in a single step)

$$\eta_i = \left\lceil \frac{\beta_i \lambda \tau}{\lambda_i Z} \right\rceil$$

How much?

$$\eta_i = \left\lceil \frac{\beta_i \lambda \tau}{\lambda_i Z} \right\rceil$$

$$\eta_i = \left\lceil \beta_i \frac{1}{\lambda_i} \frac{\lambda \tau}{Z} \right\rceil$$

β_i is a tier specific constant

λ_i is the request rate at tier *i*

$\dfrac{\lambda \tau}{Z}$ is the request rate to the system

In practice, we can estimate β by the ratio of requests at the tier and the request admitted to the system over the last time period

Available Servers

- Severs are provisioned to applications from the *free pool*
- If there are not enough servers in the free pool
  - Applications that ***benefit*** the most are given priority
  - Benefit determined by a utility function
- If the free pool is empty, servers can be de-allocated from over-provisioned (under-loaded) applications
  - Under-loaded if observed / predicted request rates are below a threshold

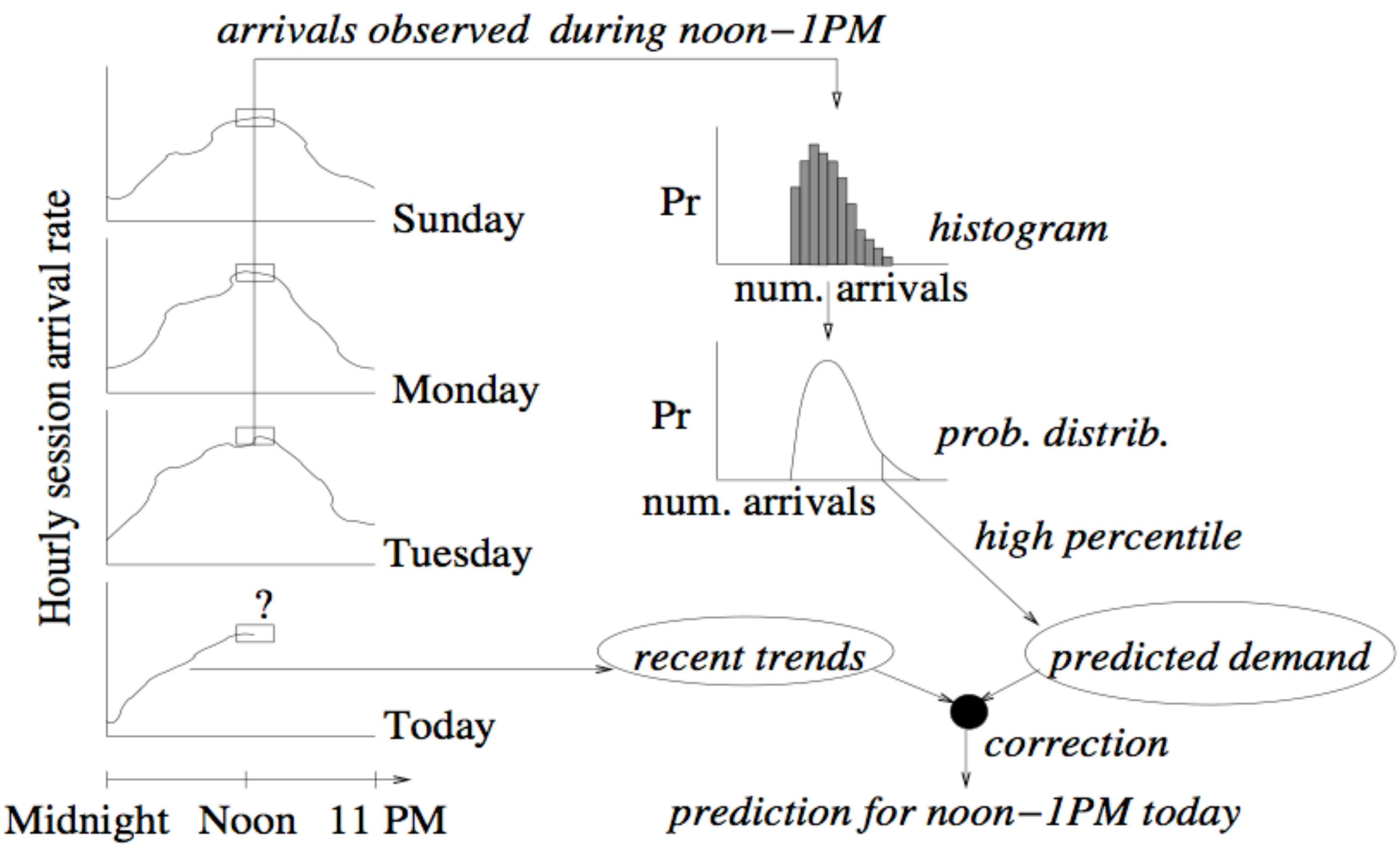
When?

- Predictive
  - Provision on a time scale of hours and days
- Reactive
  - Provision on a time scale of minutes

Predictive Provisioning

- Provision in advance for predicted workloads
  - Based on previous workloads over the past hours or days
- Provision for the peak workload seen in the given time interval
  - Use the ***tail*** of the ***arrival rate distribution***
  - Correct prediction based on previous errors

Predictive Provisioning



Predictive Provisioning

$$\lambda_{pred}(t) = \lambda_{pred}(t) + \sum_{i=t-h}^{t-1} \frac{max(0, \lambda_{obs}(i) - \lambda_{pred}(i))}{h}$$

Prediction from past days (tail of distribution)

Error correction

Reactive Provisioning

- Trigger reactive provisioning if…
  - error ratio (obs / pred) differs by more than a given threshold, or
  - request* drop rate (at the admission controller) is larger than a given threshold.
- (Use same equations as predictive provisioning)

**request* drop rate?*

Admission Control

- After provisioning is done
  - The max workload that has been provisioned for is reported to the *Sentry*
  - Sentry denies admission to new sessions if the arrival rate is above the specified max

Experimental Evaluation

- Experiments suggest that *predictive provisioning*, *reactive provisioning*, and *admission control* are both **necessary** and **sufficient** mechanisms for dynamic provisioning of n-tier systems

Discussion

- How do we distribute target response time (R) over per-tier response times d_i?
- What about utilization? (Always over-provisioning)
- Why G/G/1 queuing model (M/GI/1 or M/G/1?)
- Stateful sessions need to be serviced by the same server at each tier.
- Deployment issues:
  - Application logs and server logs need to be processed on-line.
  - Need ("simple") modifications to web and application servers (Apache and Tomcat).
  - Have to determine threshold values.
  - On-line monitoring of physical resources.