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Detecting Co-Residency
with Active Traffic Analysis Techniques

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To the Cloud?

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"An attacker can often place his or her instance on the same physical machine as a target instance... creating the ability of a malicious instance to utilize side channels to learn information about co-resident instances."

Co-Resident Watermarking

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This work...

- **Investigates** cloud side channels at the hardware level via the network interface.
- **Introduces** *co-resident watermarking*, an attack that breaks VM isolation via a network timing channel.
- **Evaluates** methodology to confirm its efficacy in the adverse compute cloud conditions and configurations.
- **Demonstrates** further side-channel applications: covert communication, traffic profiling of victim VMs.

Design: Threat Model

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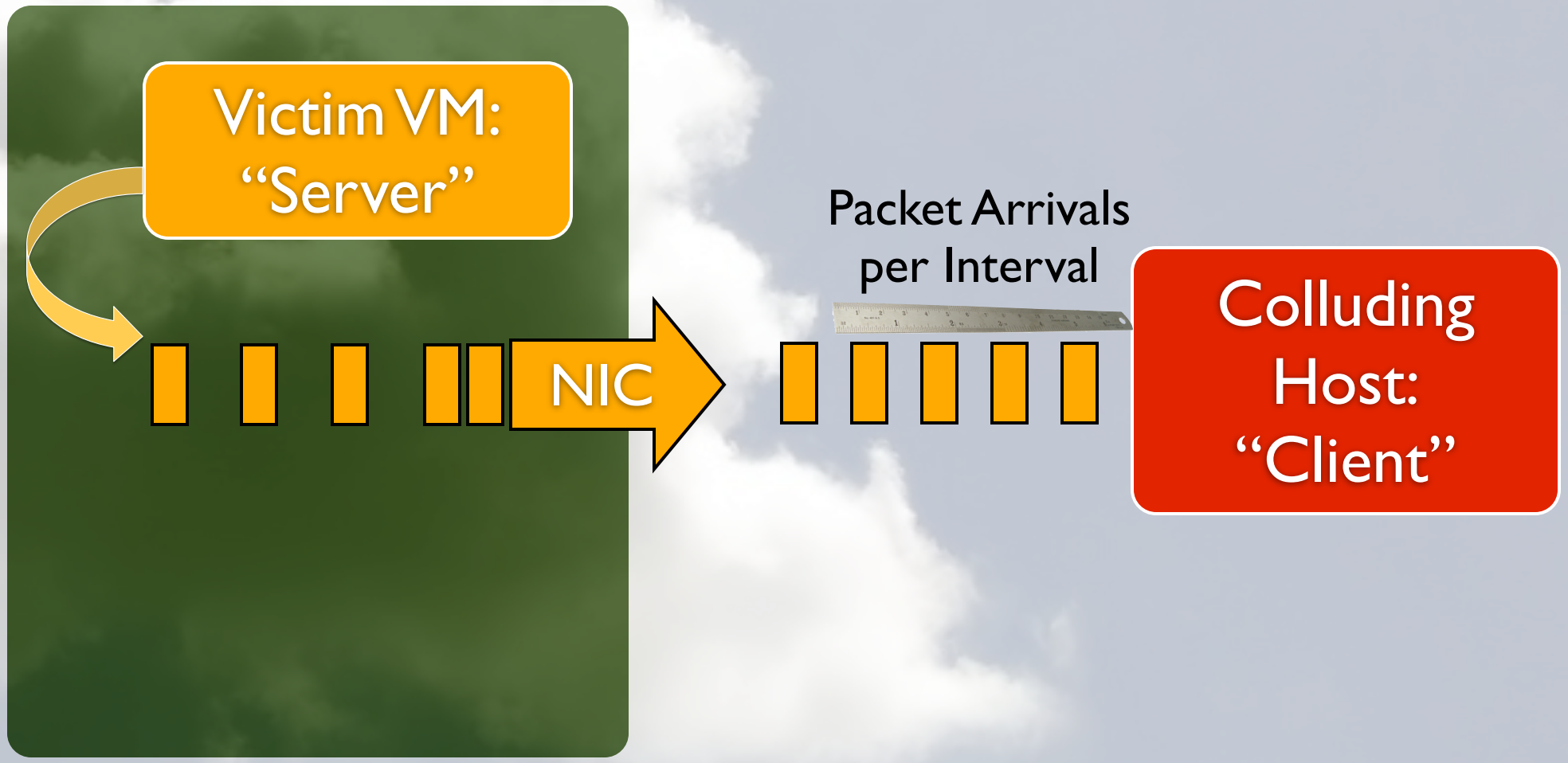
- Cloud Provider: patched all internal cross-VM side channels (e.g. L2 Cache).
- Adversary: manipulates own (legitimate) instances to find the victim's instances.
- Victim: business that runs a web-facing service.

Design: Attack Model



Design: Attack Model

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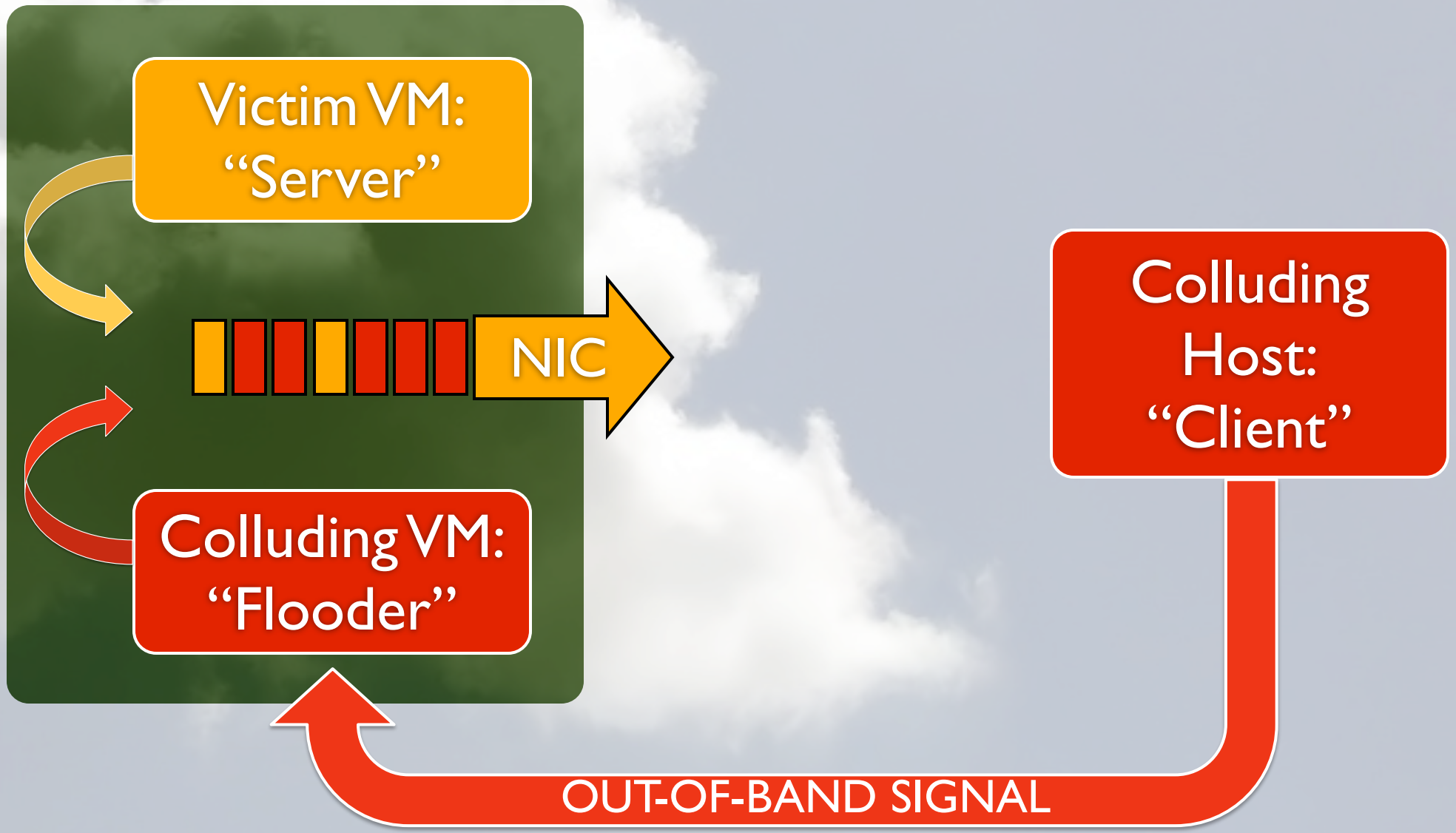

Design: Attack Model

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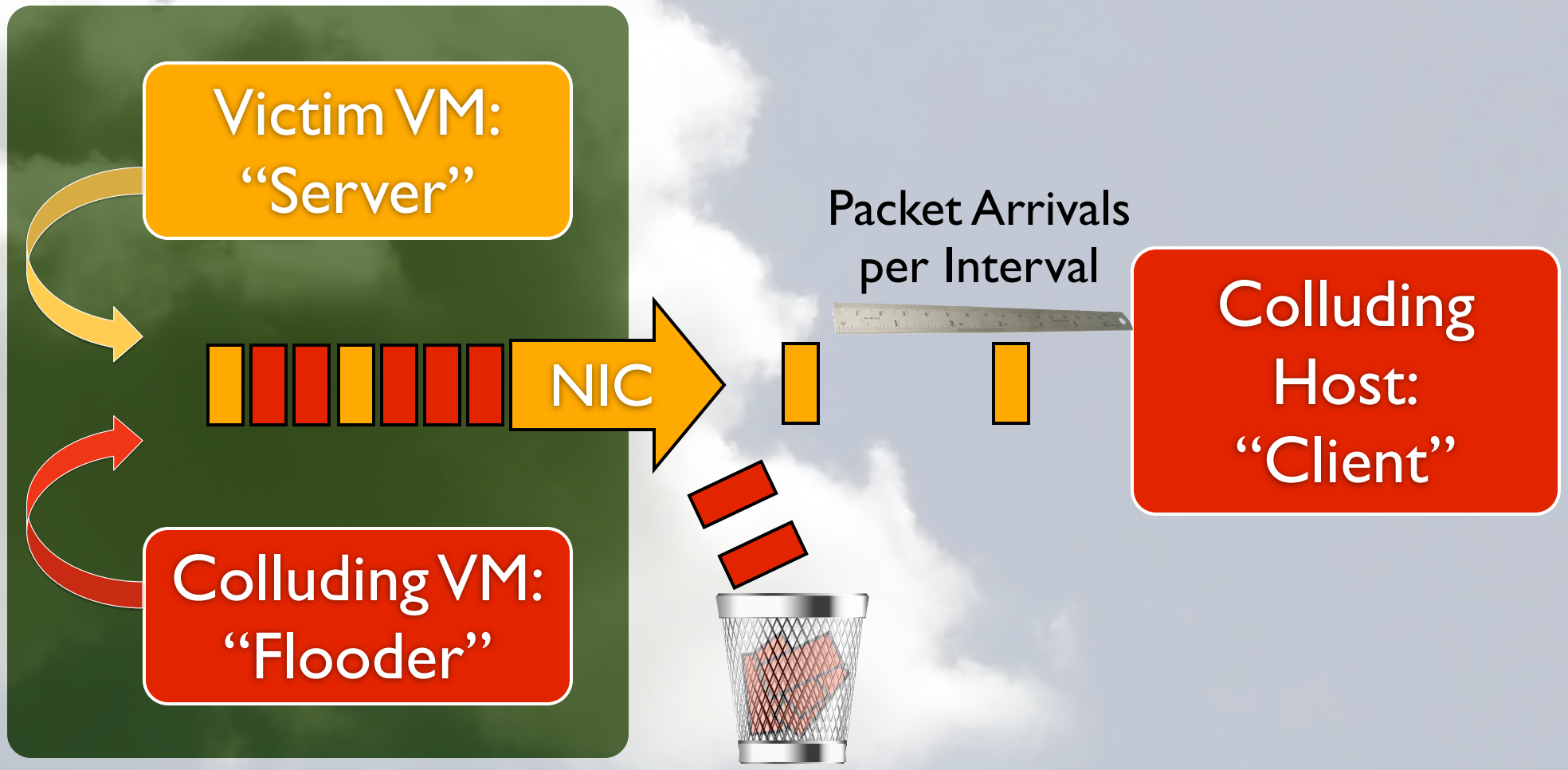

Design: Watermark Encoding

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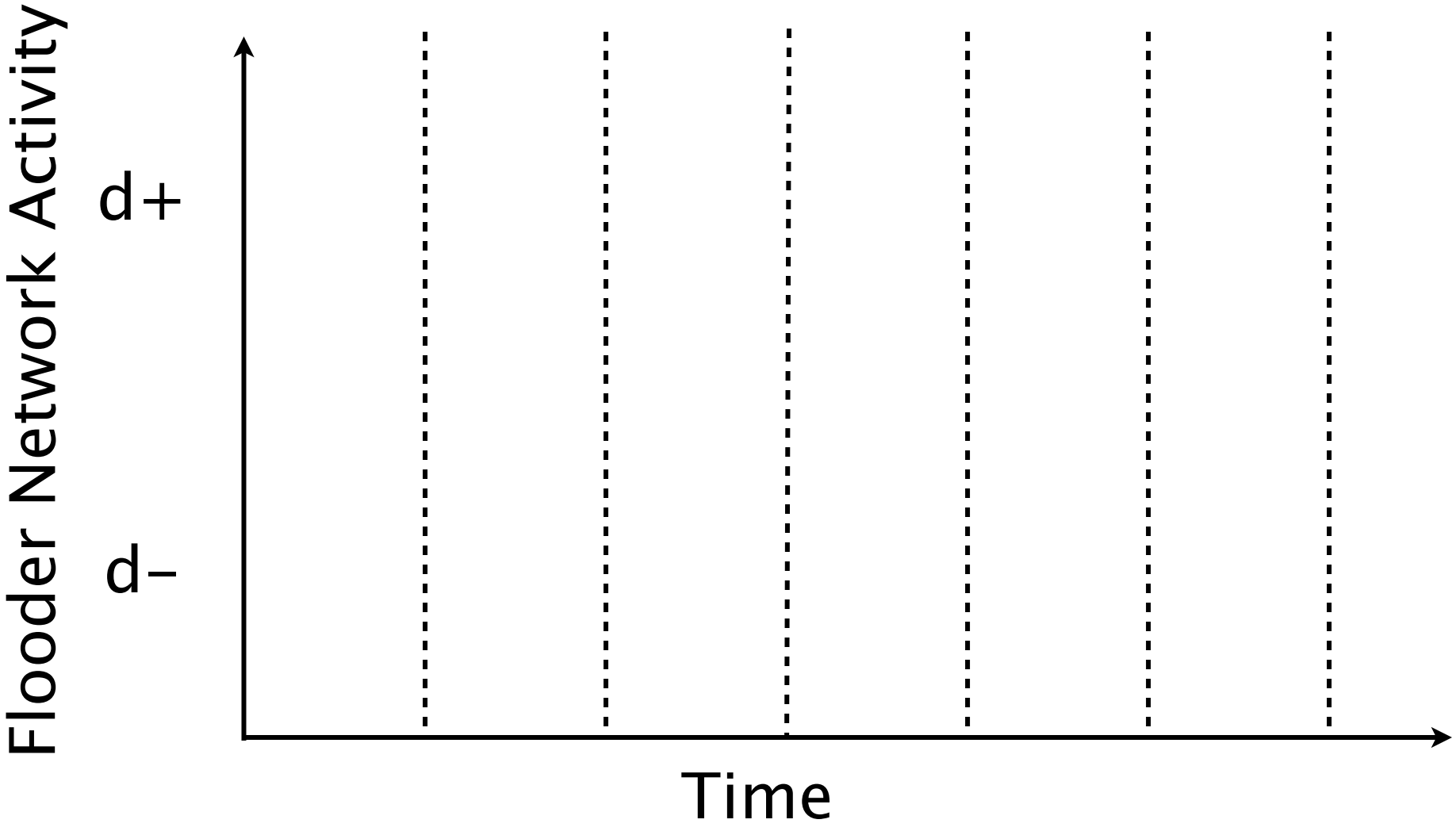

Design: Watermark Encoding

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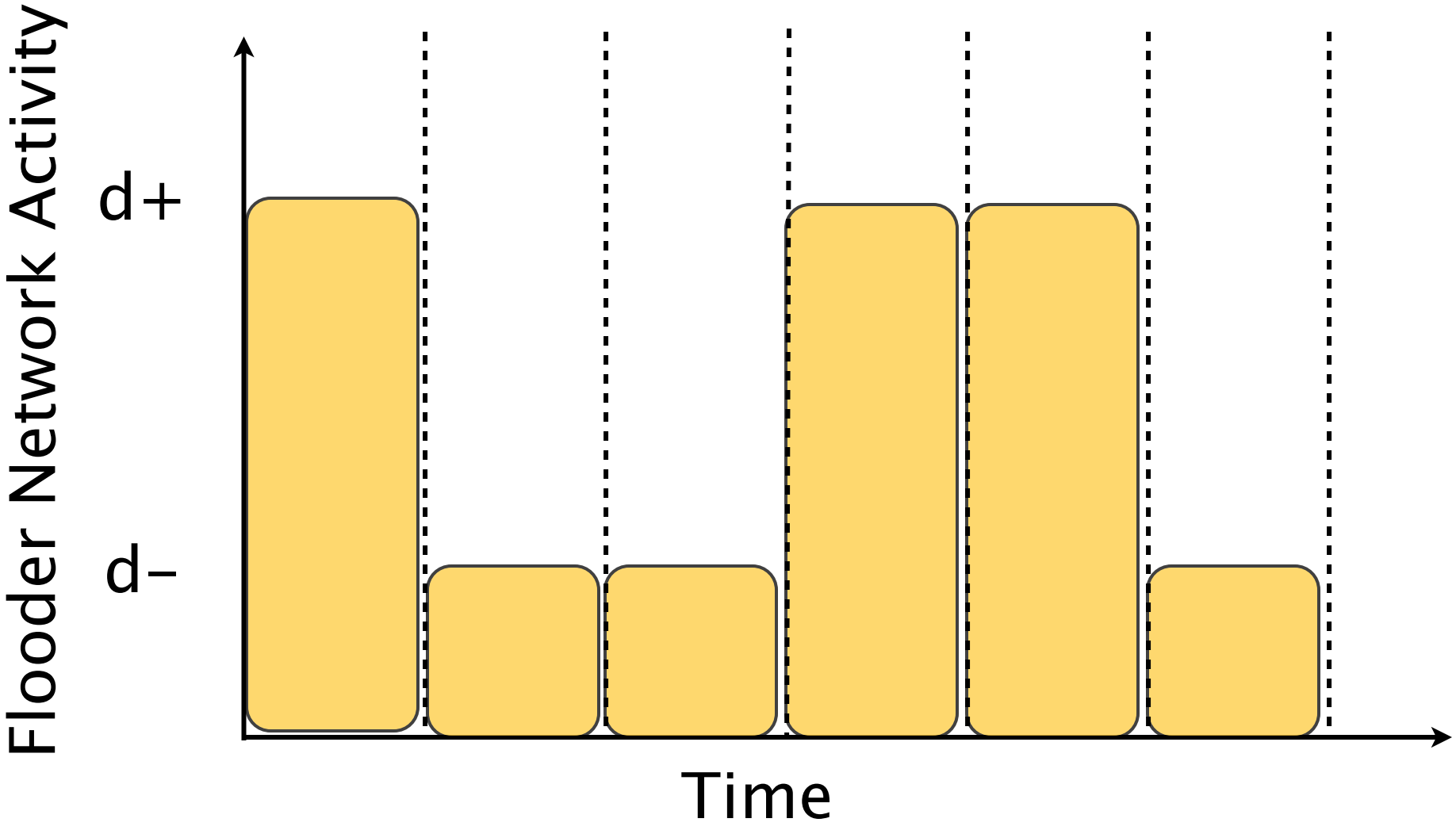

Evaluation: Goals

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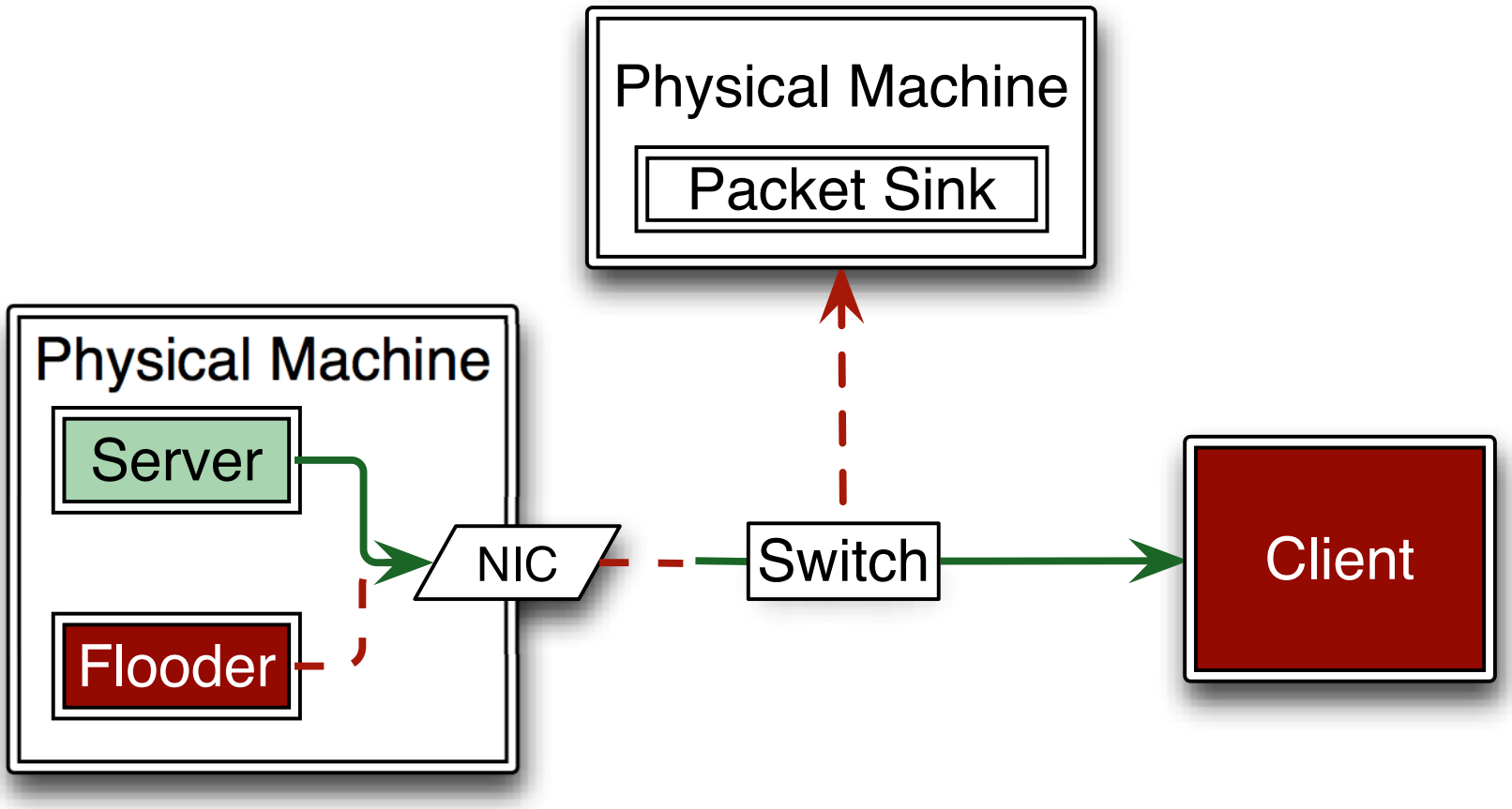
Determine if *co-resident watermarking* works...

- independent of hypervisor or network/system load
- in production cloud environments
- in adverse cloud topographies
- on advanced network devices (SR-IOV)

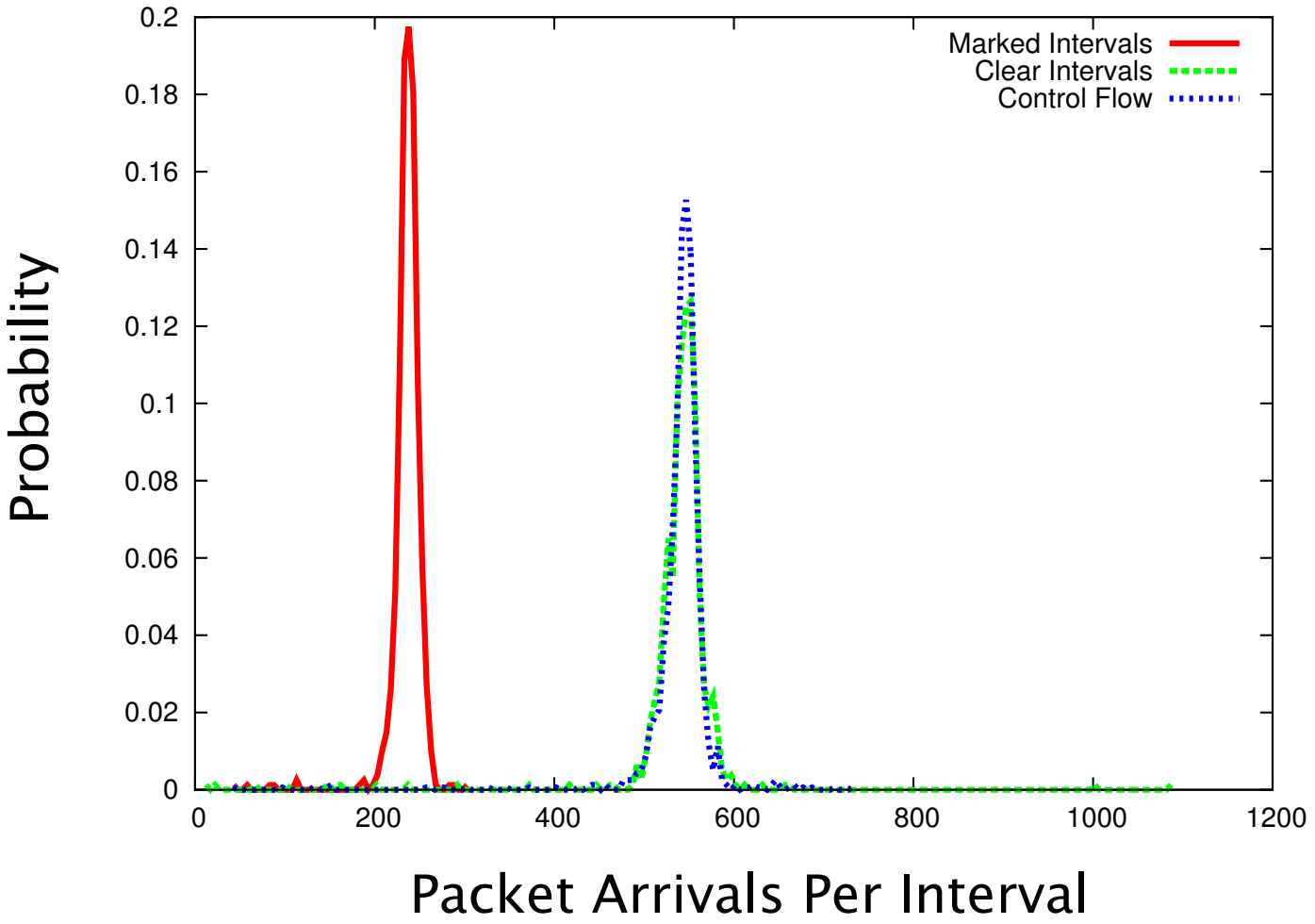
Do any conditions create false positives or negatives?

Evaluation: Participants



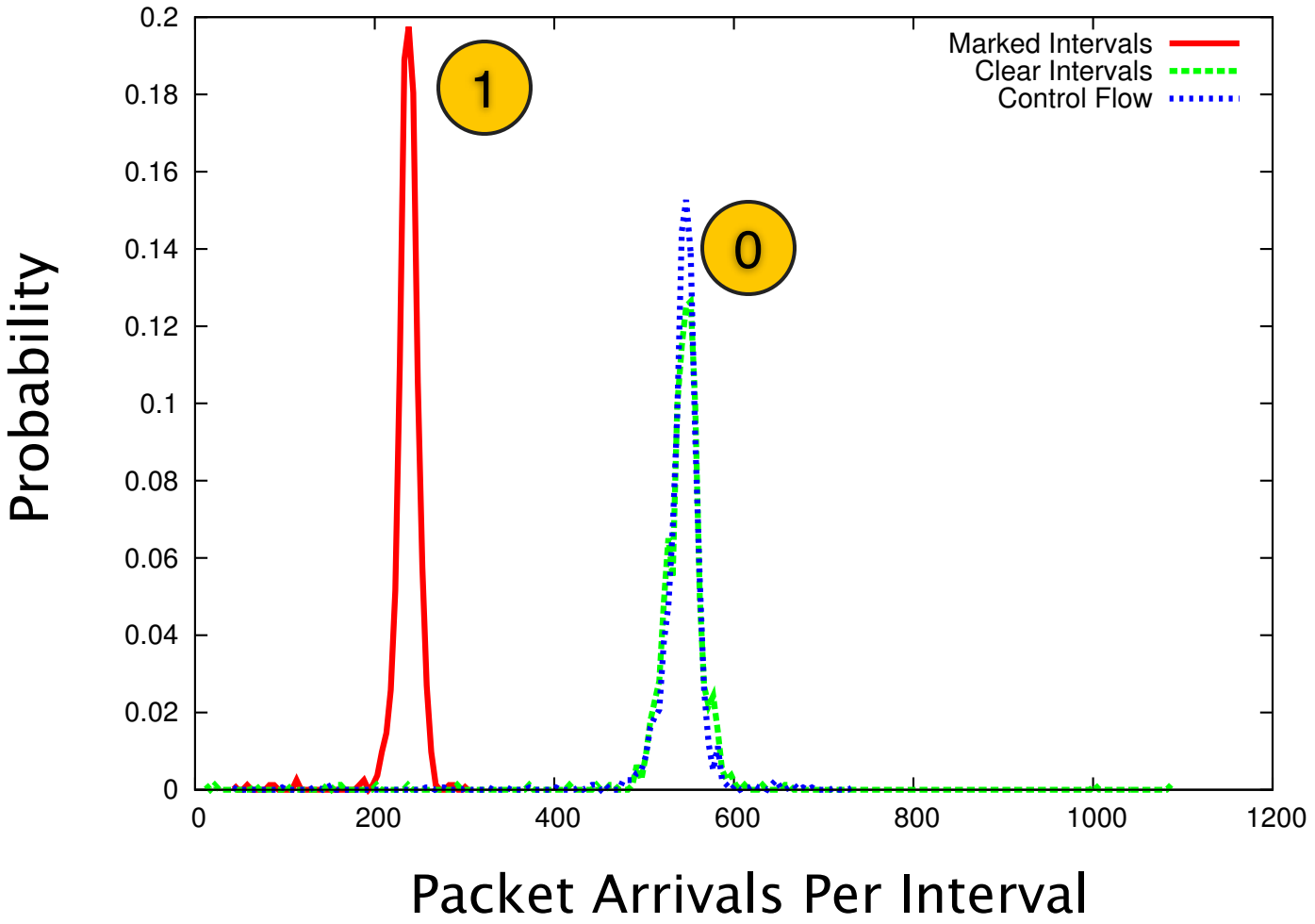
System configuration for local laboratory testbed.

Evaluation: Hypervisors



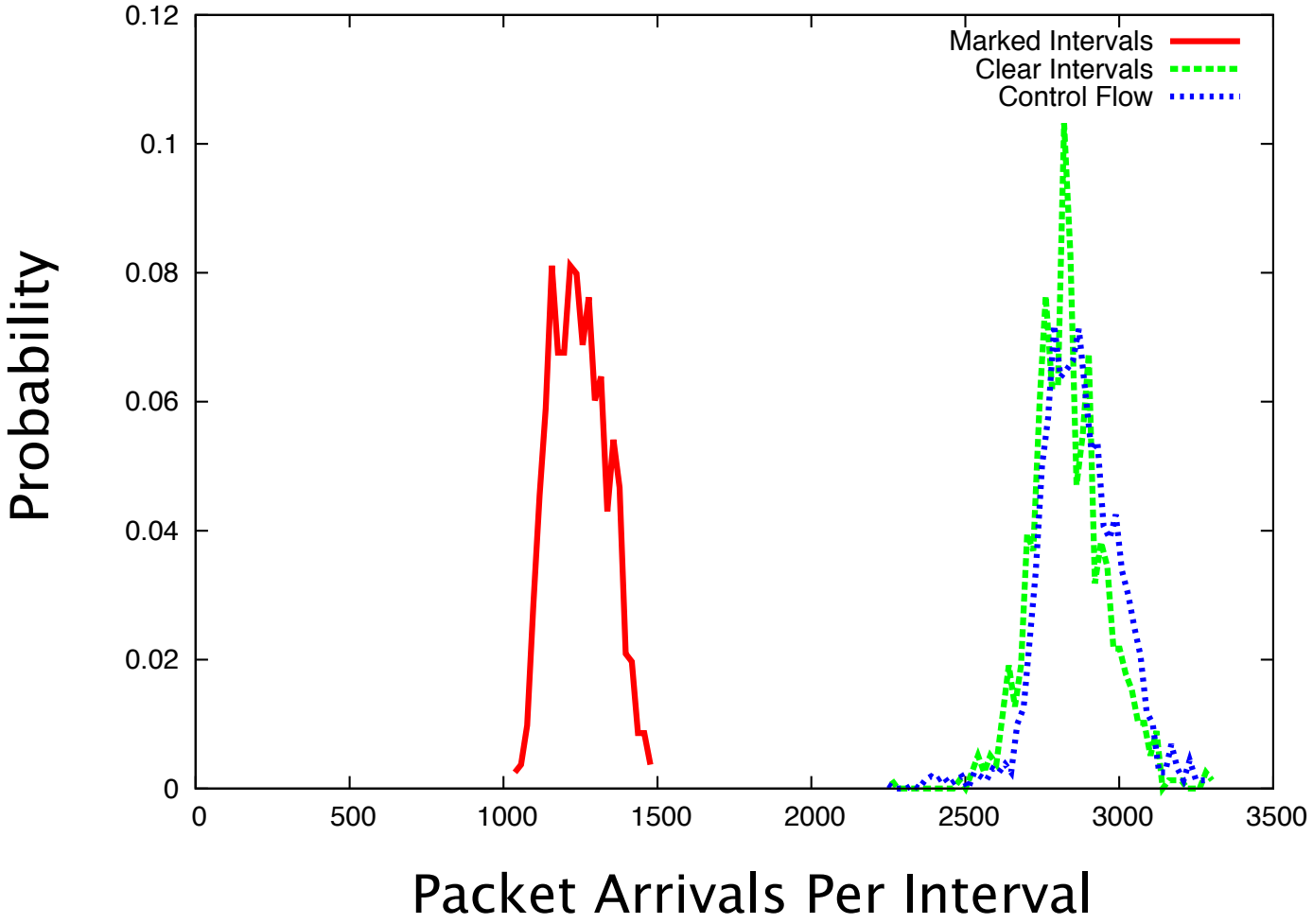
Xen

Evaluation: Hypervisors



Xen

Evaluation: Hypervisors



VMWare ESXi

Evaluation: Network State

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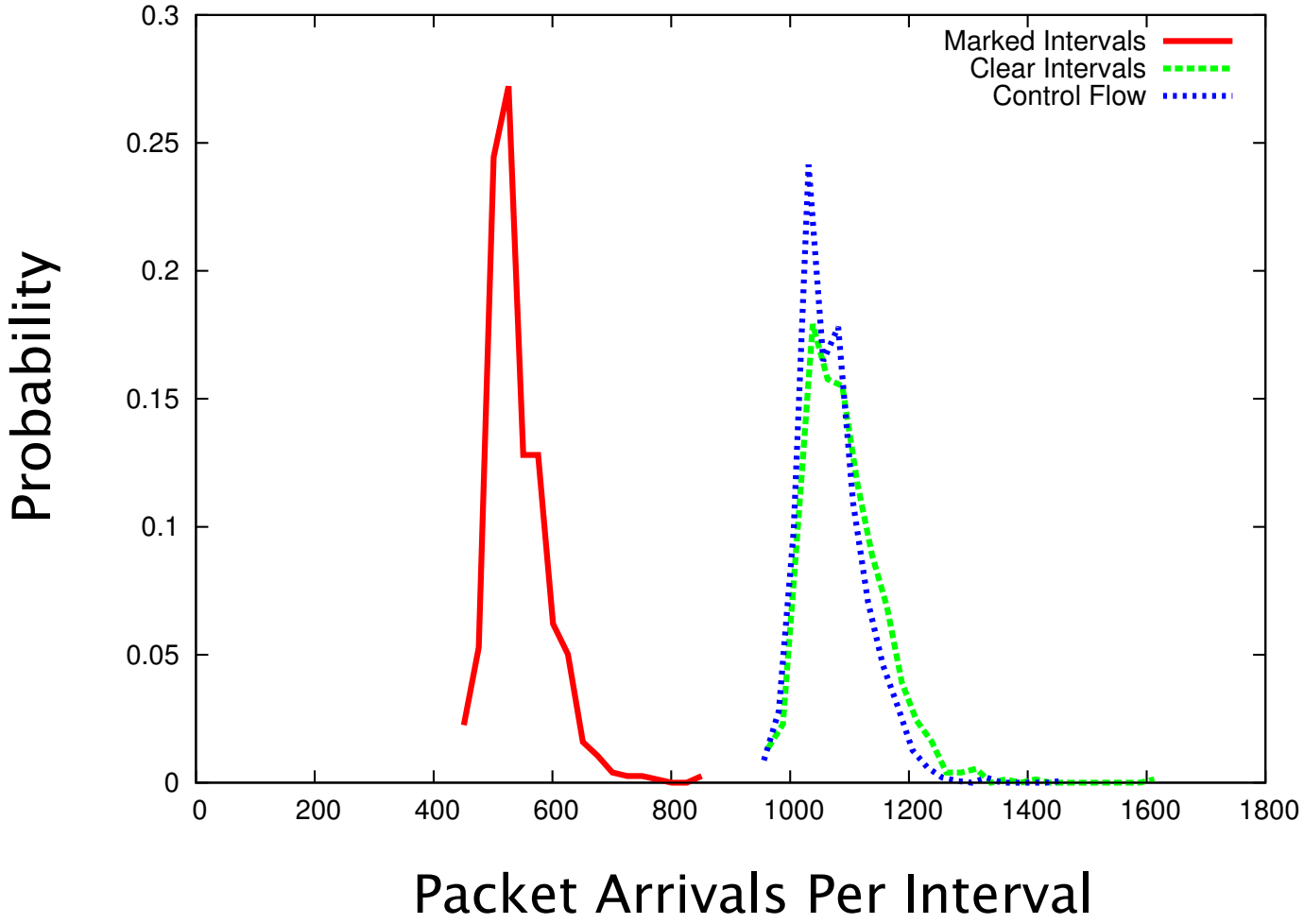
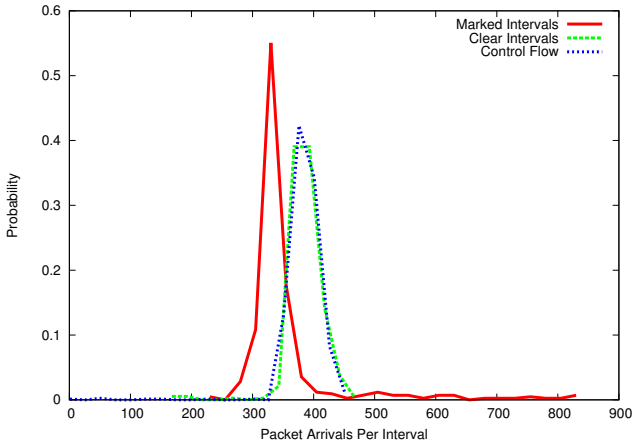
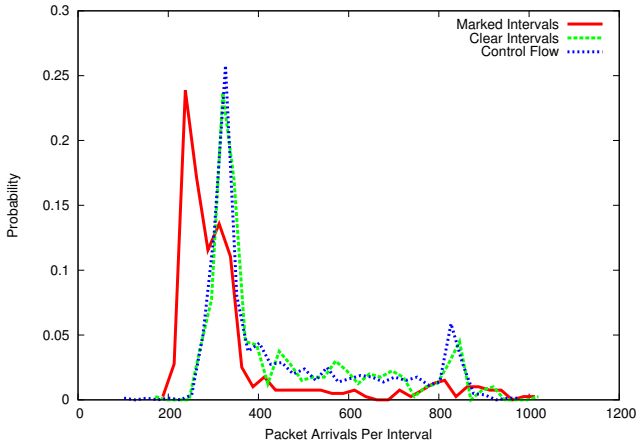


Xen, Coast-to-Coast Trial

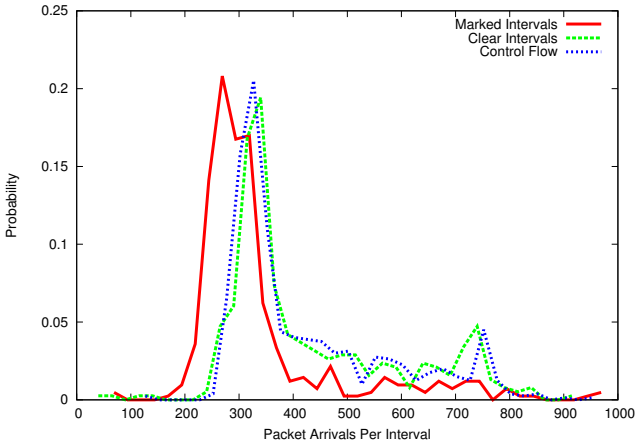
Evaluation: System Load



1 Extra Guest



2 Extra Guests



3 Extra Guests

Trial	Length	$KS_{+d,-d}$	p-val	Result
SERVER & FLOODER	2.5 *sec*	0.99	0.01	*Co-Res*
Add 1 GUEST	3.75 *sec*	0.78	0.05	*Co-Res*
Add 2 GUESTS	3.75 *sec*	0.91	0.01	*Co-Res*
Add 3 GUESTS	10 *sec*	0.49	0.05	*Co-Res*

Evaluation: 3rd Party Clouds

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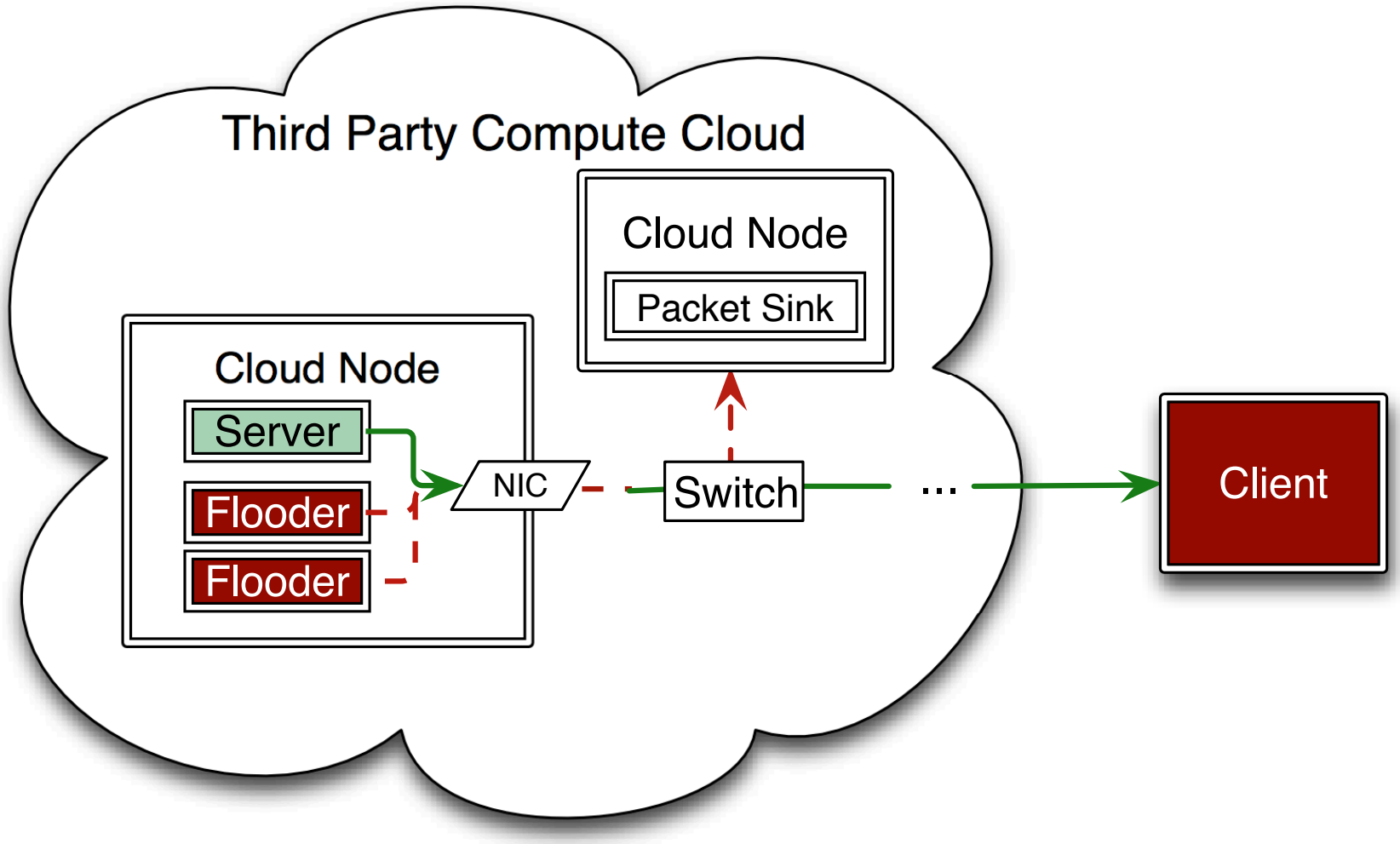
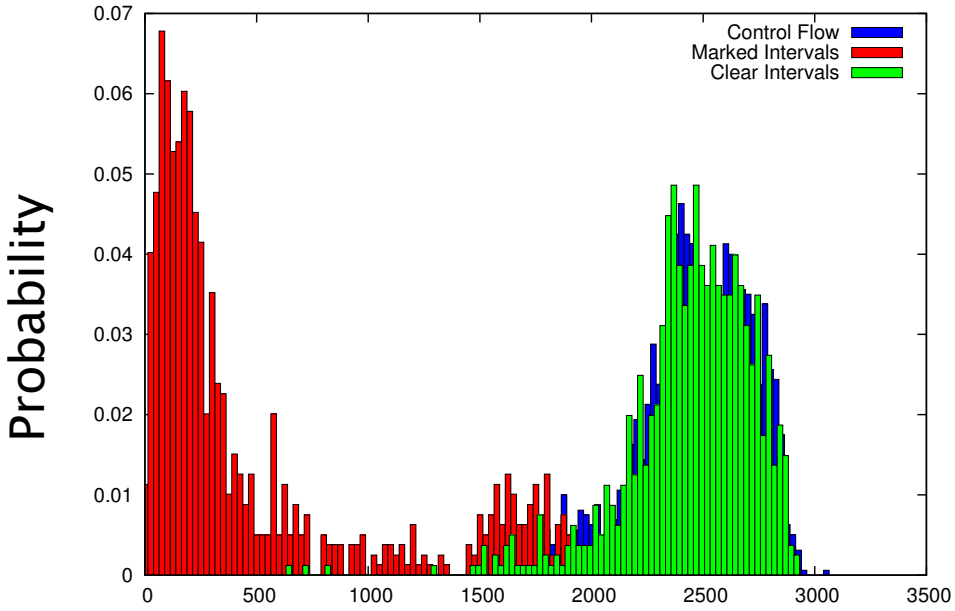
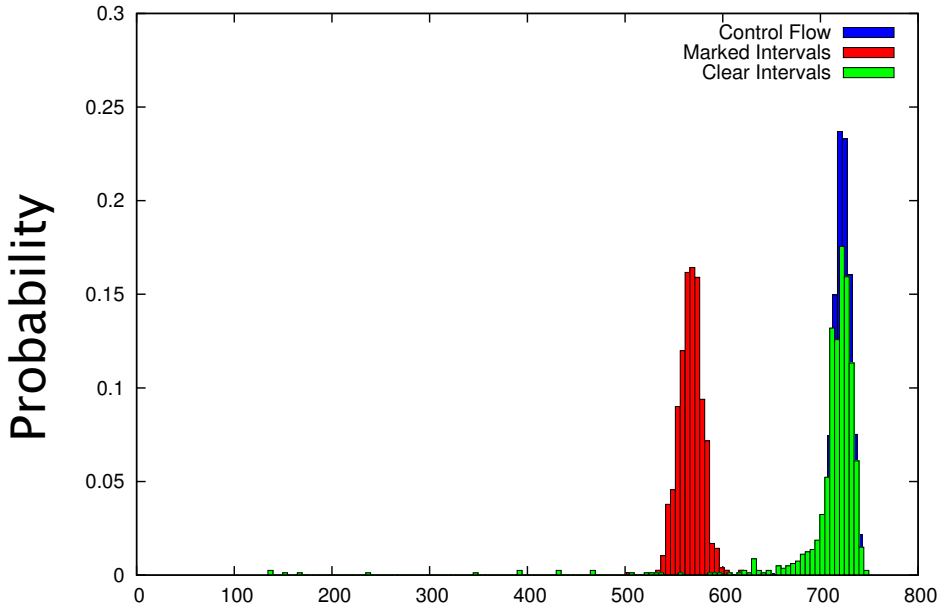


System configuration for ACISS and Futuregrid clouds.

Evaluation: 3rd Party Clouds



ACISS (KVM)



Futuregrid (Xen)

- *Co-resident watermarking* is a viable attack in production cloud environments.

Evaluation: Cloud Topography

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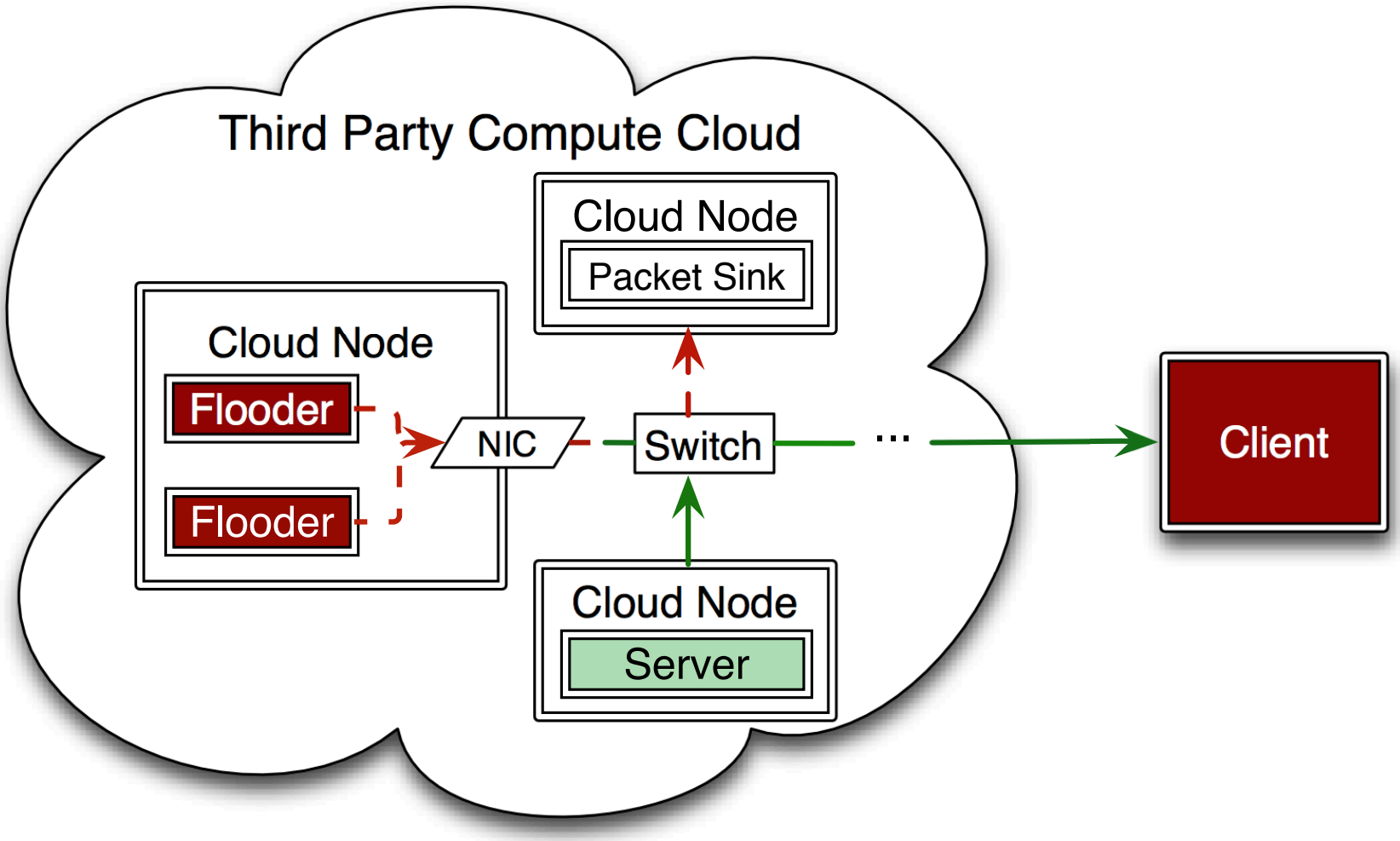
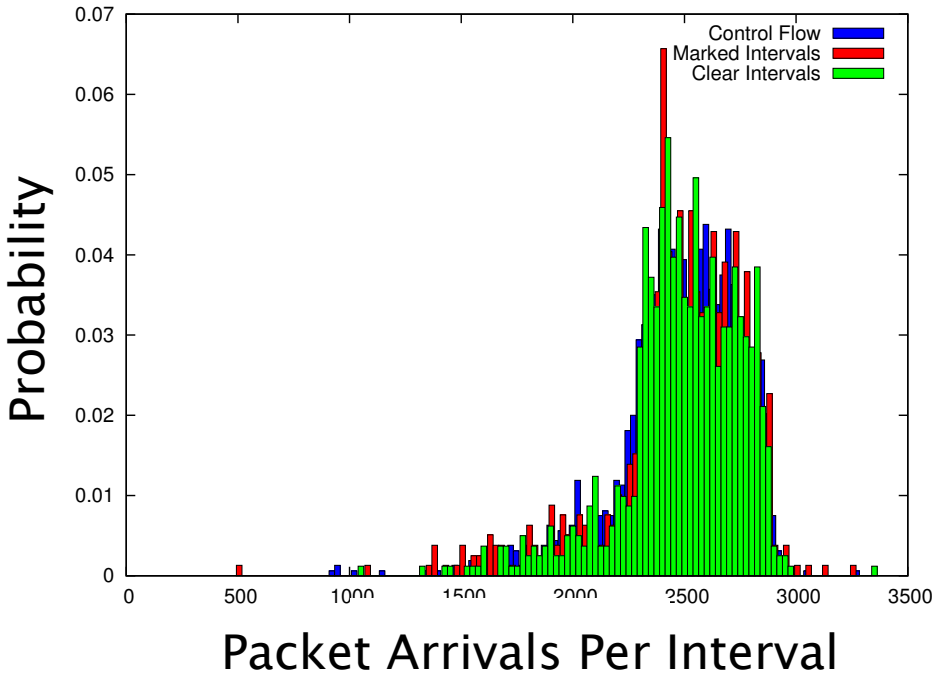
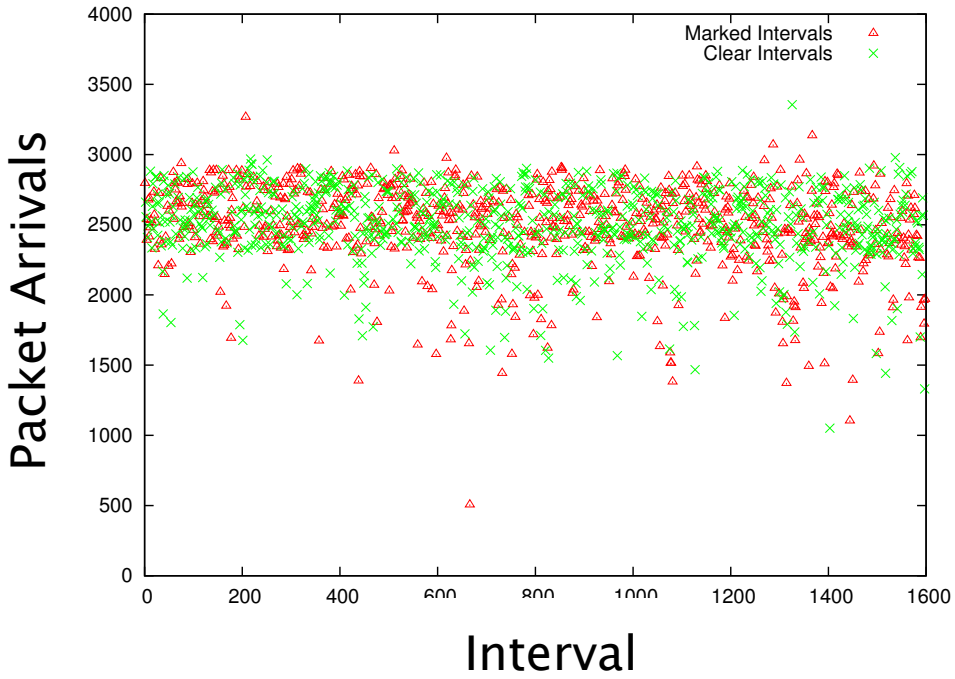


Configuration where target and adversary share first hop.

Evaluation: Cloud Topography

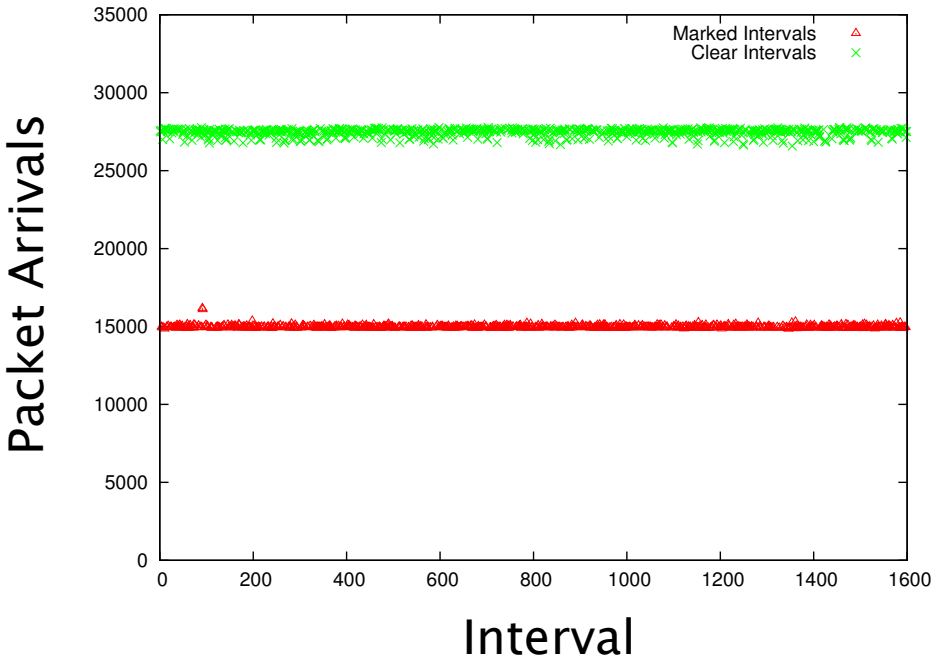




ACISS (KVM)

- *Co-resident Watermarking* does not produce false positives under adverse topographies.

Evaluation: SR-IOV Hardware



Xen, SR-IOV NIC

- Intel 10GbE Controller, SR-IOV enabled (*ixgbe*).
- Exposed virtual PCI devices that we bound to each VM.
- Pass-through technology *improved* the effectiveness of *co-resident watermarking*!

Analysis

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- So what else we can do?
  - Covert Multicast
  - Load Measurement

Analysis: Covert Multicast

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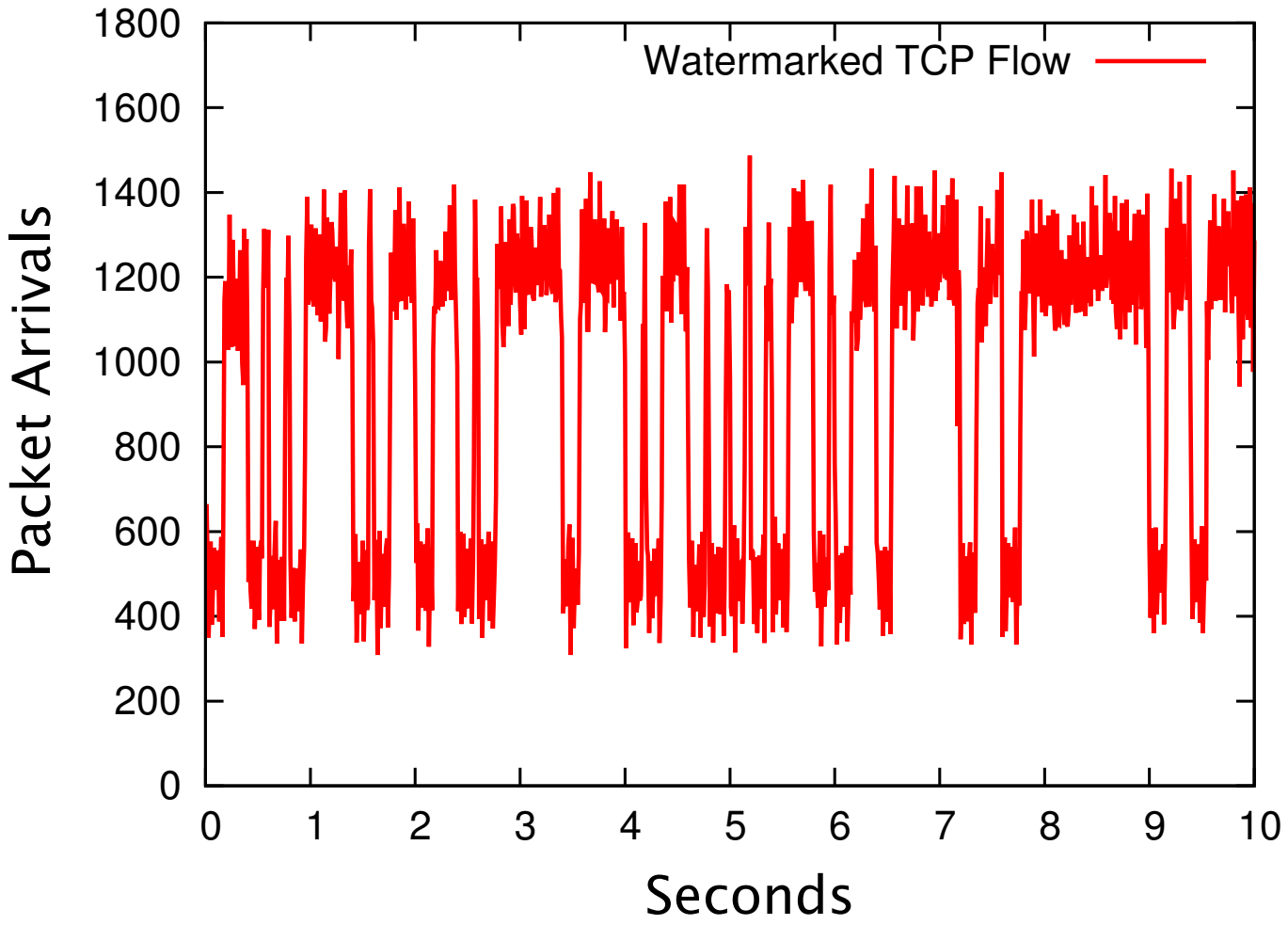
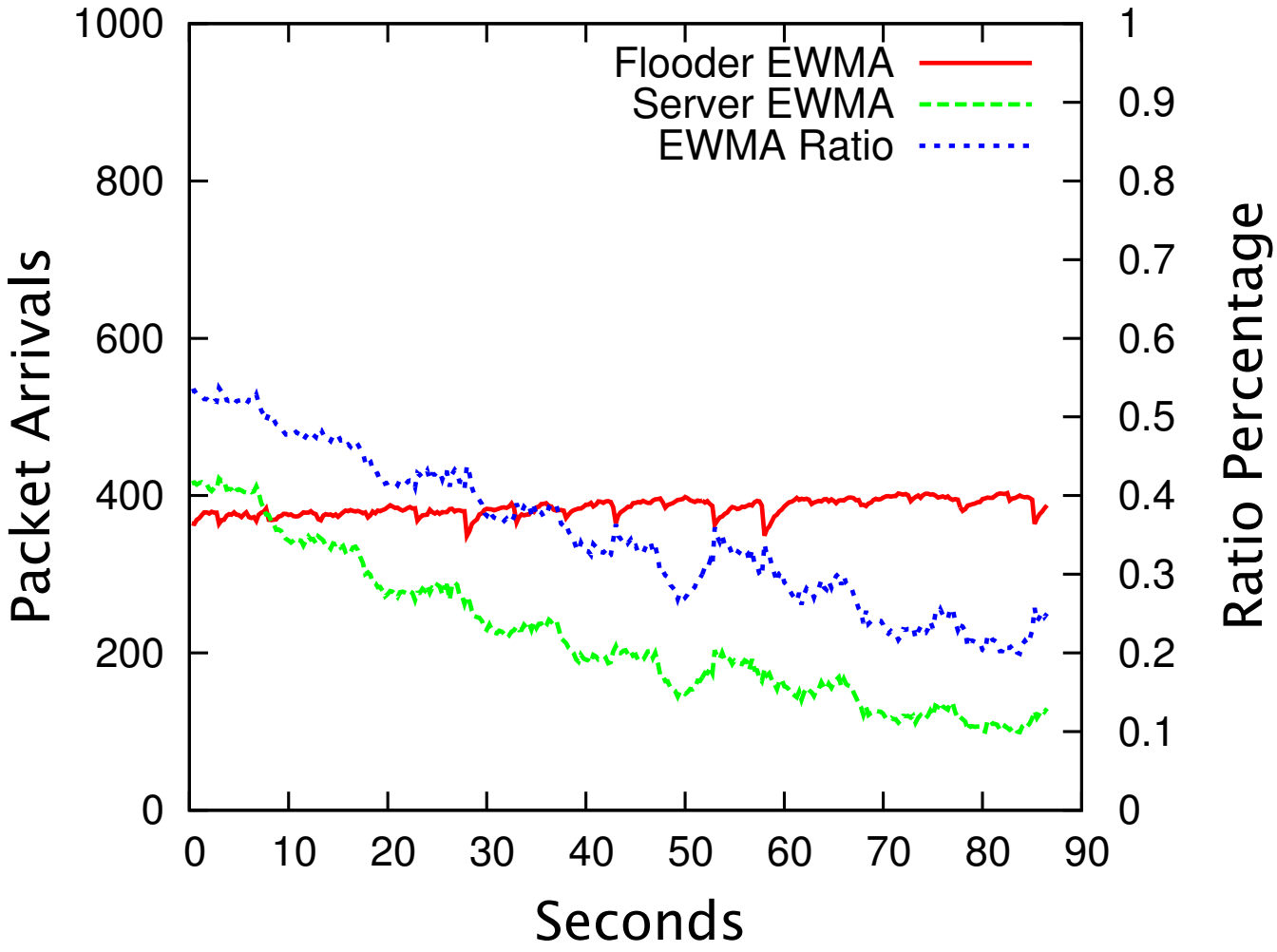


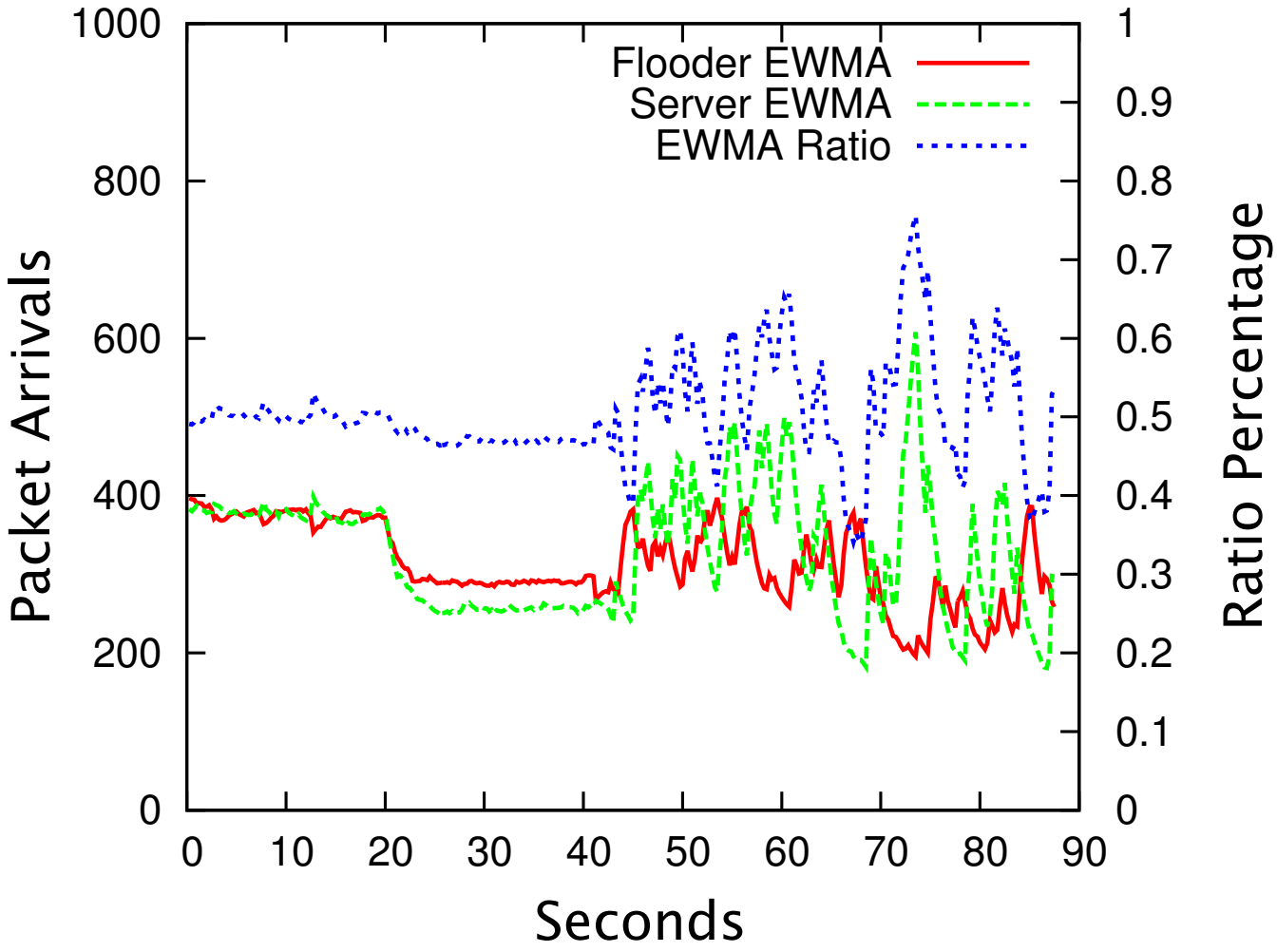
First 10 seconds of transmission of a 2048-bit key.

Analysis: Load Measurement



Flooder & Server Throughput as Server load increases.

Analysis: Load Measurement



Flooder & Server Throughput as System load increases.

Countermeasures

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- Underutilization
  - Dedicated network paths for each VM
  - Overprovision NIC's
  - Cap VM bandwidth
- L2 Cache defenses: equate to time-division multiplexing, another form of underutilization.
- Randomization: adverse effects on TCP performance.

Future Work

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- Implement an invisible network flow watermarking scheme for co-resident VMs.
- Use cross-VM network flows to profile internal conditions of cloud provider.
- Repeat trials successfully on Amazon EC2.

Conclusion

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- Co-resident watermarking exploits network flows to break virtual machine isolation.
  - 10 seconds or less for an accurate decision (Heuristic).
  - Effective independent of hypervisor, hardware, cloud state.
  - Works in production cloud environments.
- This preliminary work on the cross-VM network flow side channel underscores the difficulty of providing isolation in compute clouds.

Questions?

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