Inferring the Network Latency Requirements of Cloud Tenants

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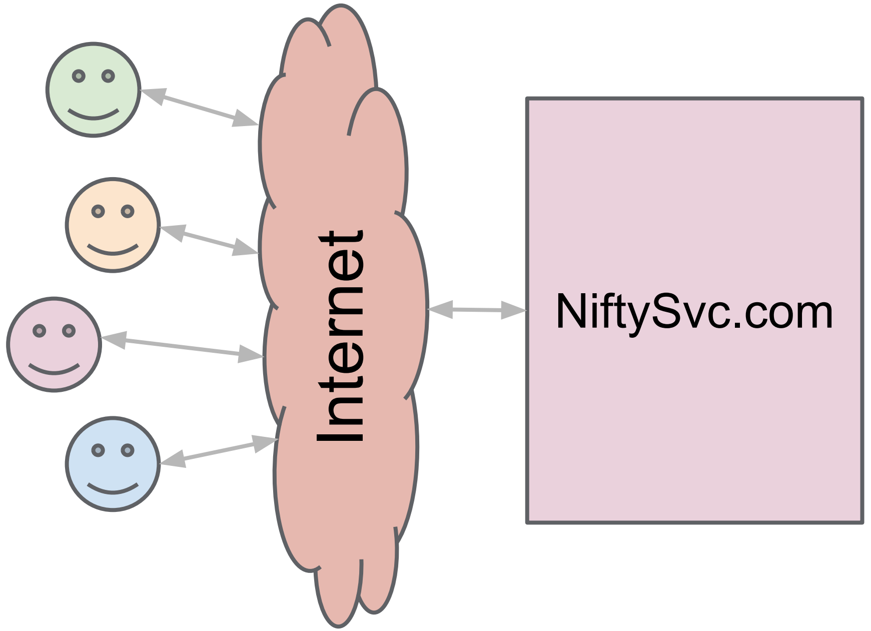
Users care about latency



"Systems that respond to user actions [within 100ms] feel more fluid and natural to users"

-- J Dean & L Barroso, *The Tail at Scale*, CACM 56(2)

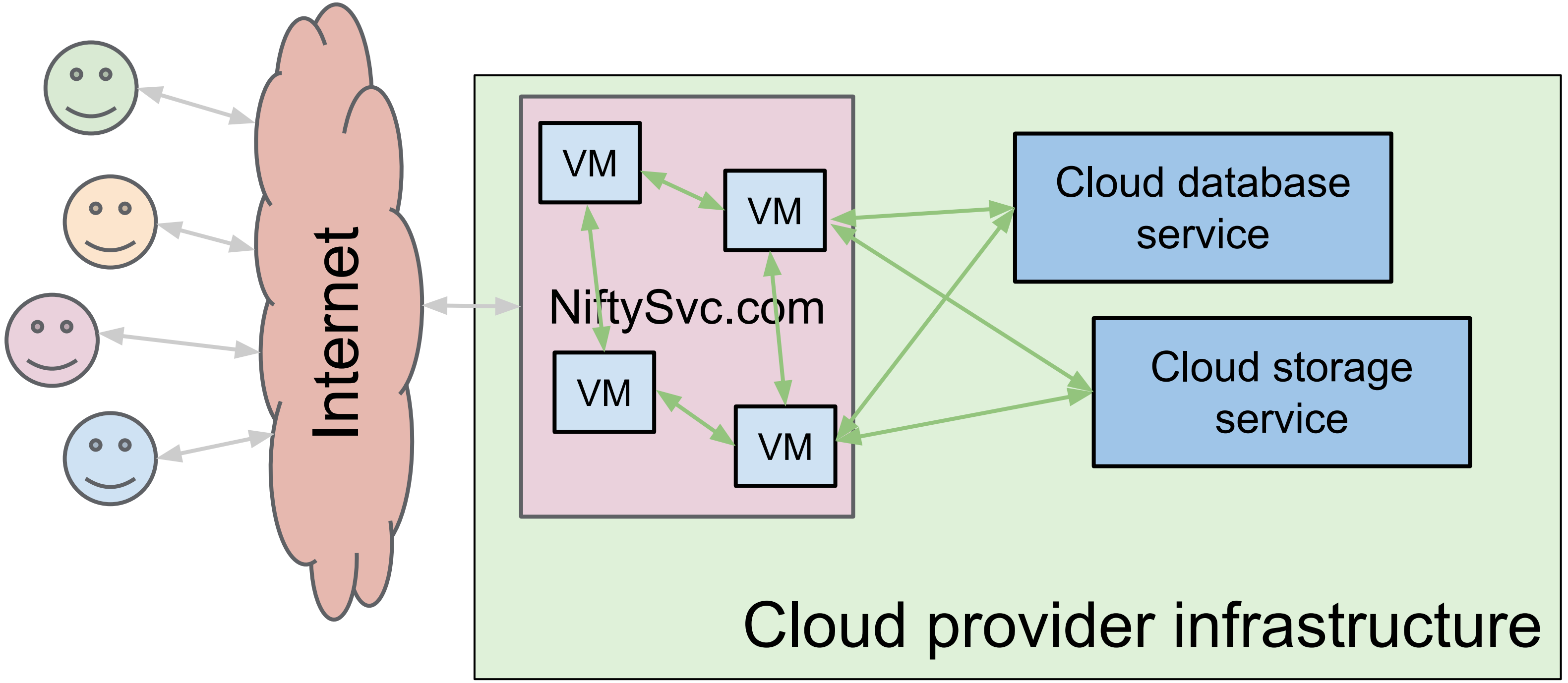
"[Amazon's] services have stringent latency requirements … measured at the 99.9th percentile"

-- G DeCandia *et al.*, *Dynamo …*, SOSP 2007

"Amazon found every 100ms of latency cost them 1% in sales"

-- (various non-original sources)

So, cloud tenants might care about intra-cloud latency



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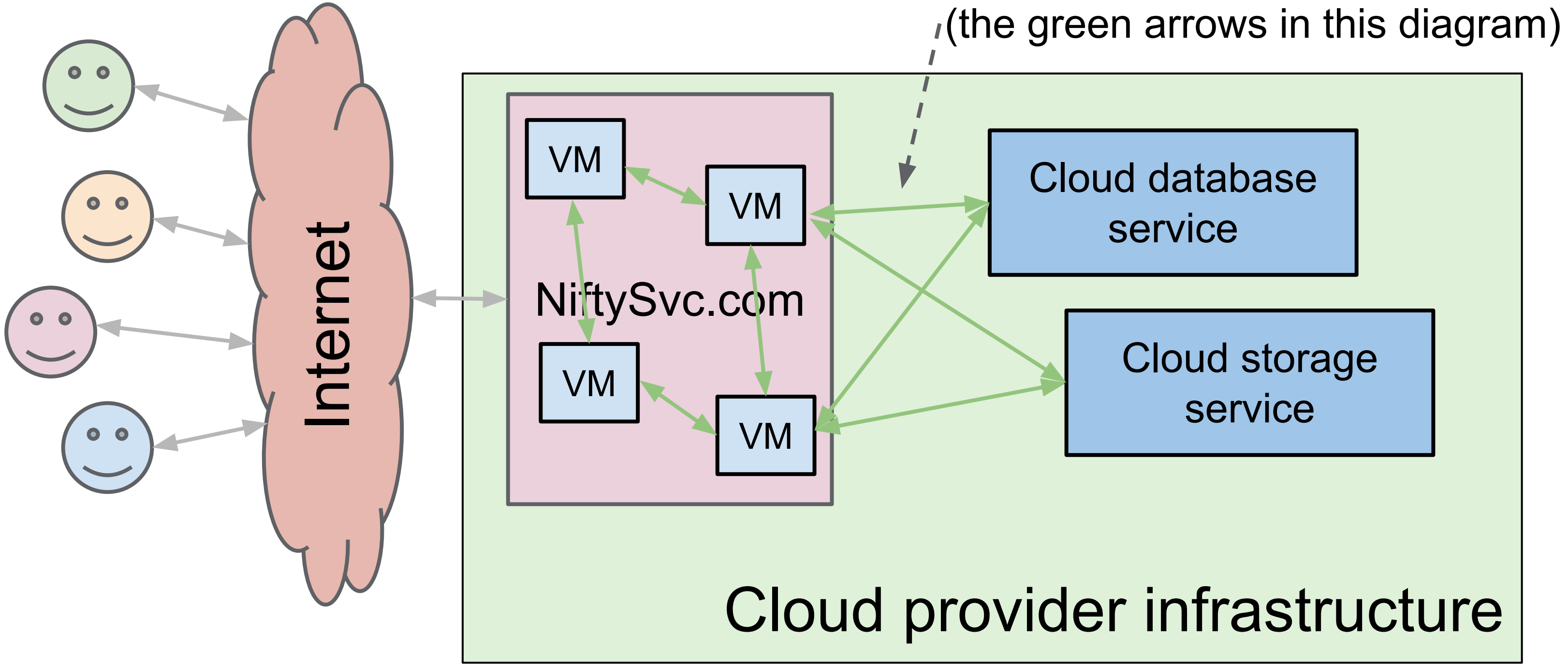

How much do tenants care about intra-cloud latency?

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- Our intuition: intra-cloud latency actually does matter to tenants
- So a cloud provider with better latency will have happier tenants
    - that is, more tenants, and/or tenants who are willing to pay more
- But building infrastructure to support low latency isn’t cheap
    - especially for low tail latency, which tends to require low utilization

Goal of our work: how much does latency matter?

How sensitive is a given cloud application (or VM) to the underlying intra-cloud network latency?

Specific focus of our work:

- Within-region vs. WAN latency
  - Intuition: local latency is easier to vary per-tenant
- Techniques requiring little or no help from the tenants
  - Intuition: tenant developers don't want to be bothered
- Not on how much bandwidth an application uses
  - previous work has looked at inferring cloud bandwidth needs
    - Proteus (Xie *et al.*, SIGCOMM '12); Cicada (LaCurts *et al.*, HotCloud '14)

One-slide summary

Our system will:

- Inject network latency using known patterns (“PN codes”)
- Measure application-level metrics
- Use correlation to detect how much latency affects these metrics

What could a provider do with this information?

Balance resource allocations between tenants:

- Use admission control, to avoid over-utilizing the network
- Place VMs to improve locality or reduce interference
  - as in Oktopus (Ballani *et al.* SIGCOMM '11) and Silo (Jang *et al.* '13)
- Rate-limit latency-insensitive tenant VMs
- Use DSCP settings to shift load between switch queues
- Adjust relative prices of VMs and guarantees for BW & latency

What could a provider do with this information?

And:

- Plan infrastructure upgrades/expansions
- Help tenants understand which provider better suits their needs

Why is inferring latency harder than inferring bandwidth?

Basic technique for inferring bandwidth needs:

- Temporarily turn off rate limiting
- Measure how much bandwidth the application (VM) uses
- Infer future needs from (measured) past behavior

It's harder to apply this method to latency:

- How do you measure "how much latency the VM uses"?

How bad is it?

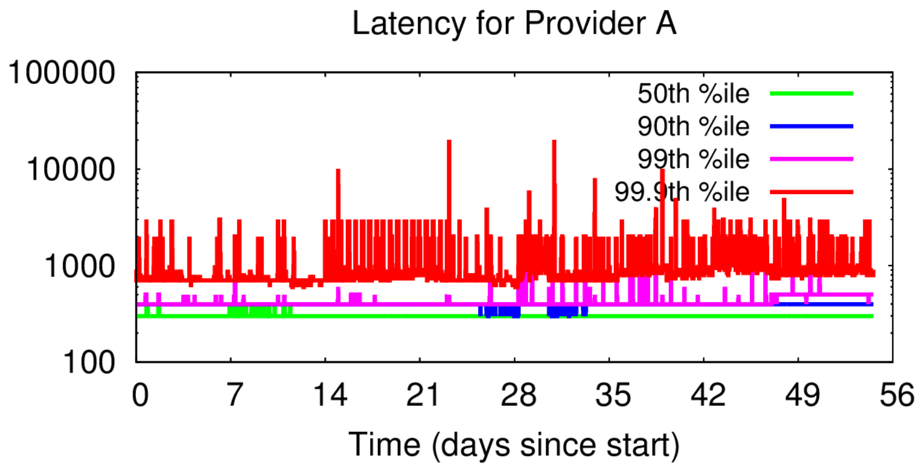
We did a simple study to quantify latency variability

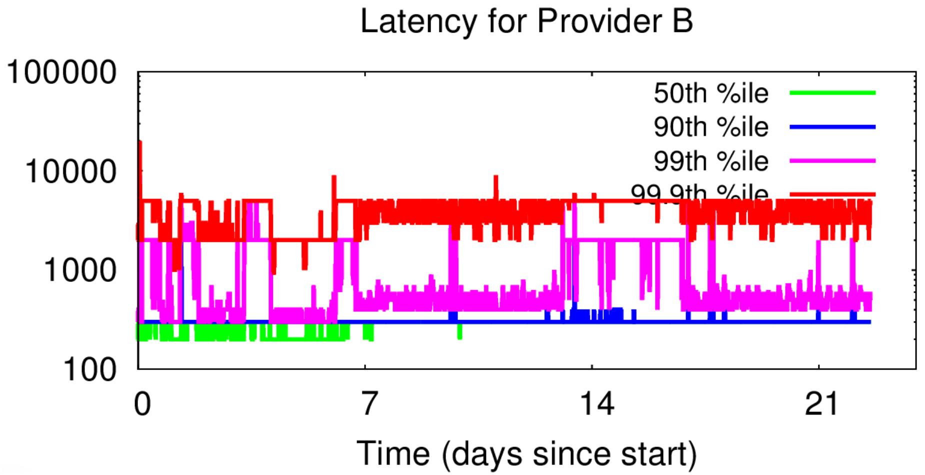
- “simple” means “WARNING: this is bad science”
- Do not attempt to compare providers using this data. Please.

Methodology:

- Buy two cheap VMs in each of several providers
- Run netperf TCP_RR for 60 seconds every 15 minutes
    - netperf reports latency histograms (in a weird way)

Latency results (see warnings on previous slide)





- Latencies can be quite large (at 99th %ile or 99.9th %ile)
- Latencies vary over both short and long time scales
- Latencies *seem* to vary between providers (**WARNING: NOT ACTUAL SCIENCE!**)

Latencies in microseconds

Our approach: Use correlation for latency inference

Goals:

- Infer a causal relationship between network latency and application-level “Service-Level Objective” (SLO) for latency
- Find threshold below which better network latency doesn’t help
- Understand how well the application tolerates latency increases

Approach:

- Measure network latency variations
- Measure SLO effects
- Correlate! Statistics!
    - As in Cohen *et al.*, “Correlating Instrumentation Data to System States”, OSDI ‘04

The hard parts:

- Measuring network latency variation
- Measuring SLO variation
- Doing this for a complex multi-VM application
- Doing this without (much) help from the tenants
- Be robust to various and unknown sources of noise
    - e.g., network traffic, application behavior, storage service latency variation, workload variations

Measuring network latency variation

Possible approaches:

- Exploit natural variation?
  - Only works if there is enough natural variation [maybe]
  - How can a VMM actually measure the latency seen by a VM?
    - add timestamps to packets? But what if there is no rapid response?
    - snoop on TCP headers? But what if no TCP? Or if VM uses IPSEC?
- Inject our own variation?
  - We can do it whenever we want (e.g., only for selected VMs)
  - No need to match up requests and responses
  - We control the frequency and amplitude
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Measuring SLO variation

What is an application-level SLO?

Examples:

- 99.9% of HTTP requests complete within 500 msec
- Handle at least 1000 requests/sec at least 99% of the time

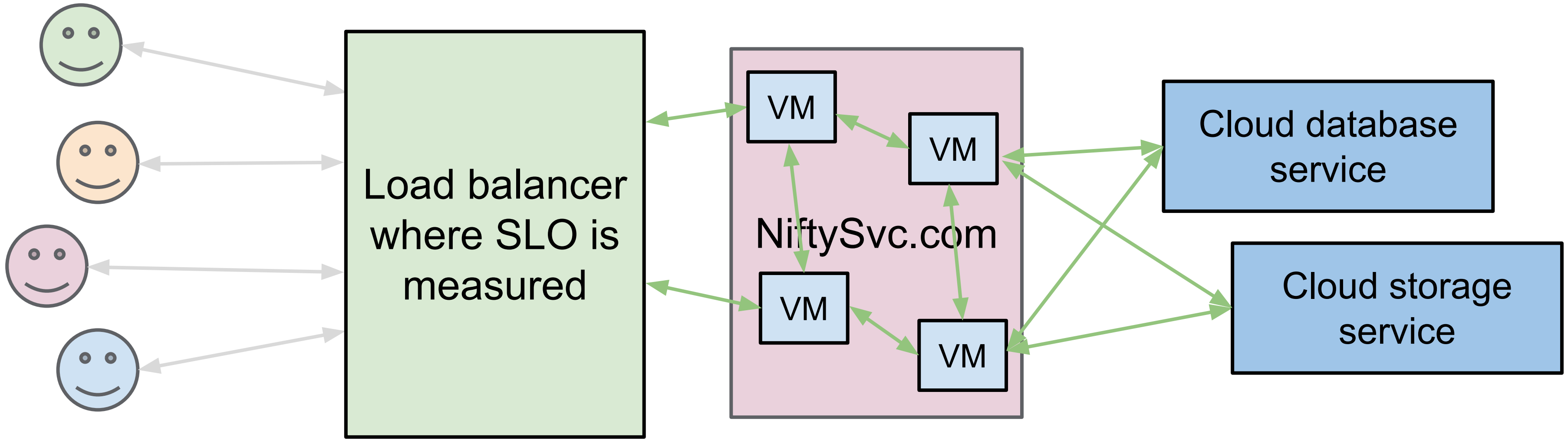
Measuring SLO variation (without help from tenants)

Options:

- Assume tenant uses provider-supplied load balancer
  - but: not all tenants use one, or they use Direct Server Return
- Measure Internet use; assume better results lead to more use
  - not always a good indicator
- VMM assumes HLT/MWAIT means VM is waiting for network
  - doesn't work if there's enough parallelism to keep cores busy
- Hook into cloud-monitoring tools (e.g., Tracelytics or AppDynamics)
  - not everyone uses these

We're still trying to figure out which of these we can use (maybe several?)

How do we know which paths are latency-sensitive?



Which green arrows are the ones whose network latency affects the overall SLO?

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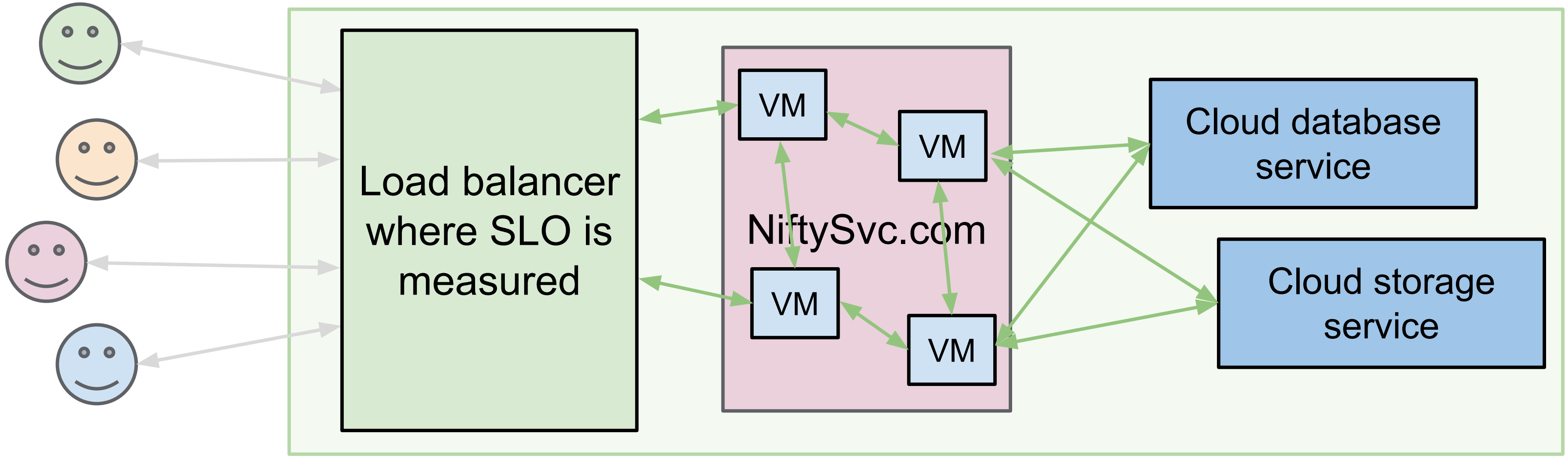

Which green arrows are the ones whose network latency affects the overall SLO? (within the cloud provider's domain)

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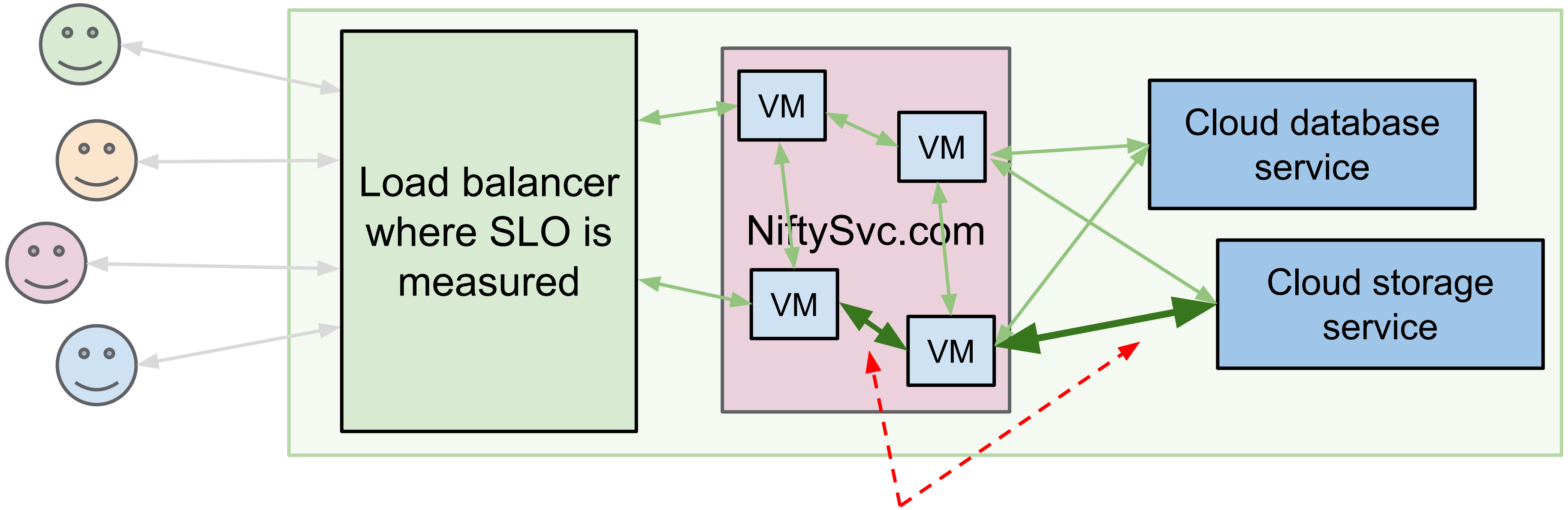
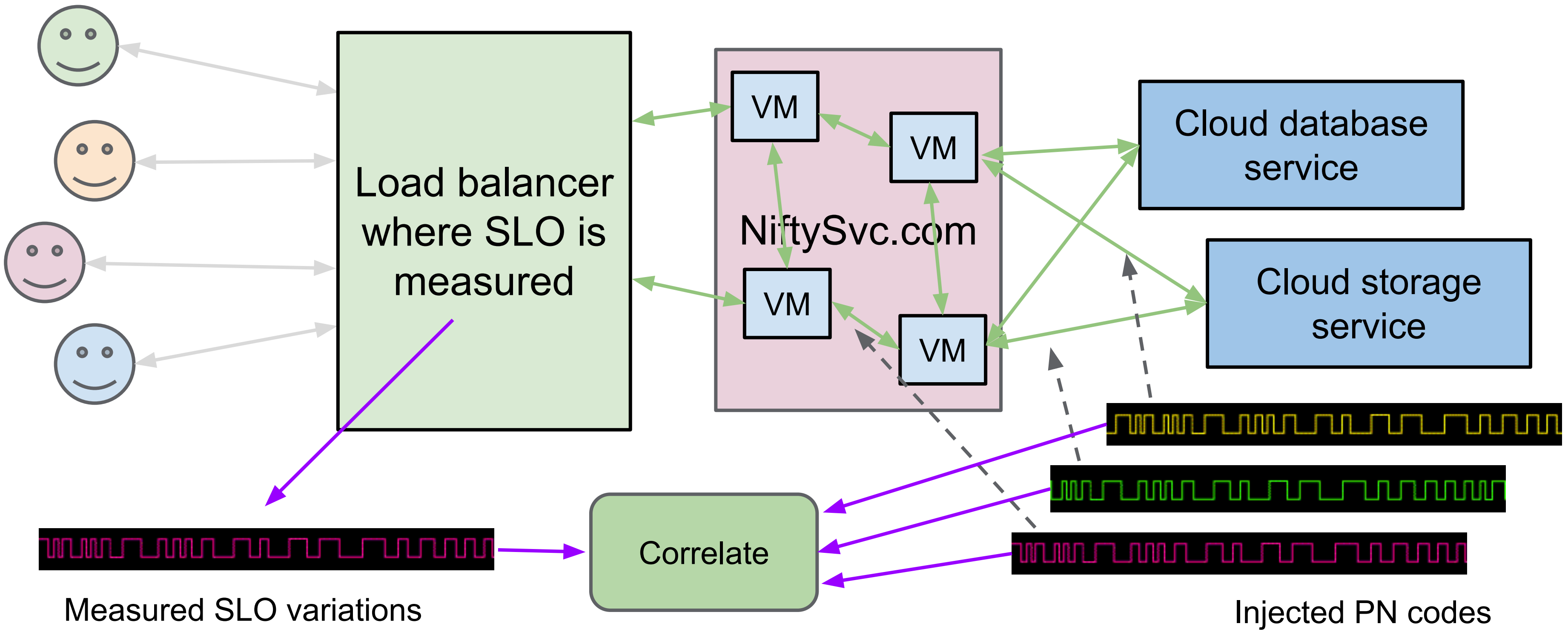


For example: these paths might matter the most

Insight: inject latency variation using pseudo-noise code

- Inject latency using time-varying pattern representing bit-sequence
  - added latency = 1
  - no added latency = 0
- Choose pattern using pseudo-noise (PN) codes
  - A set of PN codes can be chosen to be “highly orthogonal”
    - i.e., minimal correlation between pairs of PN codes
  - Assign one PN code to each latency path (i.e., each green arrow)
- Correlate time-varying SLO measurements with *known* PN codes
  - This is what GPS receivers do (more or less)
- This should allow us to:
  - Understand which network paths actually matter
  - Separate effects of network latencies from various noise sources

Cartoon version of PN codes in action



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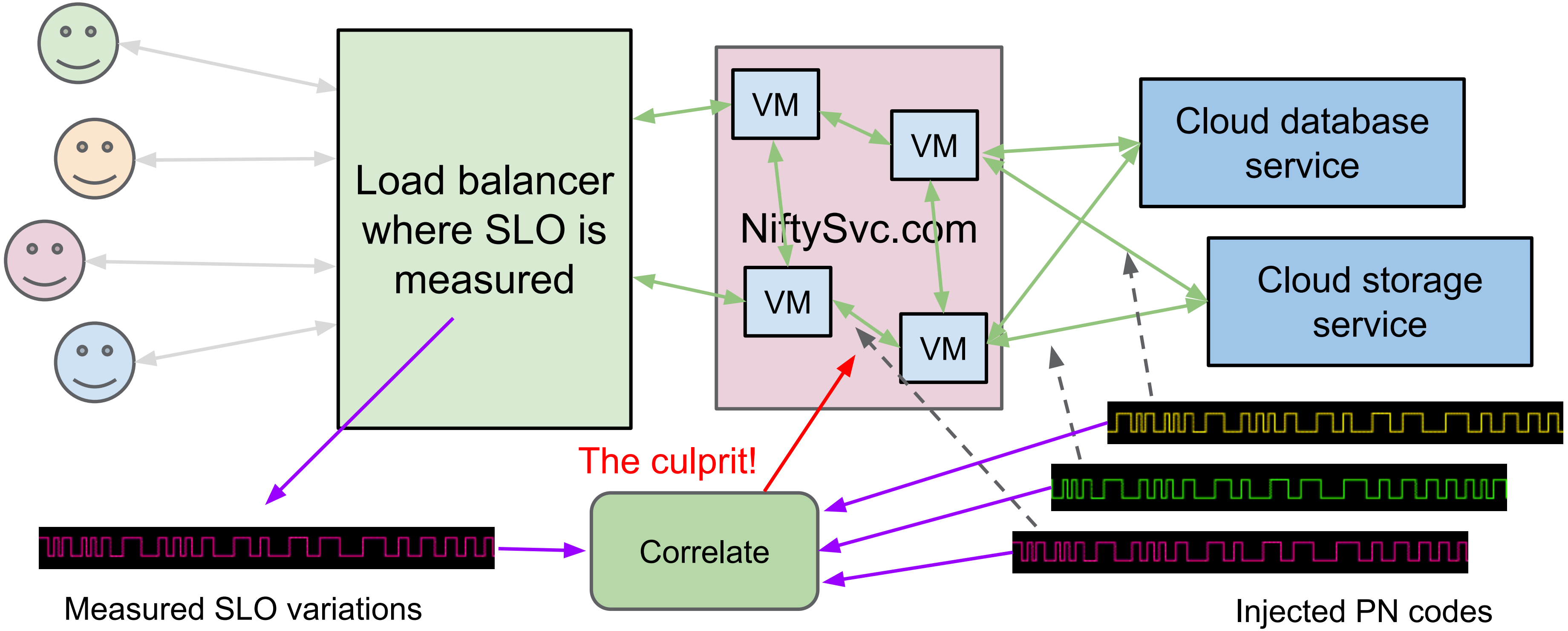


Characteristics of PN codes

We will have to experiment to find out the necessary

- Amplitude: how much time packets are delayed for
- Frequency: how long a “1” or “0” bit lasts
- Duration: how many bits in a PN code

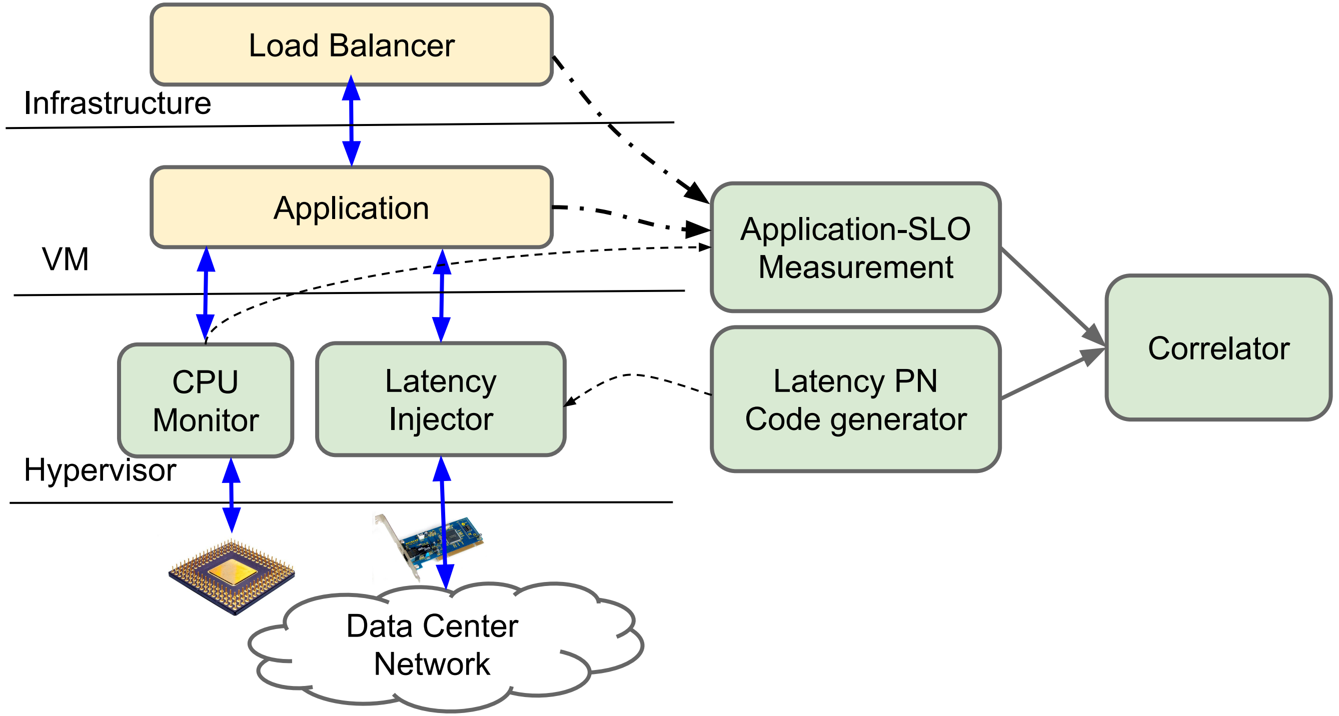
to support reasonably-fast correlation … without annoying users

Implementation

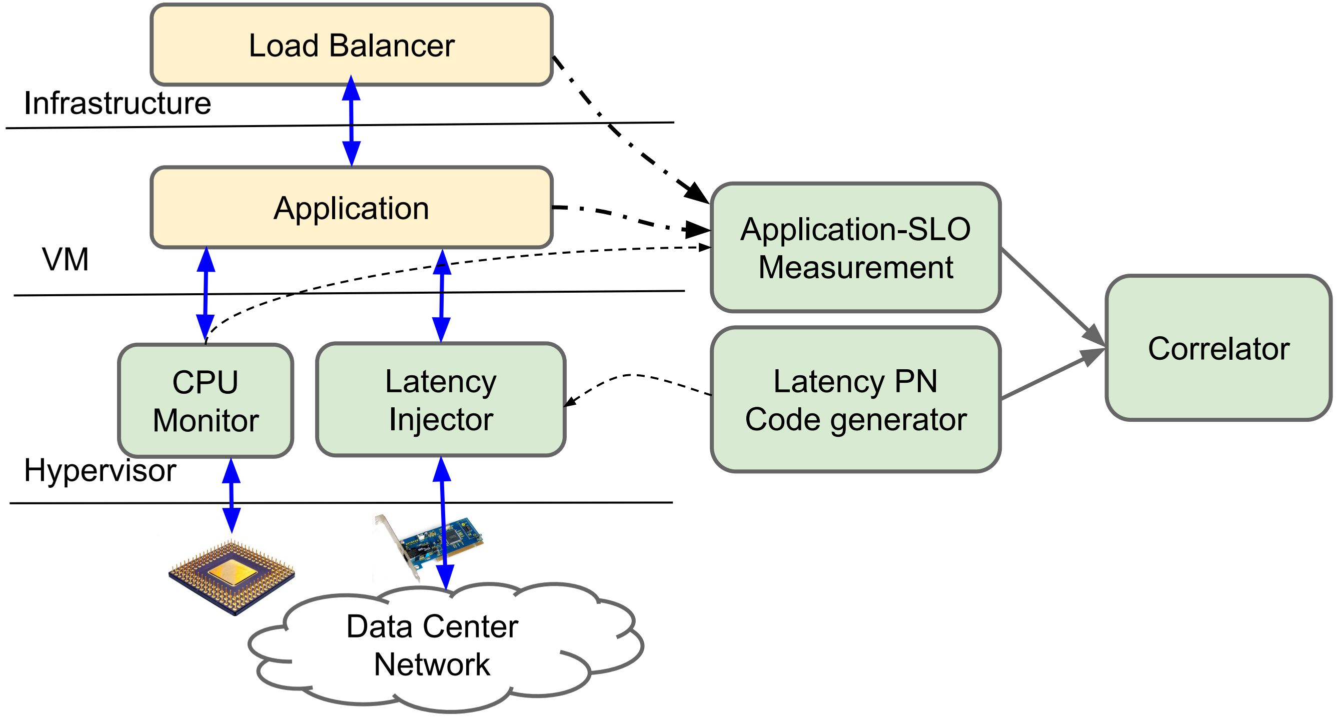
Progress so far:

- Hired a really good intern

System diagram



Implementation/research challenges



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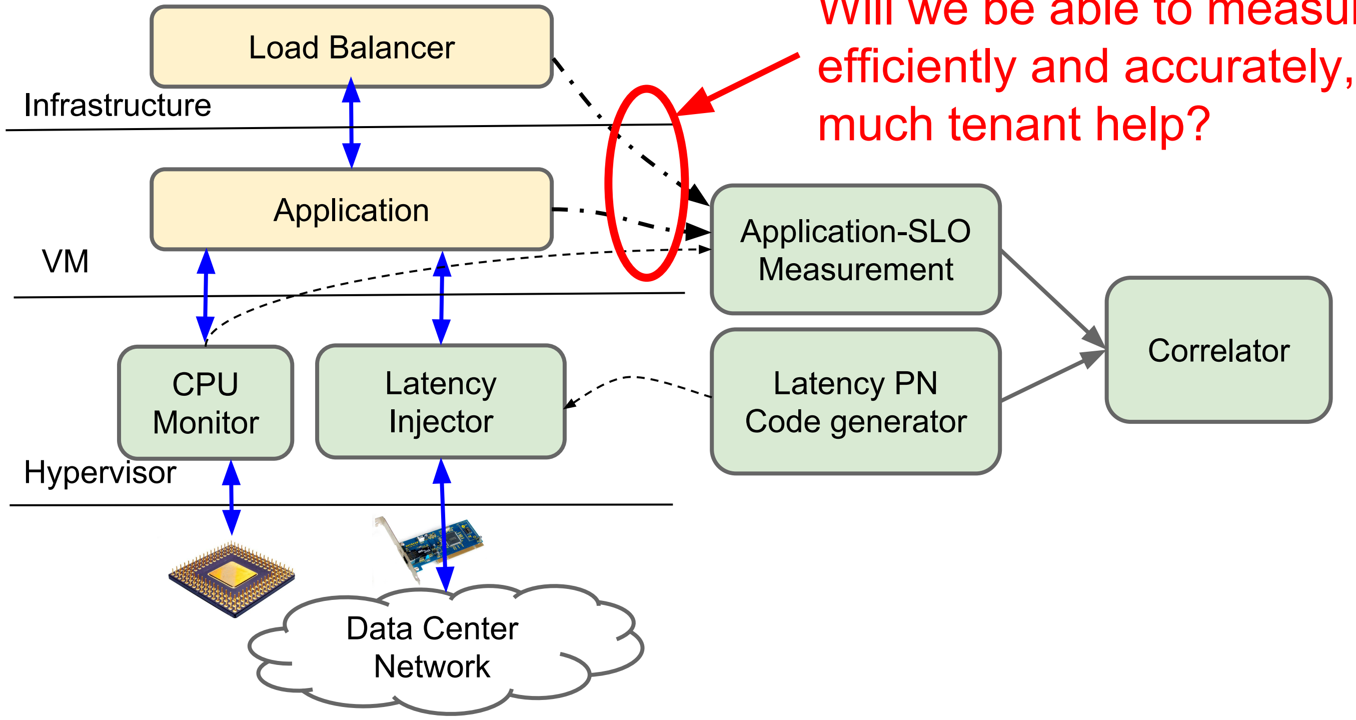
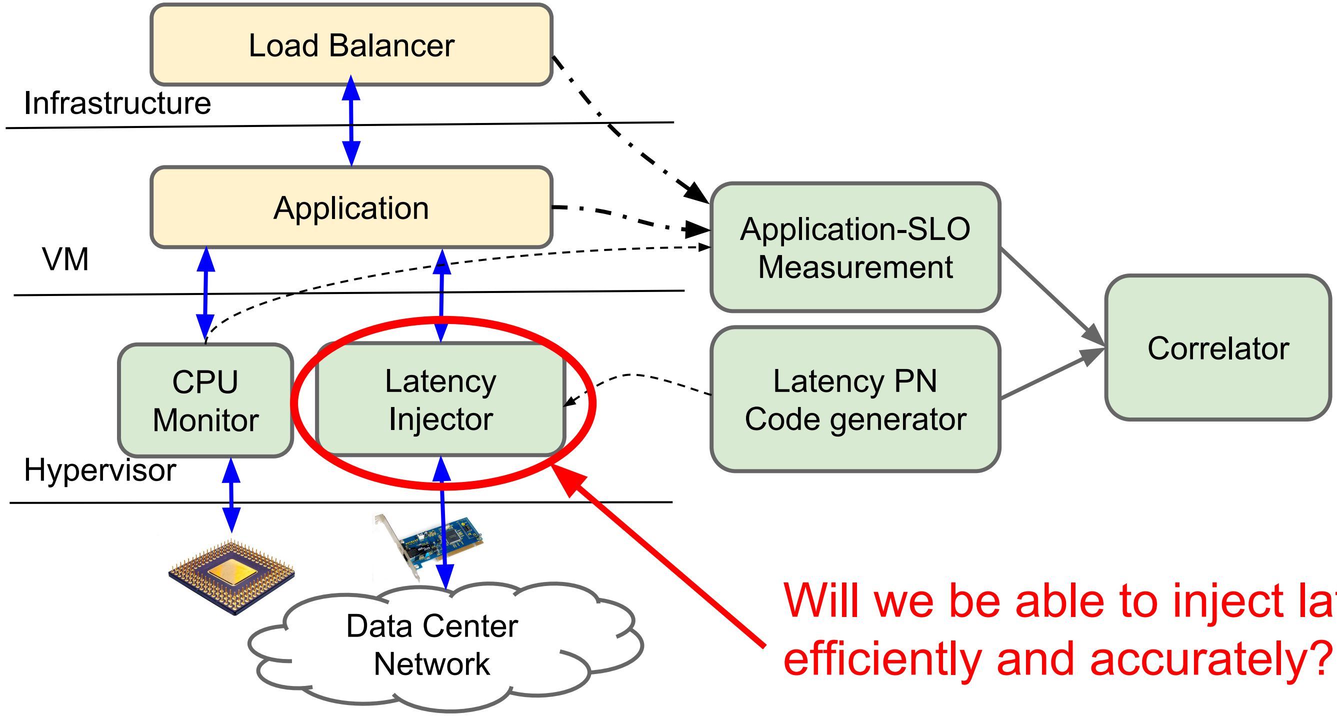


Will we be able to measure SLOs efficiently and accurately, without much tenant help?

Implementation/research challenges



Will we be able to inject latency efficiently and accurately?

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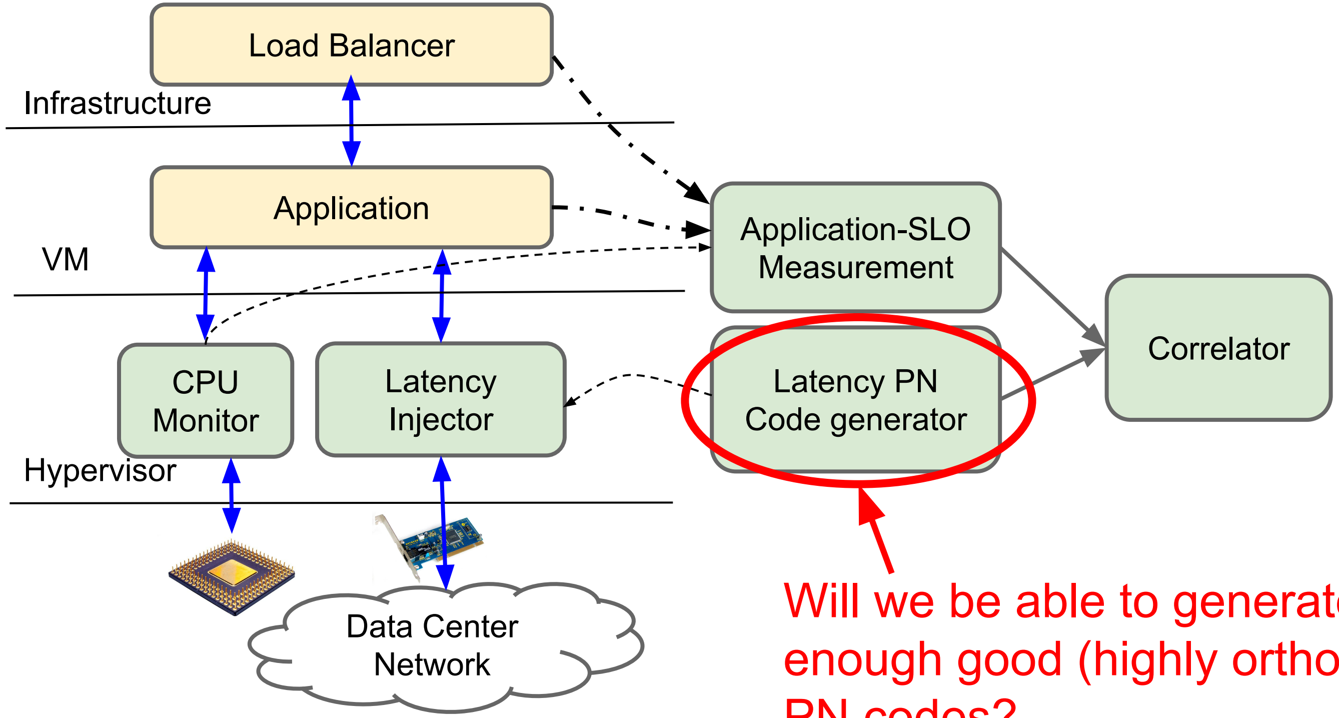
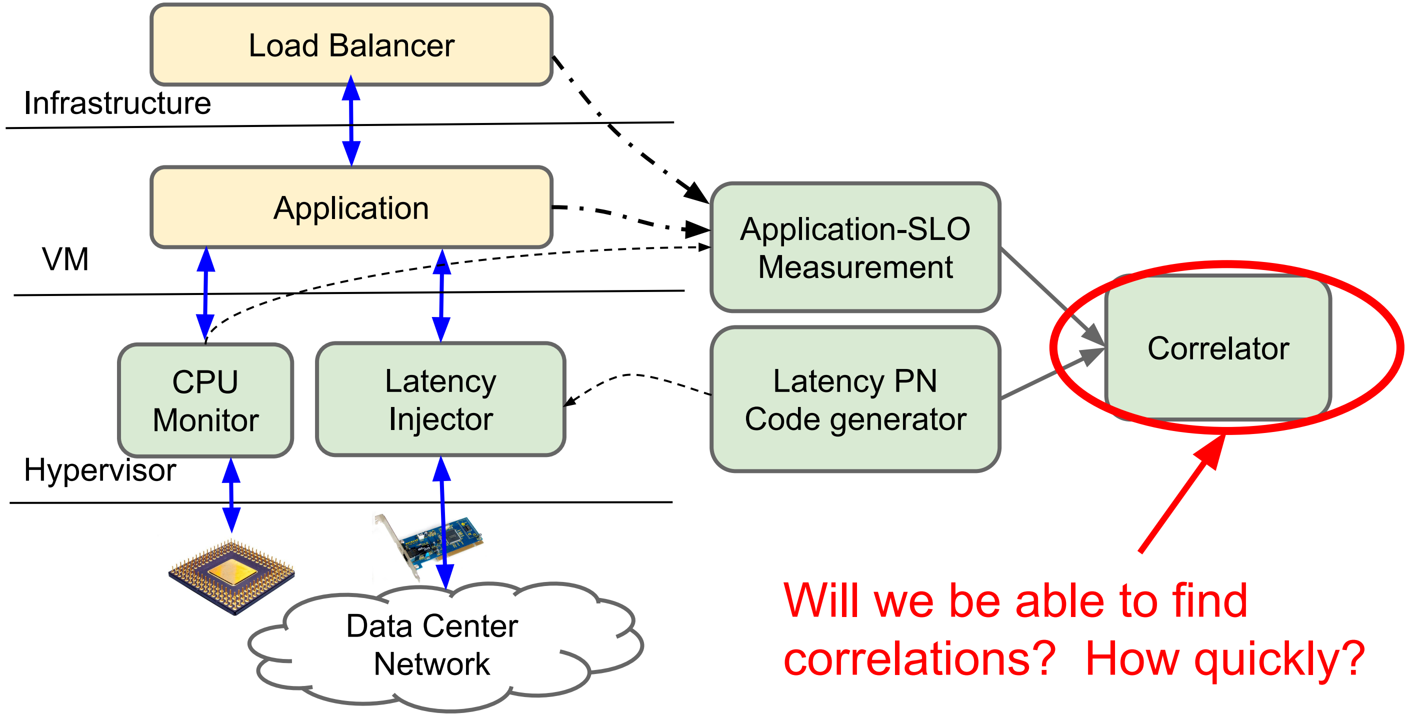


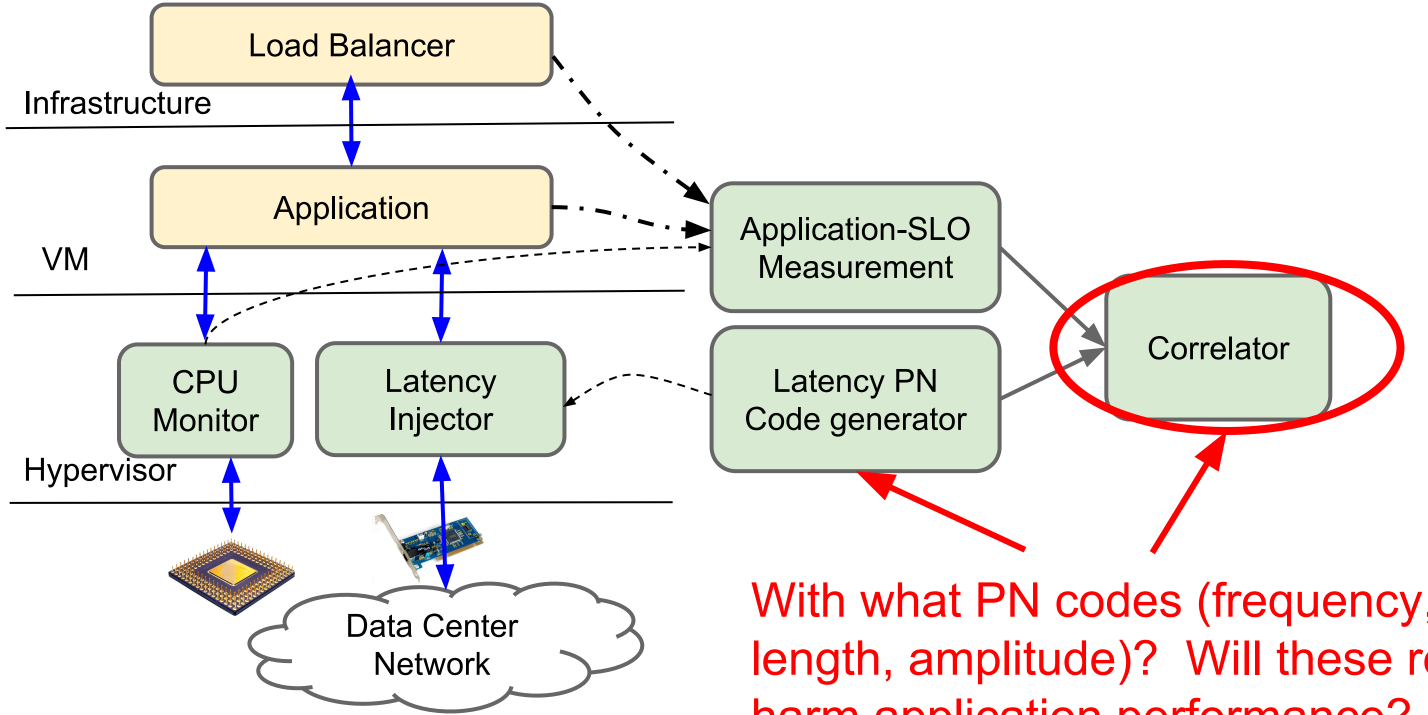
Will we be able to generate enough good (highly orthogonal) PN codes?

Implementation/research challenges



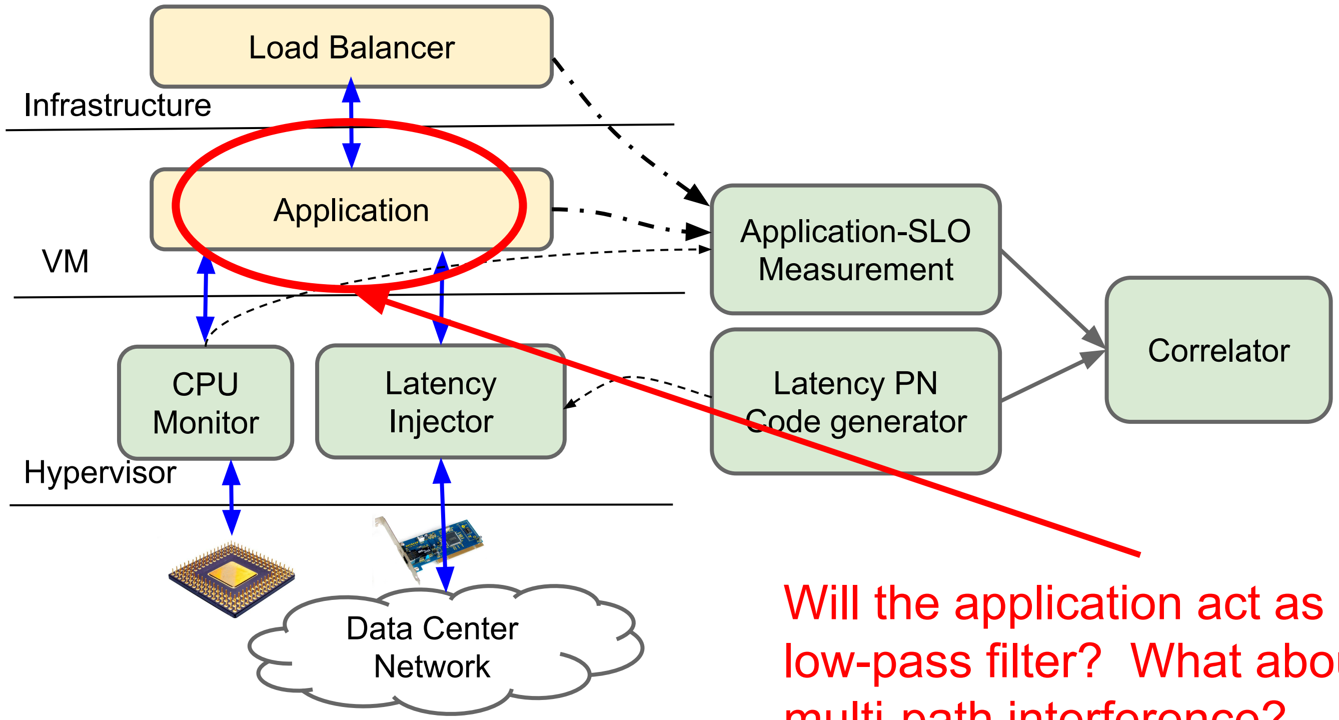
Will we be able to find correlations? How quickly?

Implementation/research challenges



With what PN codes (frequency, length, amplitude)? Will these really harm application performance?

Implementation/research challenges



Will the application act as a big low-pass filter? What about multi-path interference?

Q&A