Pacer: Comprehensive Network Side-Channel Mitigation in the Cloud

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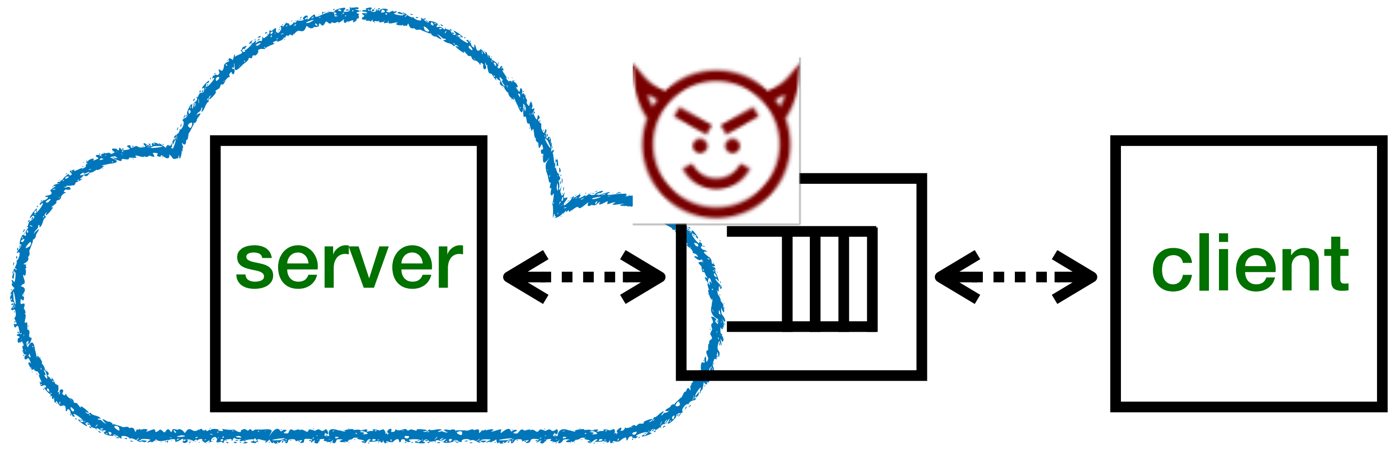
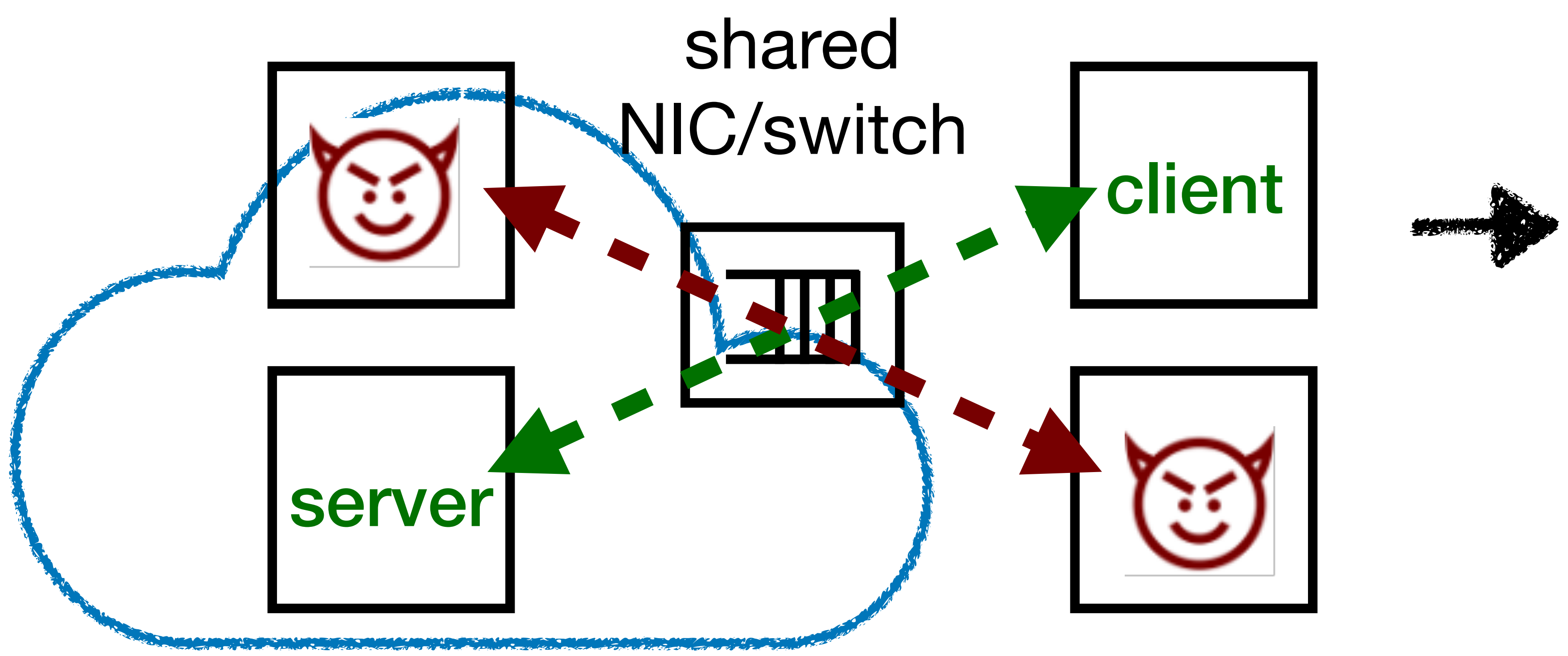
Network side channels

Step 1: Observing victim's traffic shape

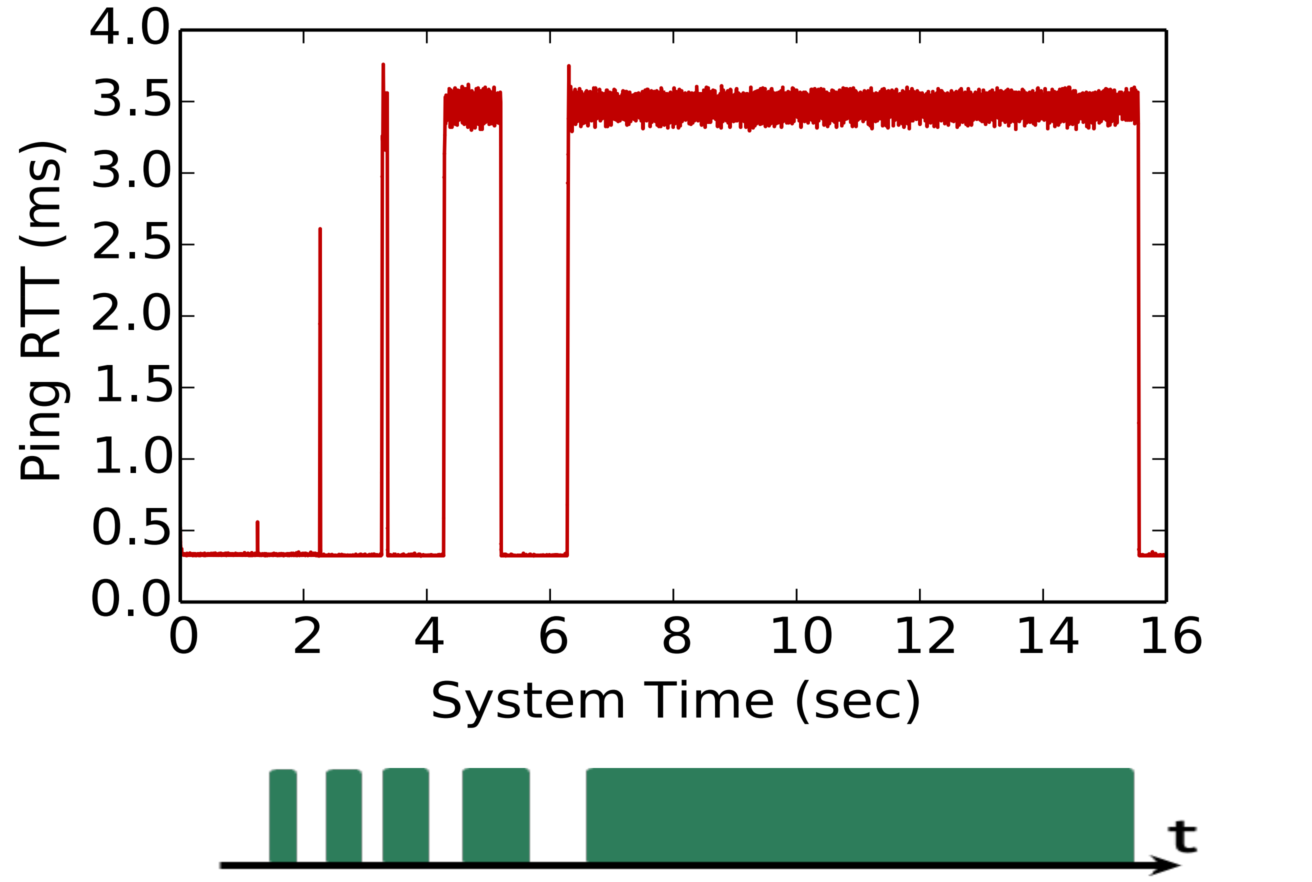
A. Direct observation at a link



B. Contention at a shared link



Adversary's timing measurements



Adversary can infer victim's traffic shape (burst sizes, timing)

Step 2: Inferences from traffic shape

- Traffic content (web pages[PETS02], VoIP[S&P08], videos[Security17])
- Users' medical, financial secrets[S&P10]

Pacer: Key ideas

Cloaked tunnel abstraction ensures secret-independent traffic shape by design

Paravirtualized implementation for IaaS clouds

Batched transmission scheduling masks architectural side channels

In the paper:

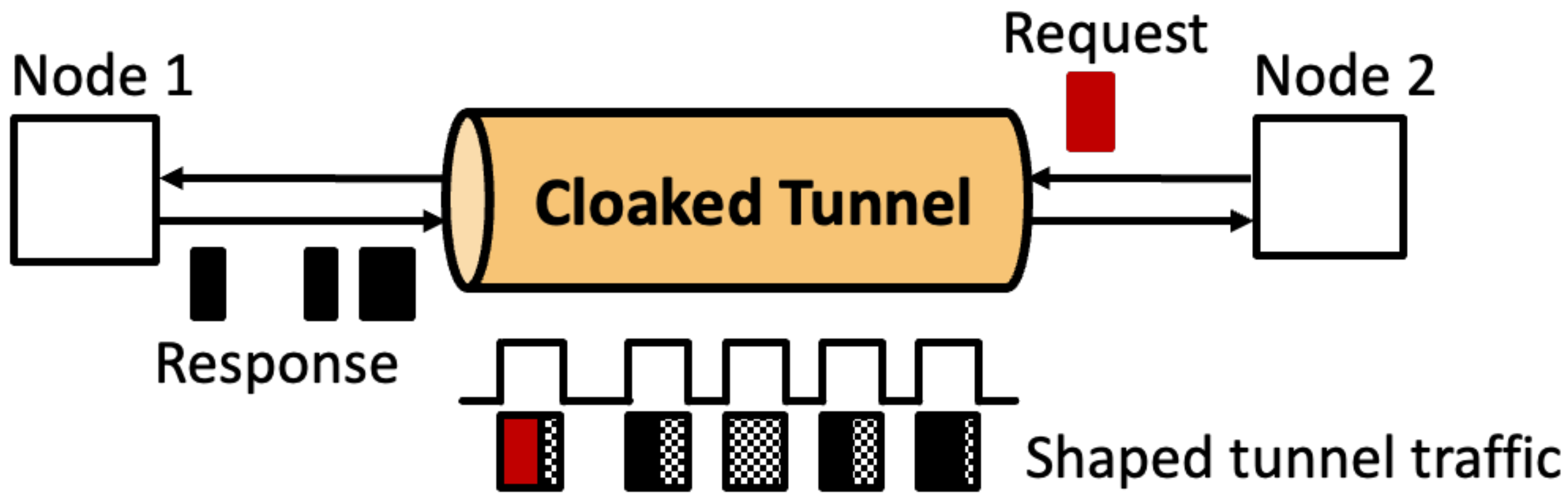
Exploiting public inputs to efficiently shape bursty traffic

Graybox profiling to automatically compute efficient traffic shapes

Detailed evaluation results

Formal proof of security

Key abstraction



Key property: Shape of the tunnel traffic is independent of secrets

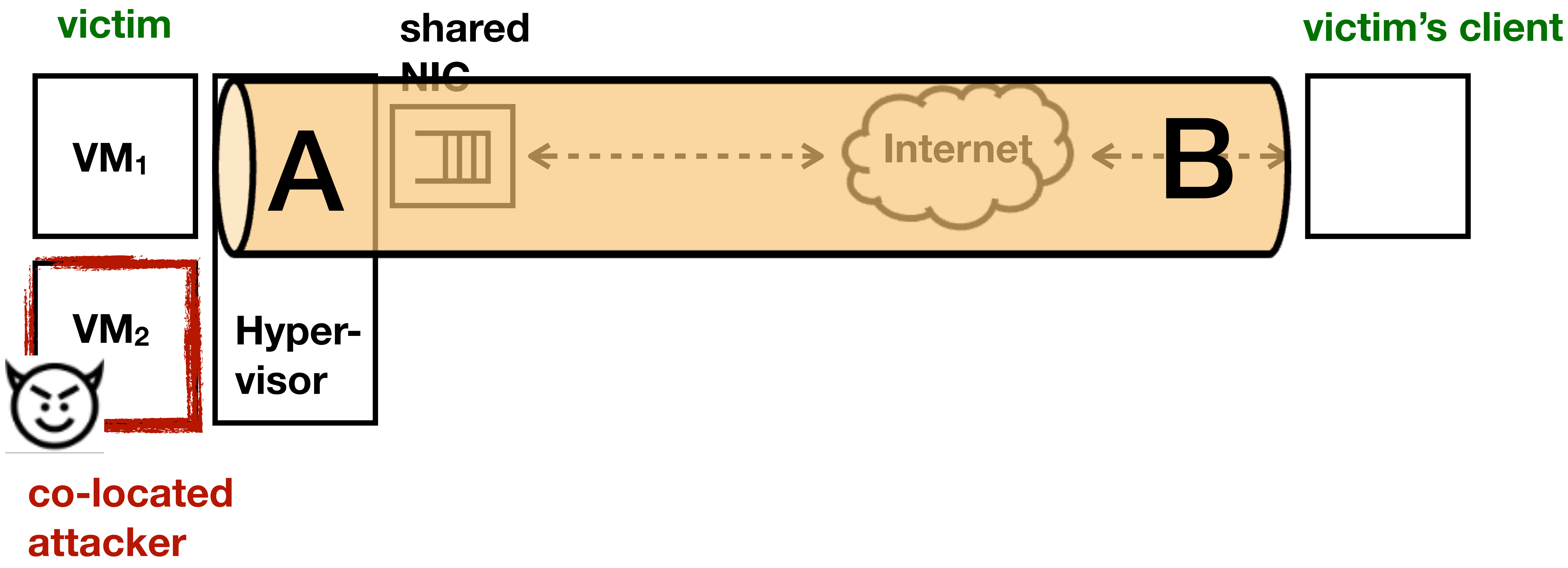
Unobservable payload

- Hide flow control
- Encrypt all packets to hide padding
- Elicit same response for padding and payload

Secret-independent timing

- Transmit on schedule
- Must not be delayed by secrets

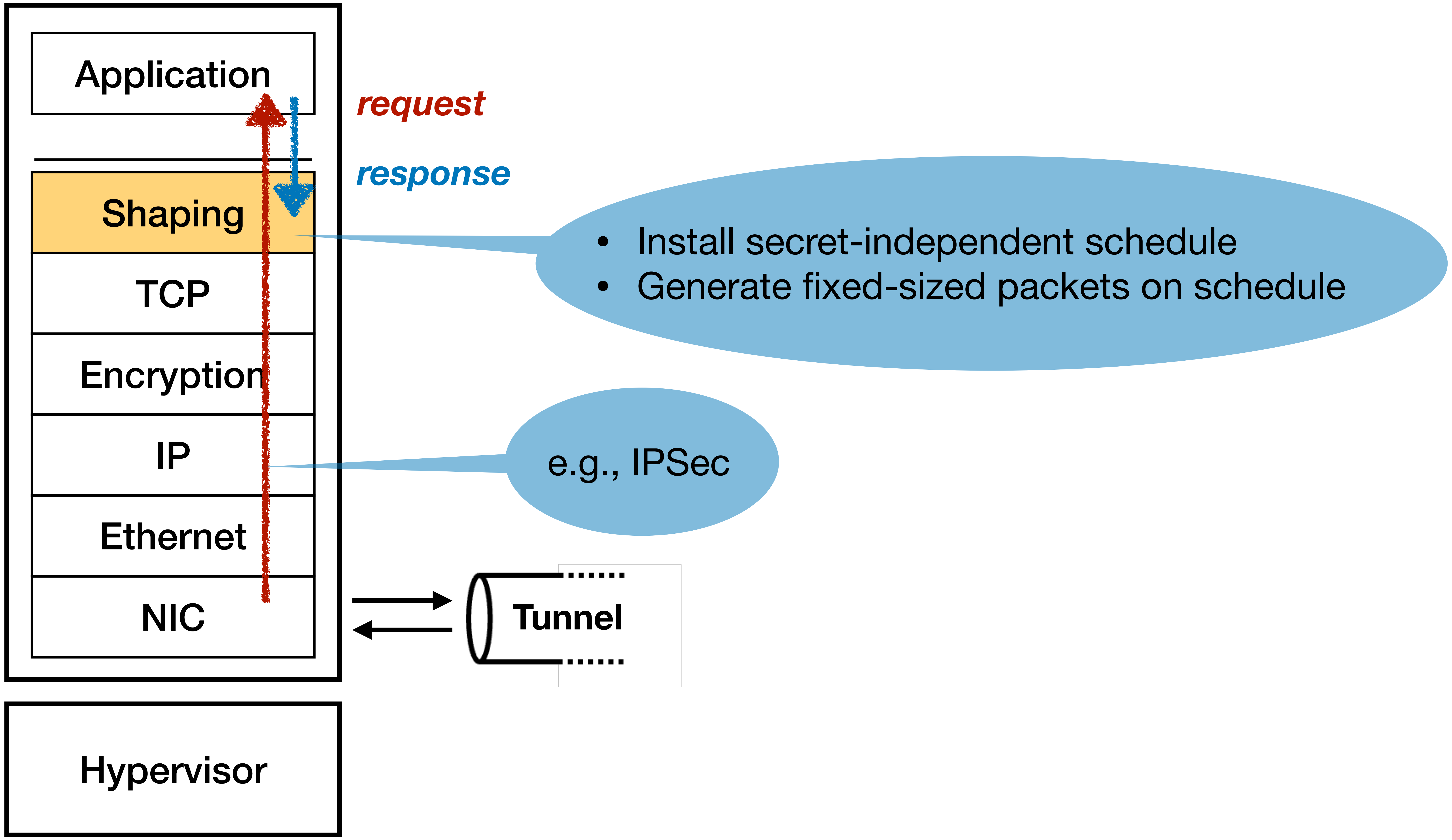
Tunnel endpoints for Cloud tenants



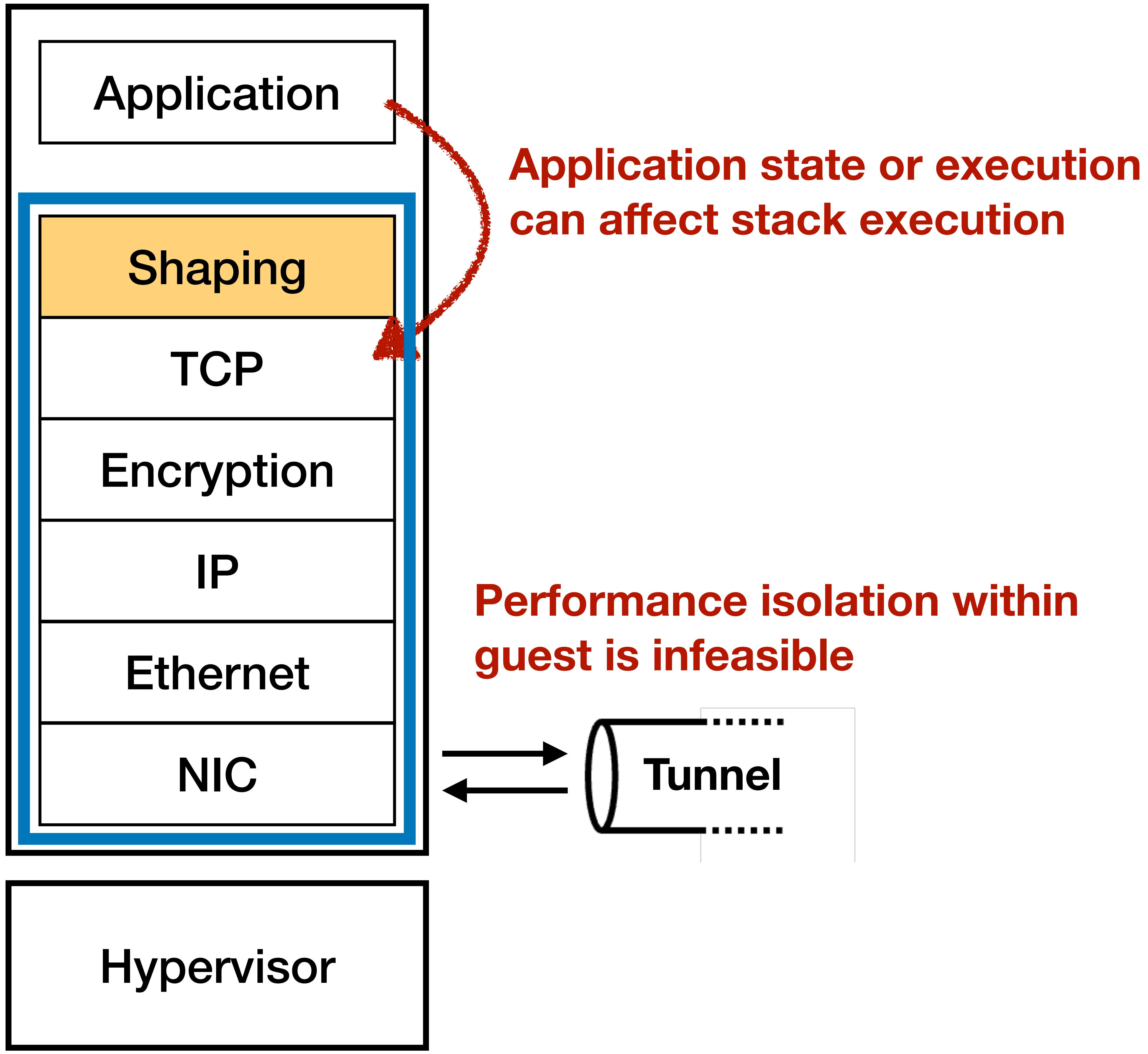
Endpoint A integrated with VM host

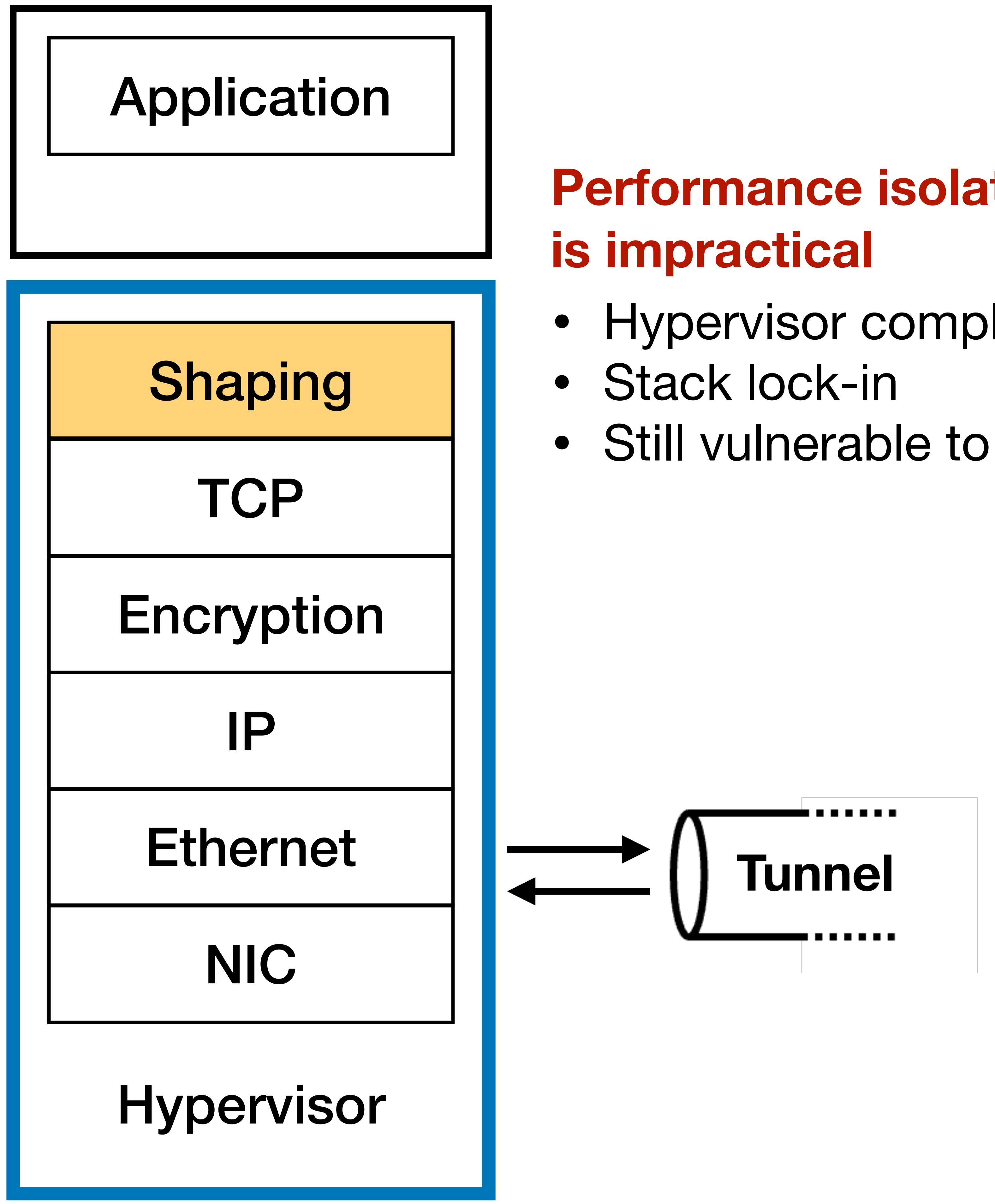
Endpoint B on client device or premises

Endpoint architecture (conceptual)



Challenge: timing delays

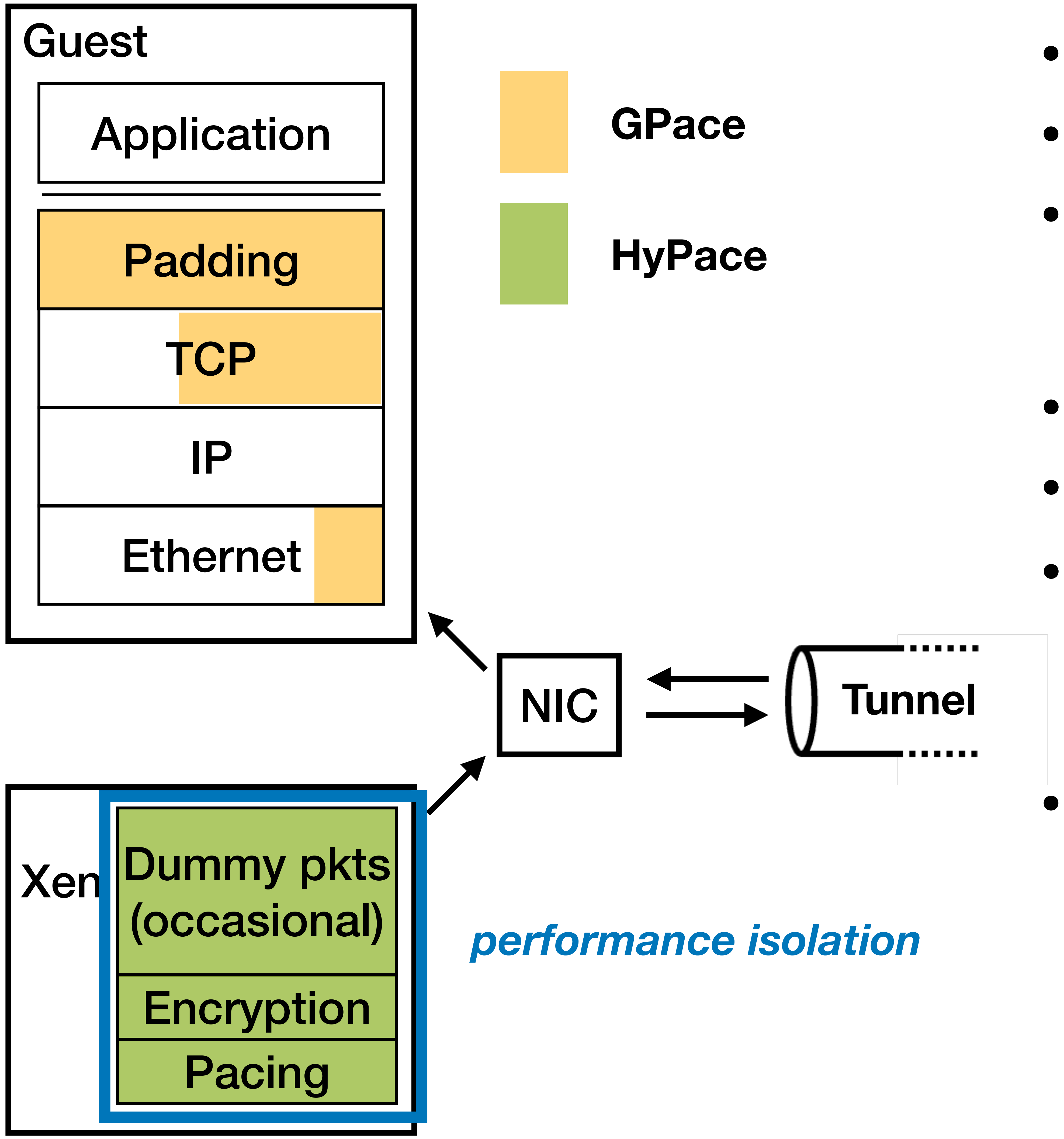




Performance isolation in HV is impractical

- Hypervisor complexity
- Stack lock-in
- Still vulnerable to side channels

Pacer's cloaked tunnel



Unobservable payload

- End-to-end padding
- All packets with valid TCP seq#
- Encryption after padding

Secret-independent timing

- Transmit packets on a schedule
- Mask secret-dependent delays in HyPace
- Transmit fixed batch of packets in each interval

- Respects congestion control (practical requirement)

Evaluation

Security:

- Accuracy of CNN attack classifier
- Formal model and proof of HyPace

Performance:

- Bandwidth vs privacy overheads for static content
- Client latency, throughput of a medical website
- Streaming experience from a multi-tier video service

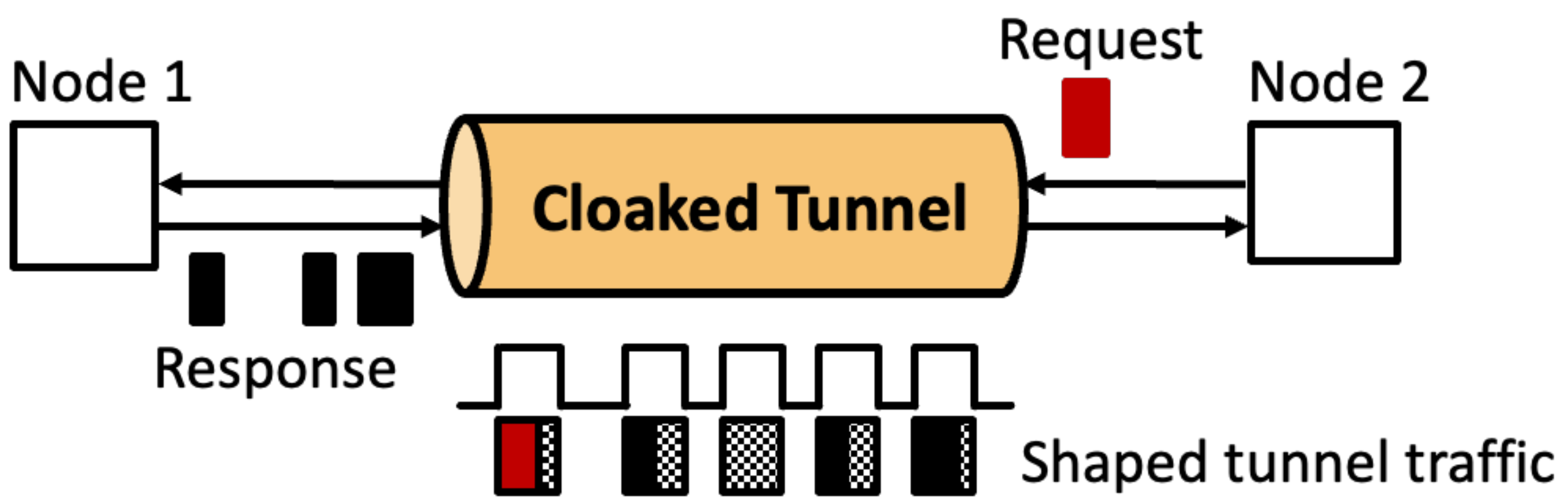
Application overheads

Metric/Application	Medical	Video
Average bandwidth overhead	143%	4x
Latency overhead	10x – 18x	1-tier: 30x 2-tier: 400x
Peak throughput overhead	14.4%	NA

No jitter at client-side

Overheads depend on application's data, workloads, and public inputs

Summary



✓ **Secure by design**
Secret-independent traffic shapes
Masking secret-dependent delays

✓ **Efficient and practical**
Public input-dependent shaping
React to congestion control

✓ **Usable**
Minimal changes to application
Modest changes to hypervisor and guest OS

Code:
https://gitlab.mpi-sws.org/pacer