Predicting service metrics for cluster-based services using real-time analytics

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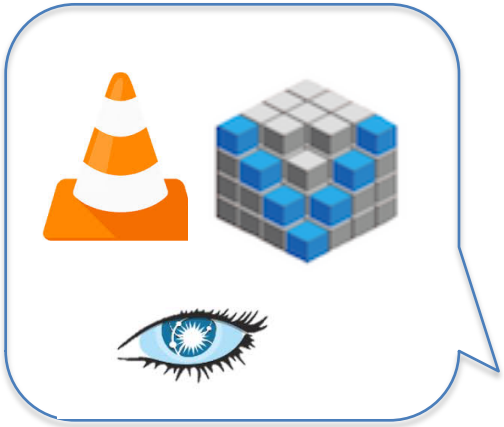
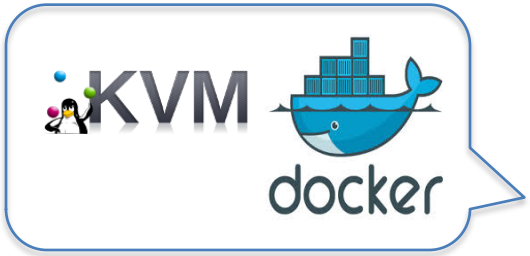
Overview



Services



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Operating System

Hardware

Real-time service metrics Y

- Video frame rate, read latency, ..

Analytics

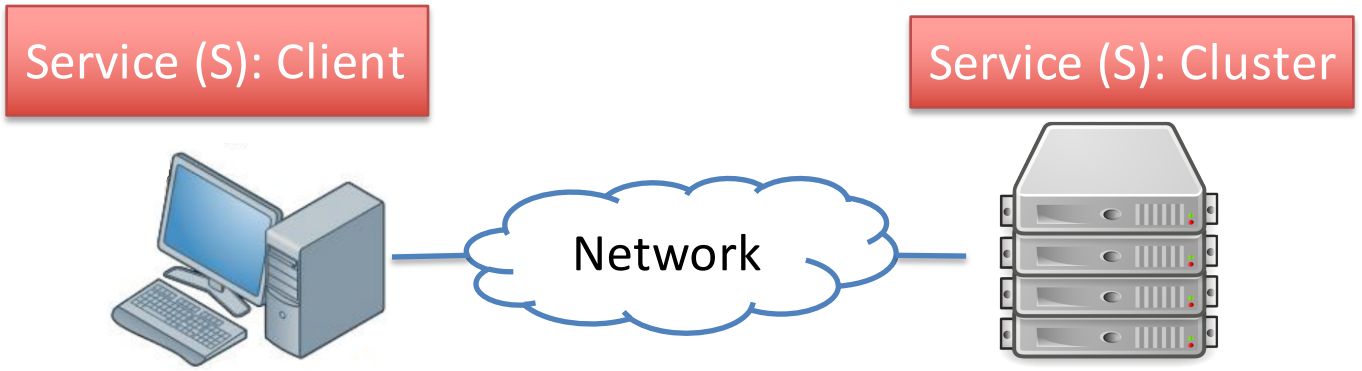
Device statistics X

- CPU load, memory load, #context switching, #processes, etc..
- We read raw data from /proc provided by Linux kernel

Outline

- Real-time prediction problem
- Service-agnostic approach
- Device statistics and service metrics
- Testbed and traces
- Real-time analytics engine
- Evaluation: batch, online, real-time
- Conclusions

Real-time prediction problem



Y: service-level metrics

- Video frame rate, audio buffer rate, network read rate
- Video streaming (VLC)

X: device statistics

- CPU load, memory load, #context switching, #processes, …

Problem : **M: X→ $\hat{Y}$** predicts Y in real-time

Use case : Building block for real-time service assurance for service operator or infrastructure provider

Service-agnostic approach

Existing works

1. Apply formal models to model the system and the service
2. Statistical learning on few service-specific features (<10)

Design goal ➔ "Service-agnostic prediction"

Our approach

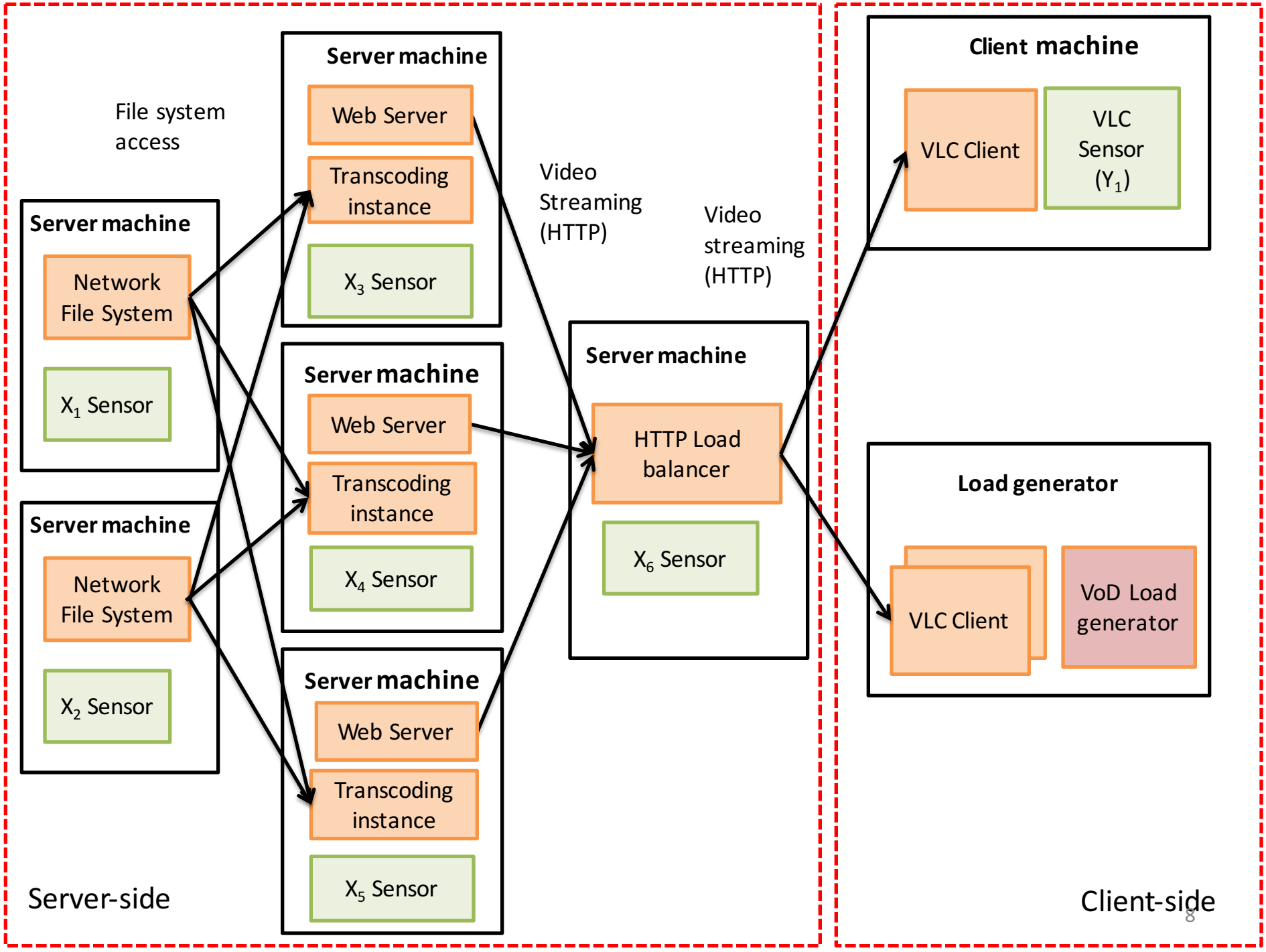
1. Take "all" available statistics (>= 4000 features)
2. Learn using low-level (OS-level) metrics

Device statistics X

- Interface: System Activity Report (SAR) X
  - SAR computes metrics from /proc over time interval
  - CPU core utilization, memory and swap space utilization, disk I/O statistics, …
  - About 840 features per machine
- SAR is based on /proc directory
  - Linux Kernel statistics
  - CPU core jiffies, current memory usage, virtual memory statistics, #processes, #blocked processes, …
- Use numerical features only for model predictions

Service-level metrics Y

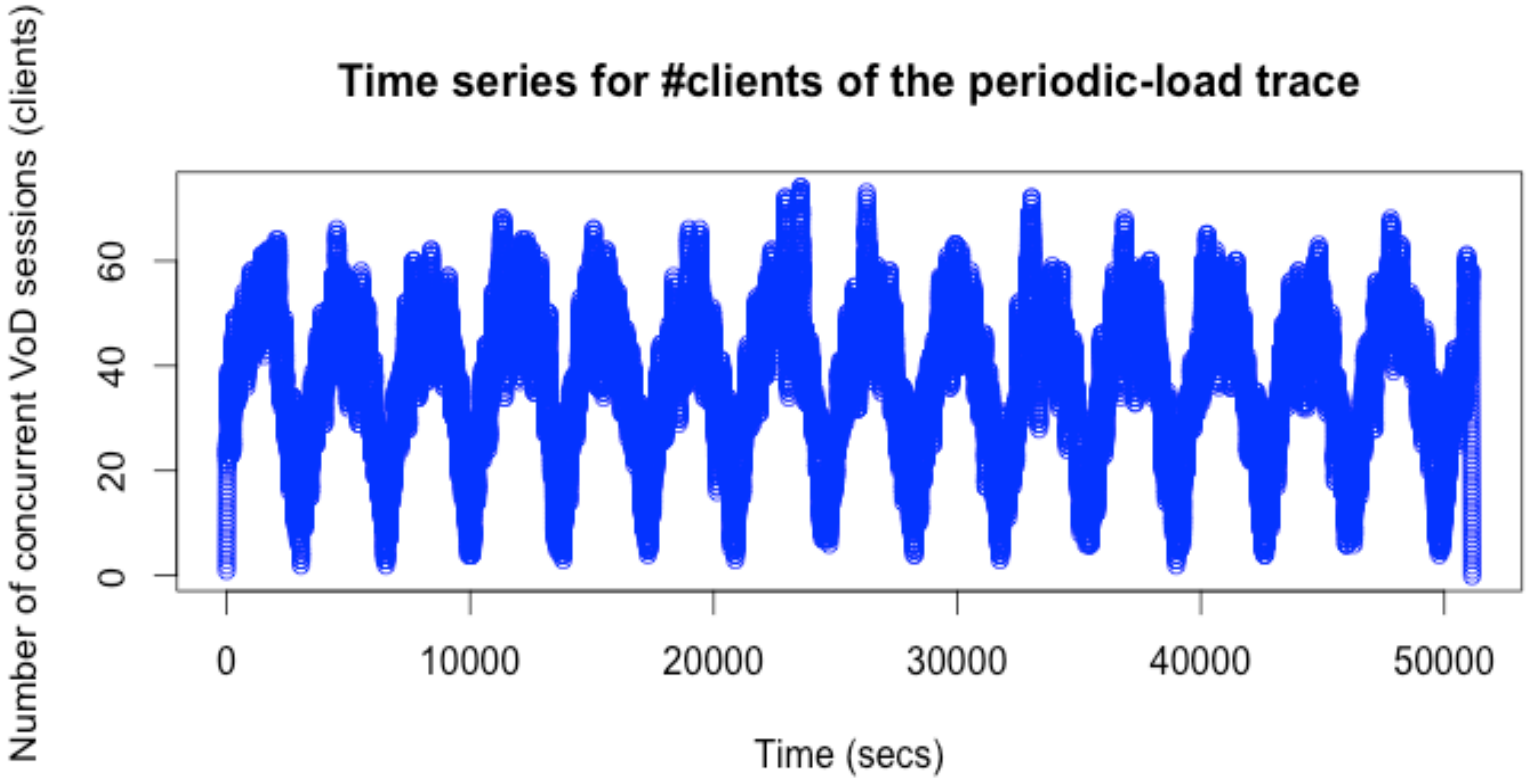
- Video streaming service based on VLC software
- Measured metrics
  - Video frame rate (frames/sec)
  - Audio buffer rate (buffers/sec)
  - Network read rate (operations/sec)
- Instrumented VLC software


File system access
Server machine
Network File System
X_1 Sensor
Server machine
Network File System
X_2 Sensor
Server machine
Web Server
Transcoding instance
X_3 Sensor
Server machine
Web Server
Transcoding instance
X_4 Sensor
Server machine
Web Server
Transcoding instance
X_5 Sensor
Video Streaming (HTTP)
Server machine
HTTP Load balancer
X_6 Sensor
Video streaming (HTTP)
Client machine
VLC Client
VLC Sensor (Y_1)
Load generator
VLC Client
VoD Load generator
Server-side
Client-side

Dell PowerEdge R715 2U rack servers
CPU: two 12-core AMD Opteron processors
Memory: 64 GB RAM
Harddisk: 500 GB hard disk
NIC: 1 Gb network controller

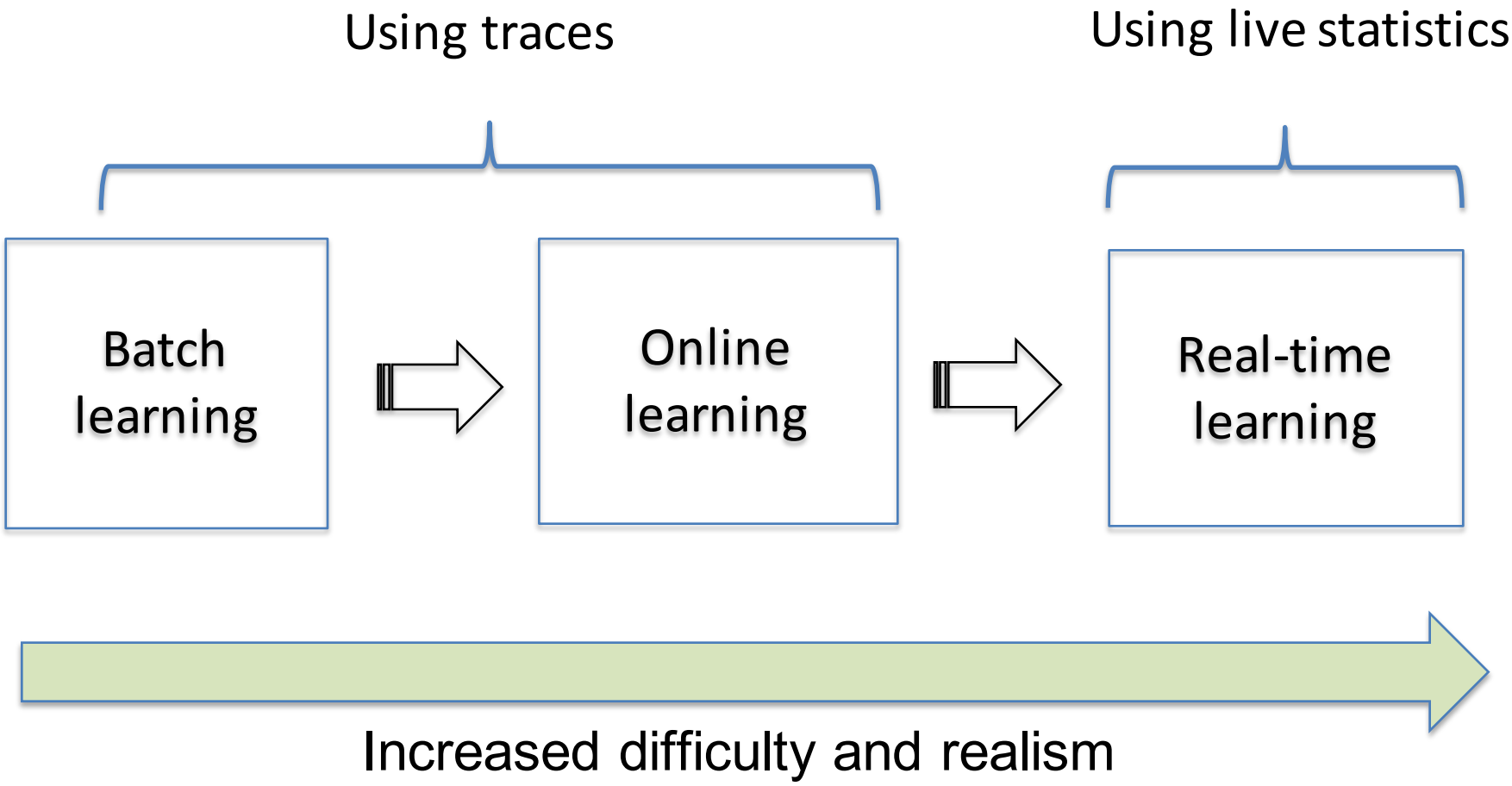
X-Y traces

Load patterns: Periodic-load, flashcrowd, poisson, ….

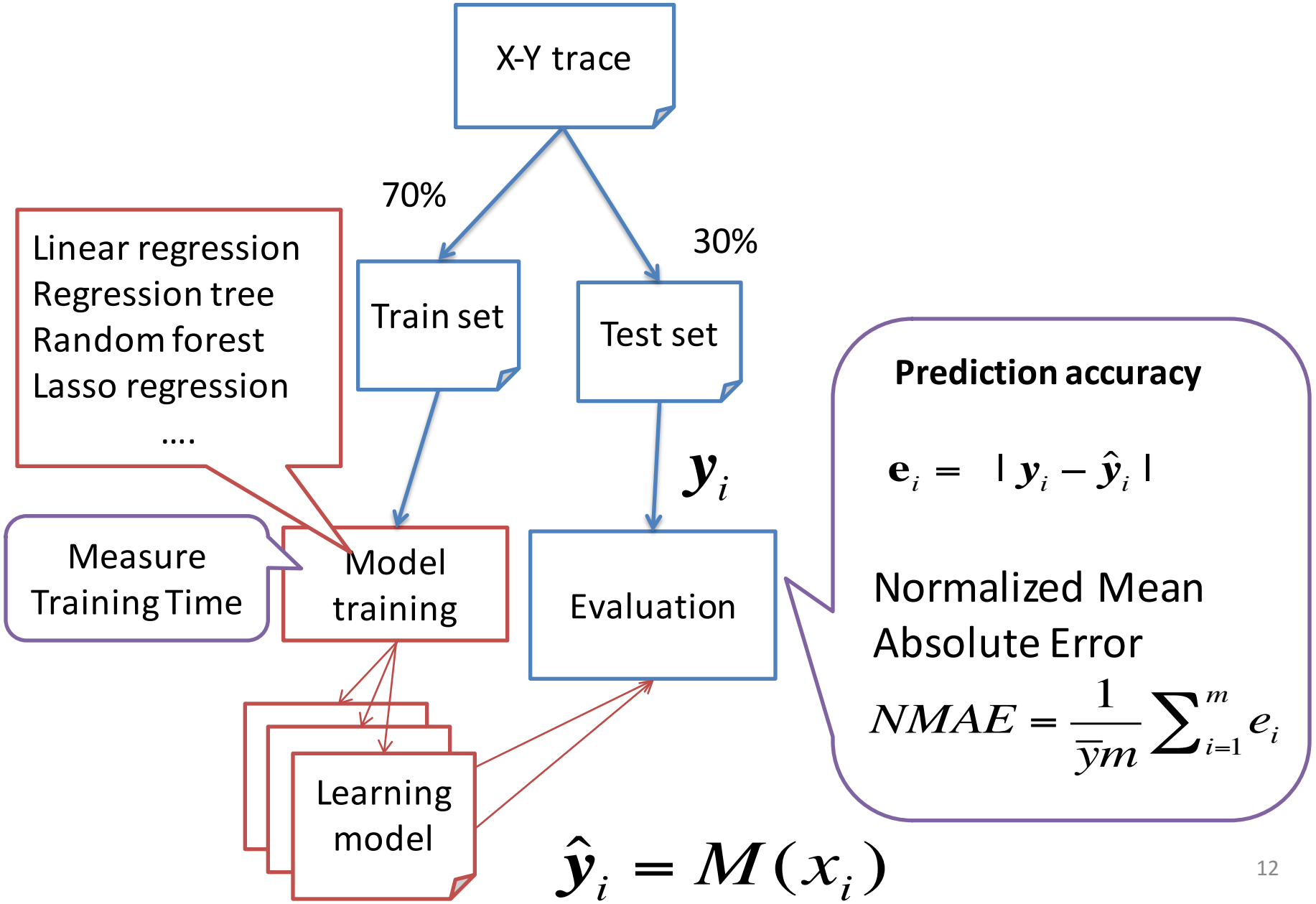


Traces published at **http://mldata.org**

Prediction methods



Batch learning on traces



Reduce feature set

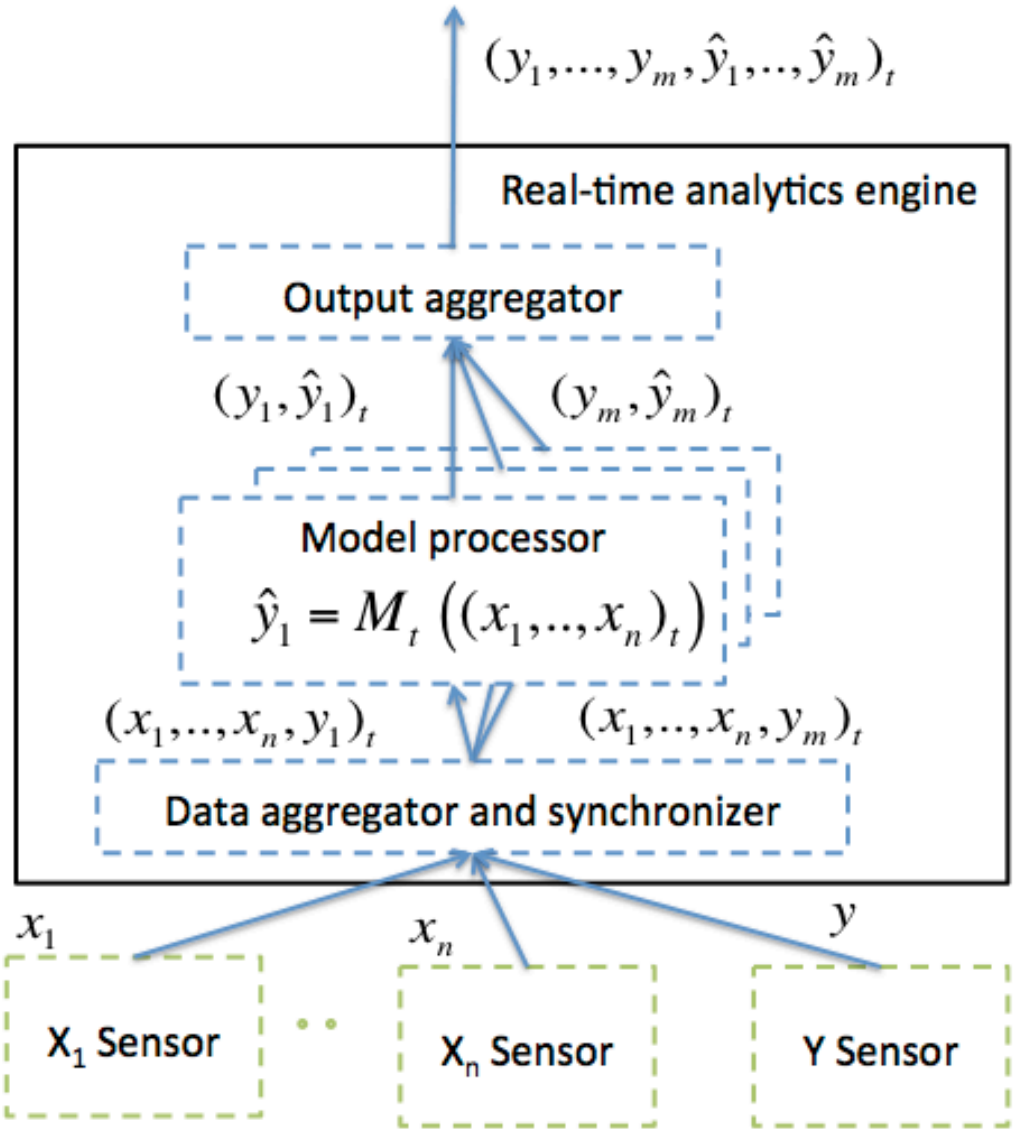
- Exhaustive search is infeasible
  - Requires $O(2^p)$ training executions (p = ~5000)
- Forward stepwise feature selection
  - Heuristic method $O(p^2)$ training executions
  - Incrementally grows the feature sets
- Reduce feature set from 5000 => 12 features

Effect of feature set reduction

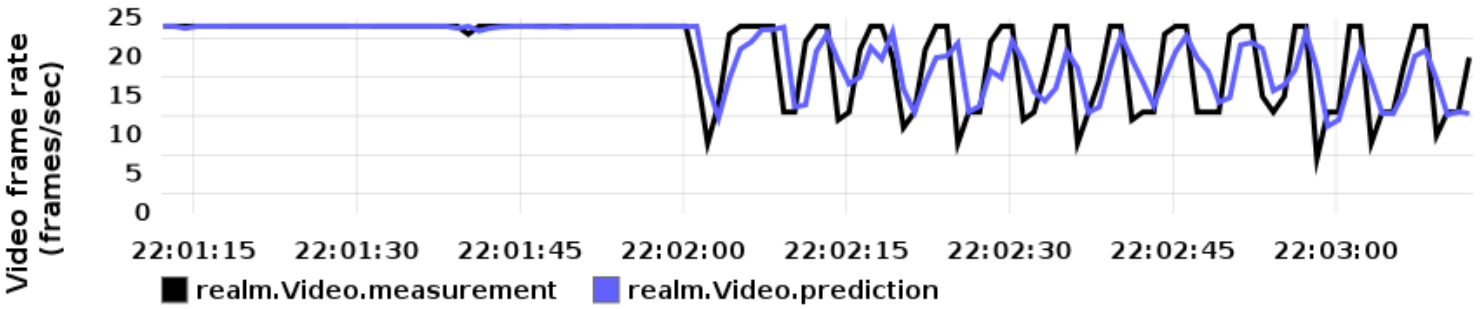
Trace	Feature set	Video		Audio	
		NMAE (%)	Training (secs)	NMAE(%)	Training (secs)
Periodic-load	Full	12	> 59000	32	> 70000
	"Minimal"	**6**	862	**22**	1600
Flash-load	Full	8	> 55000	21	> 75000
	"Minimal"	**4**	778	**15**	1750

=> Minimal feature set
improves prediction accuracy
reduces training time

Real-time analytics engine

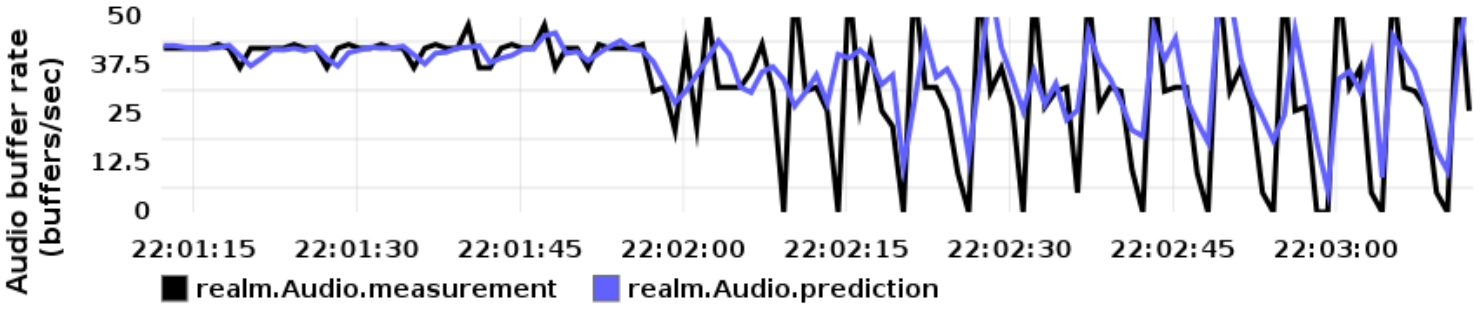


Real-time Predictions of Service Metrics from Device Statistics



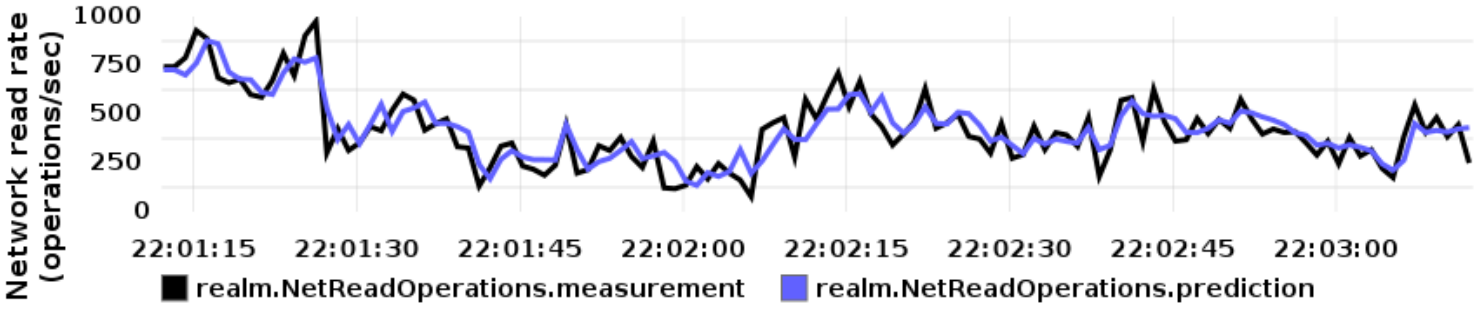
Normalized Mean Absolute Error (last 5 minutes)

4.43 %



Normalized Mean Absolute Error (last 5 minutes)

13.73 %



Normalized Mean Absolute Error (last 5 minutes)

18.77 %

Real-time learning results

Real-time load pattern	NMAE(%)		
	Video	Audio	Network
Periodic-load pattern	3.6	14	28.5
Flash-load pattern	5.6	11	28

Discussion

- It is feasible to predict real-time service metrics from device statistics
- Feature set reduction is critical for real-time prediction
- Random forest on our testbed is the best performing method
- The key strength of this approach is that it is service agnostic