Fast checkpointing with criu-image-streamer

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Two Sigma

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Google Preemptible VMs
Up to 5x cheaper
30sec eviction deadline

16 CPUs, 128GB RAM, 2GB/s Network
Goal: **Checkpoint in 30s**

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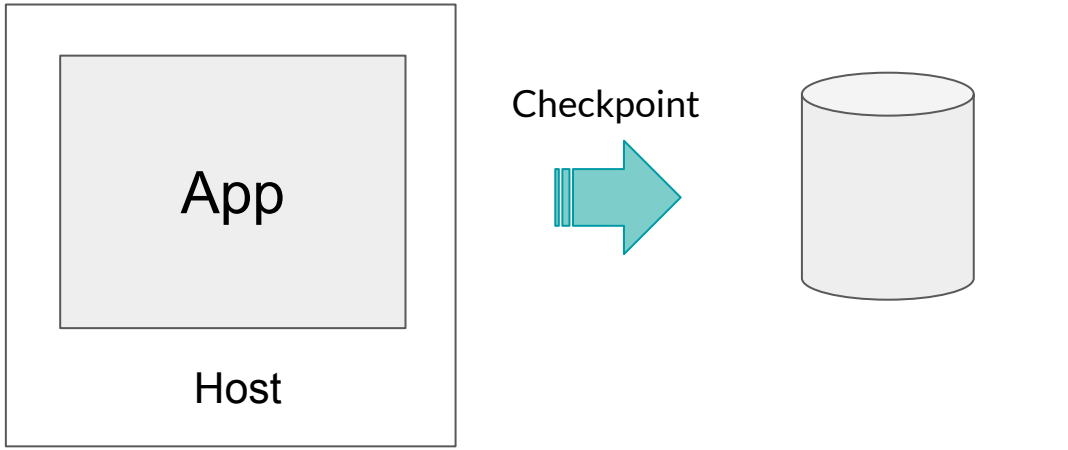
Goal: **Checkpoint in 30s**

128/30 = 4.2GB/s


SHOEI

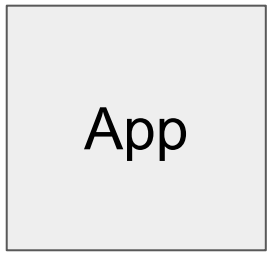
Problem: Fast checkpointing



Running Application

Remote Storage
AWS S3, GCS

Checkpointing: the old way



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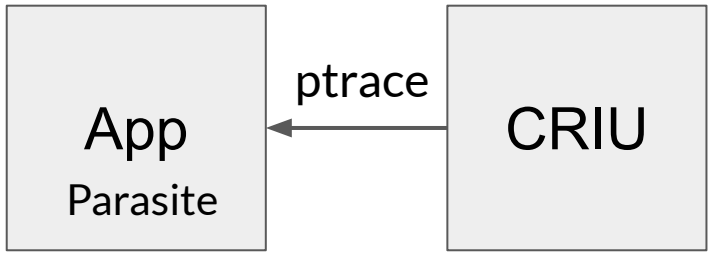

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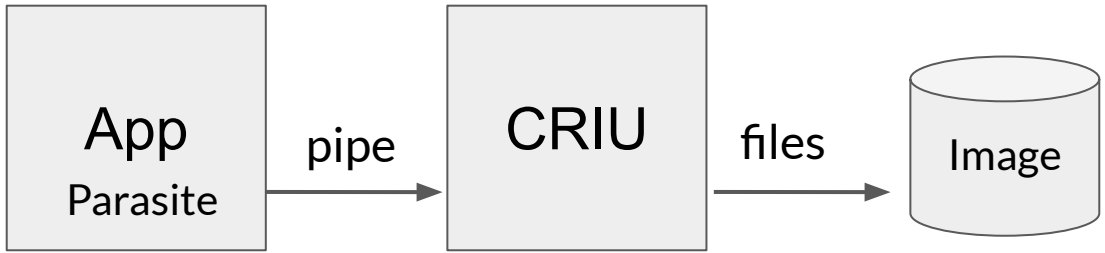

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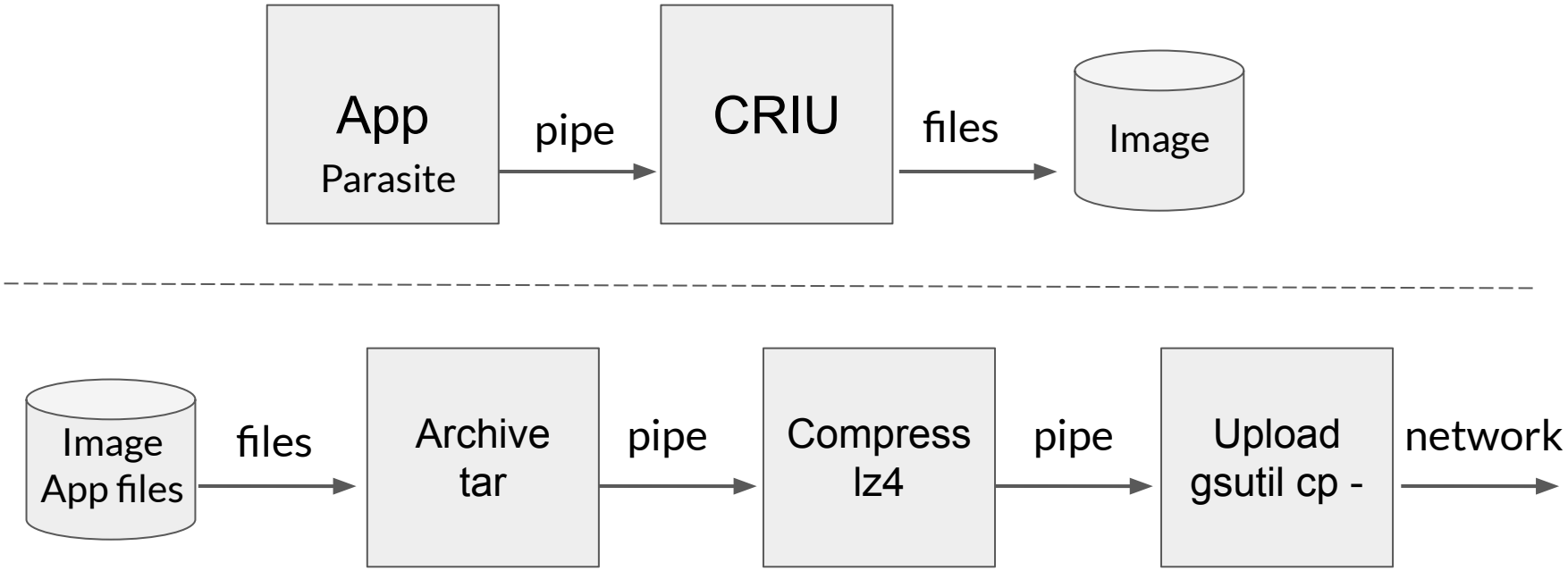

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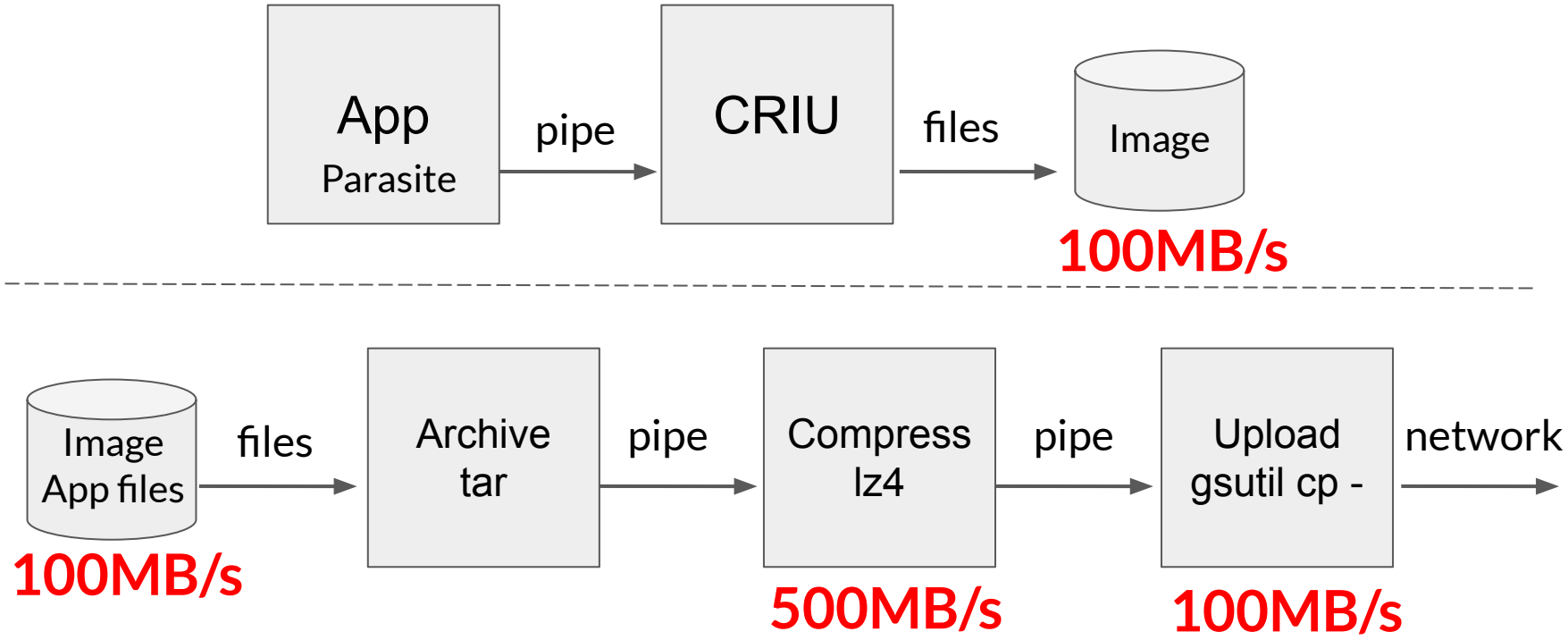
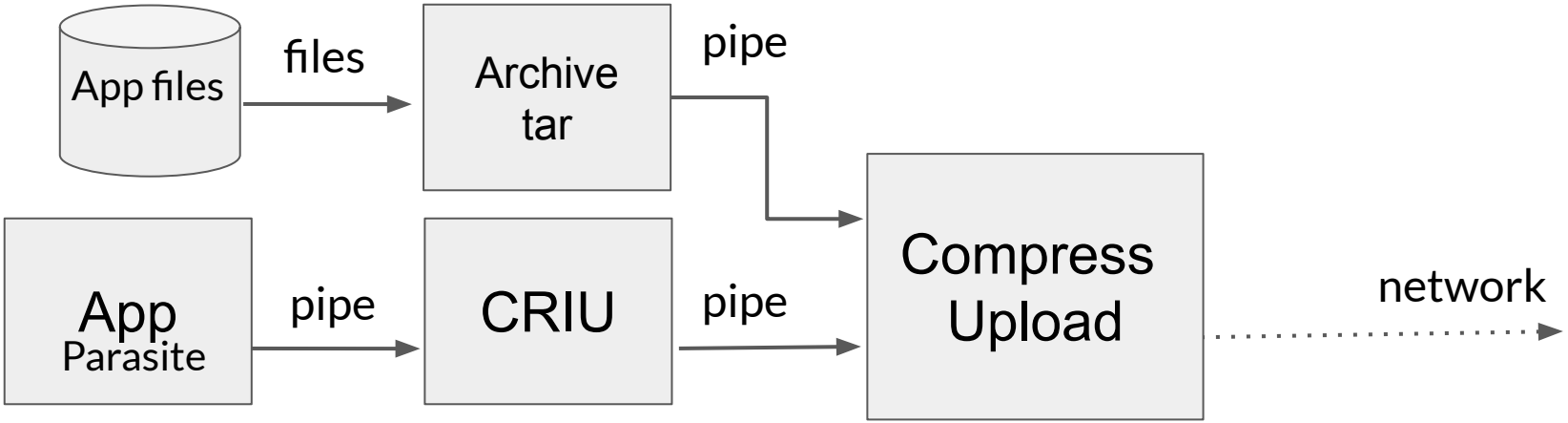
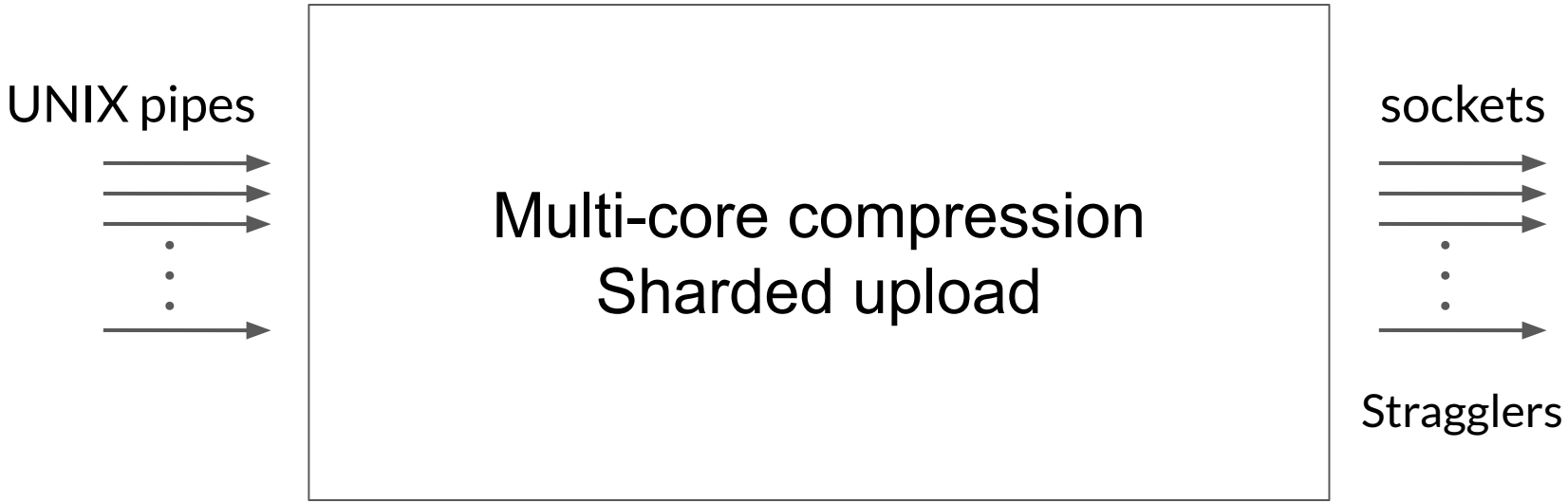


Streaming Checkpointing



Problem: Compress and upload stream



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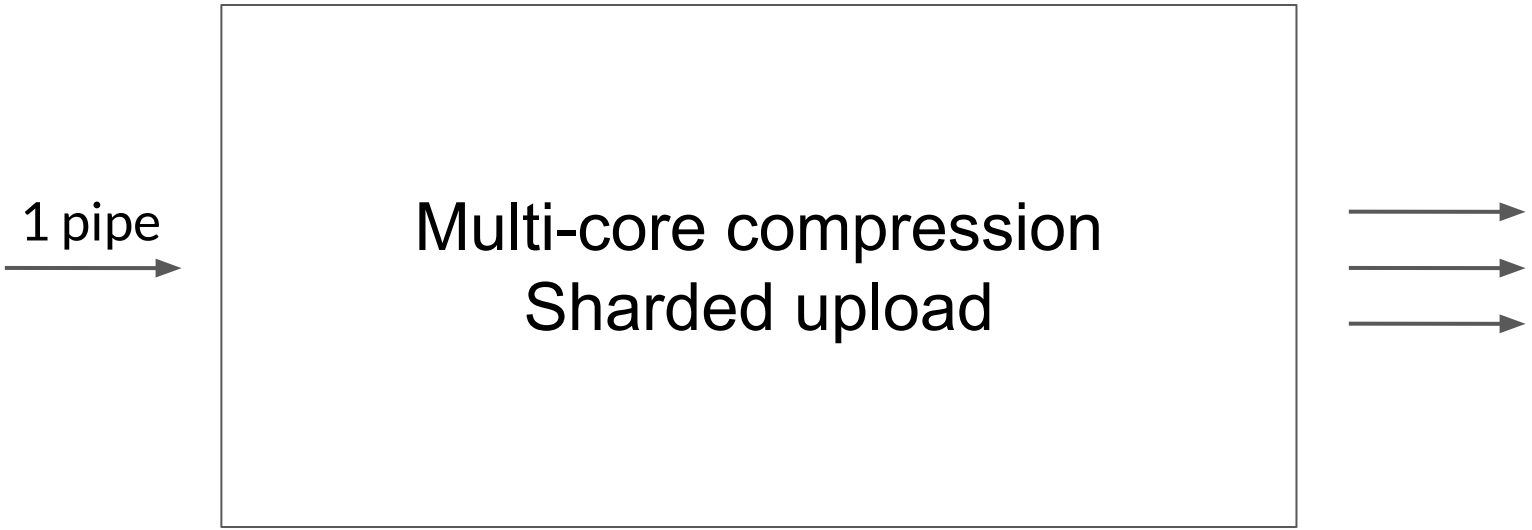

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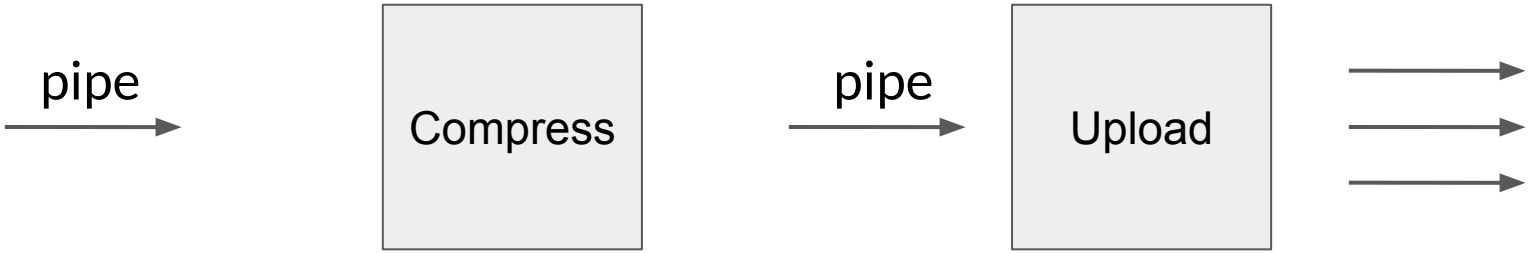

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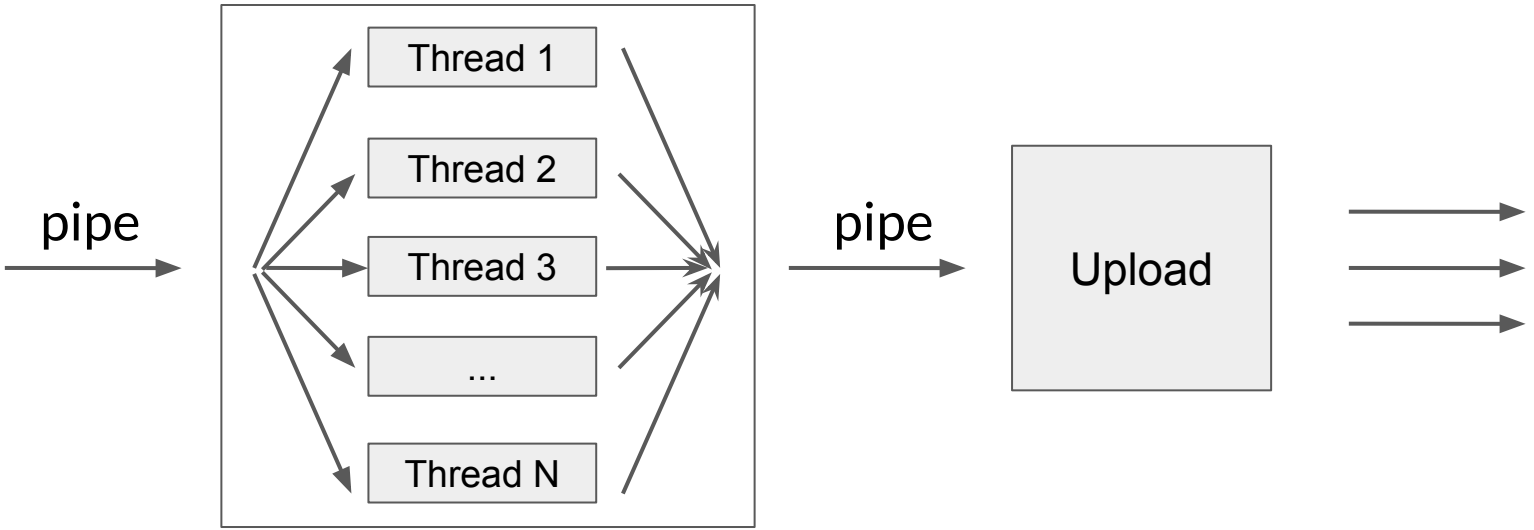

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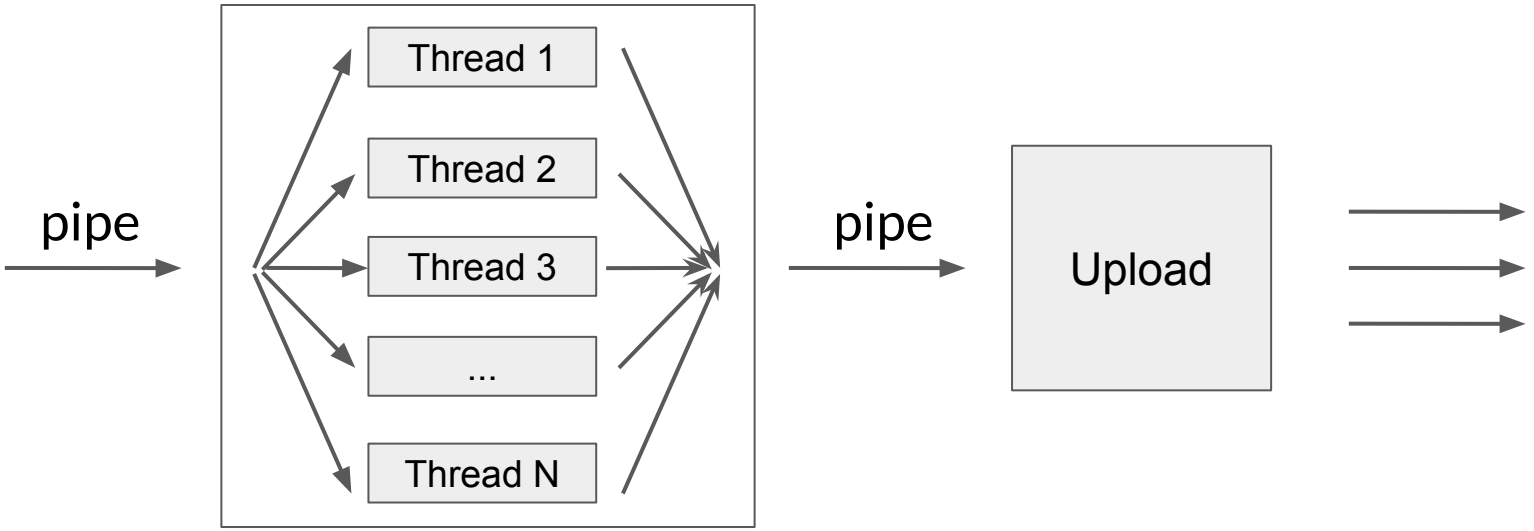
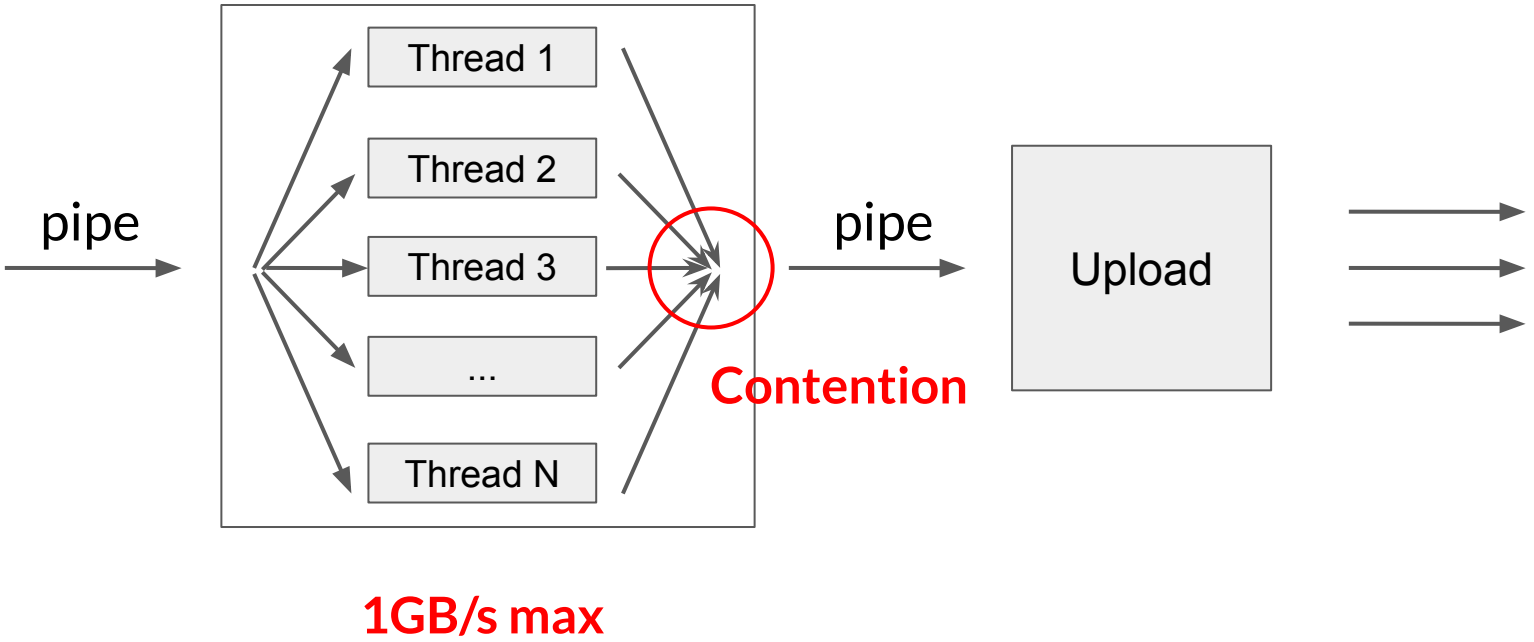


1GB/s max

Problem: Compress and upload stream



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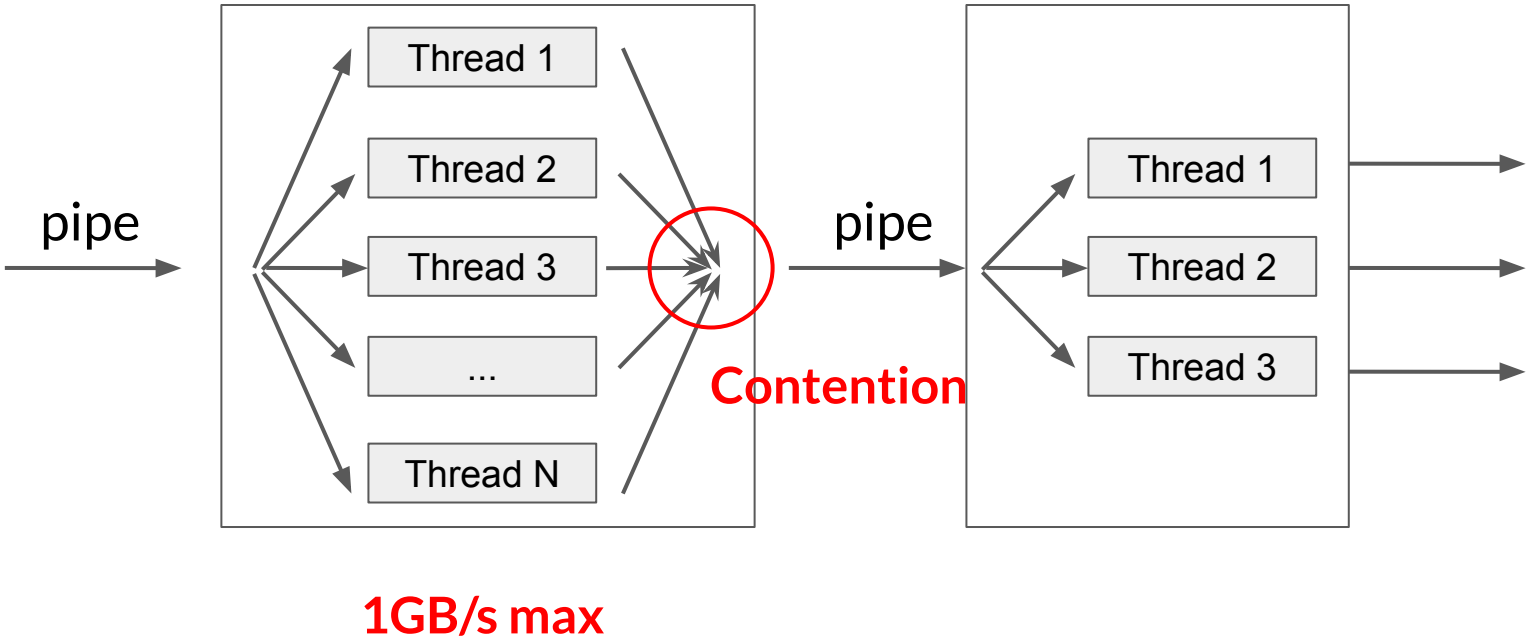

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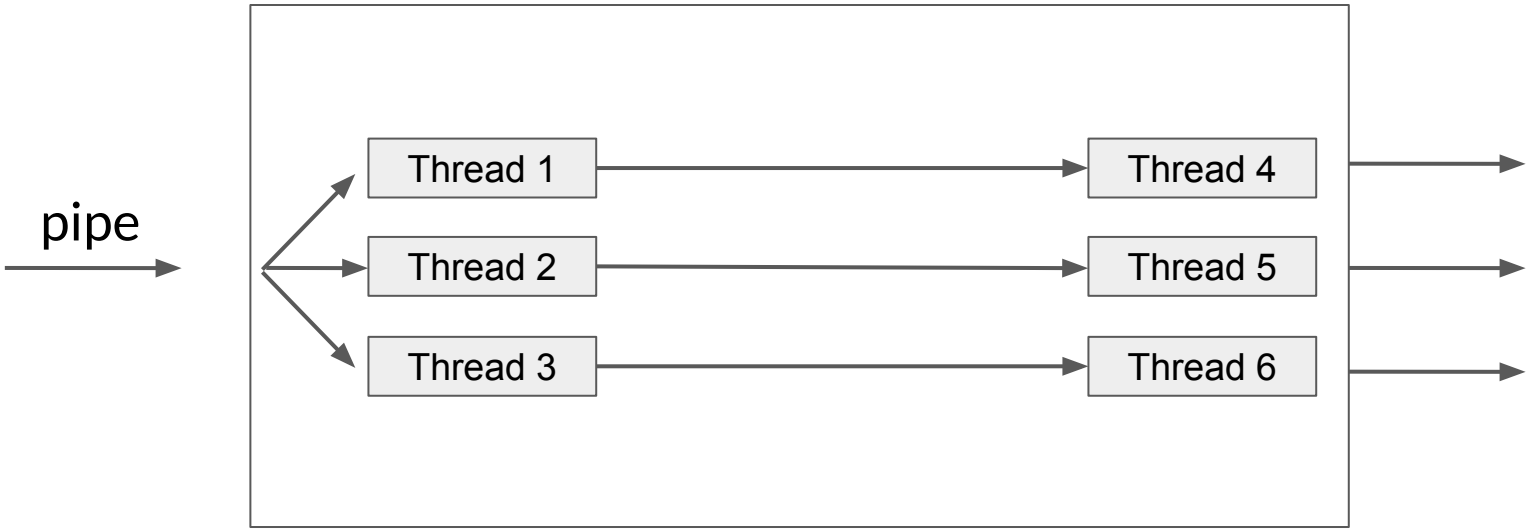

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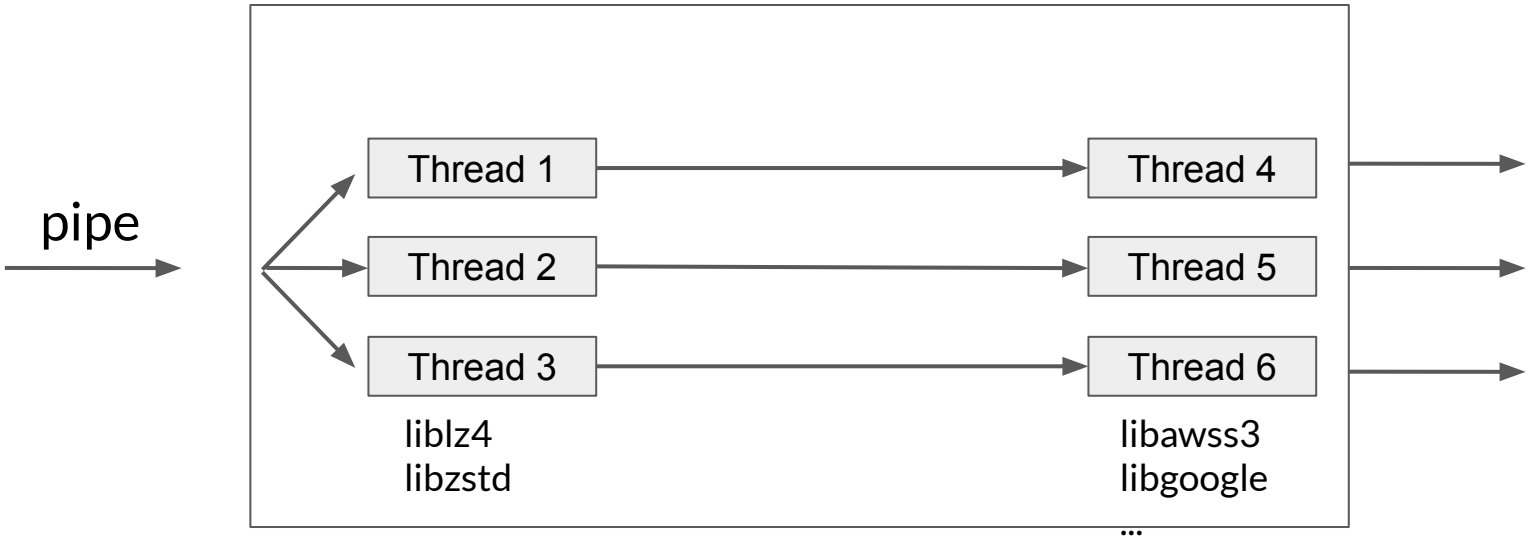

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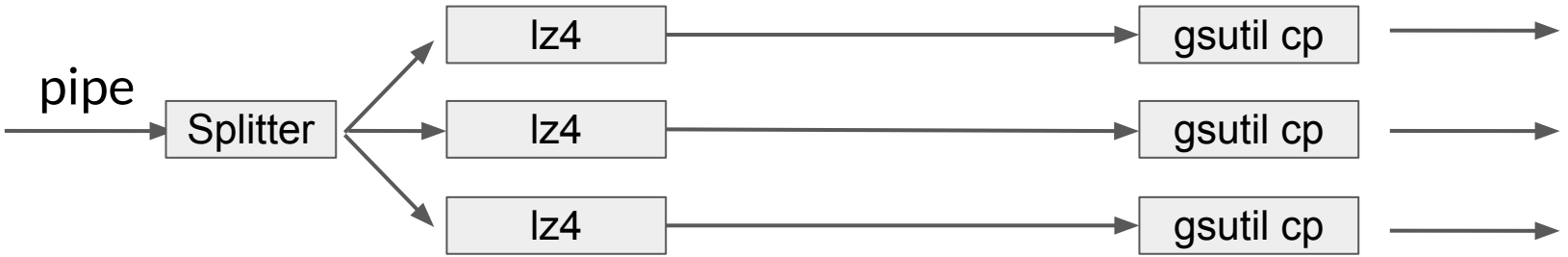
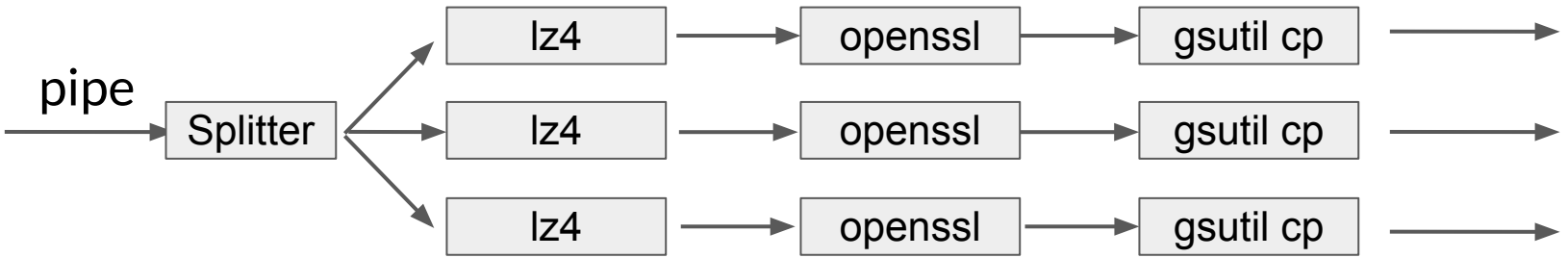


Shell command

lz4 - - | gsutil cp - gs://bucket/file

Problem: Compress and upload stream



Shell command

lz4 - - | openssl ... | gsutil cp - gs://bucket/file

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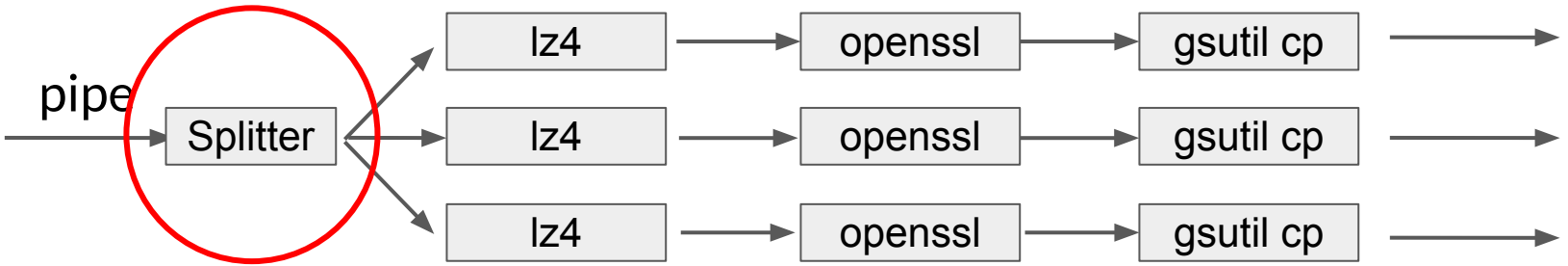
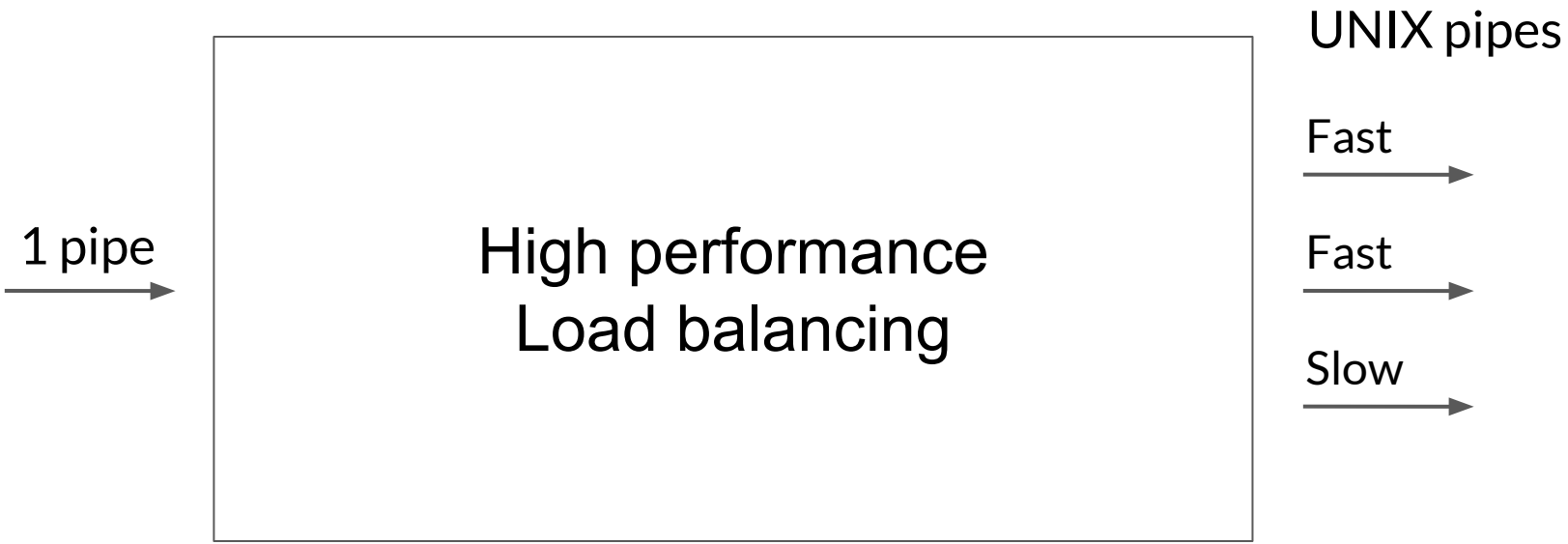


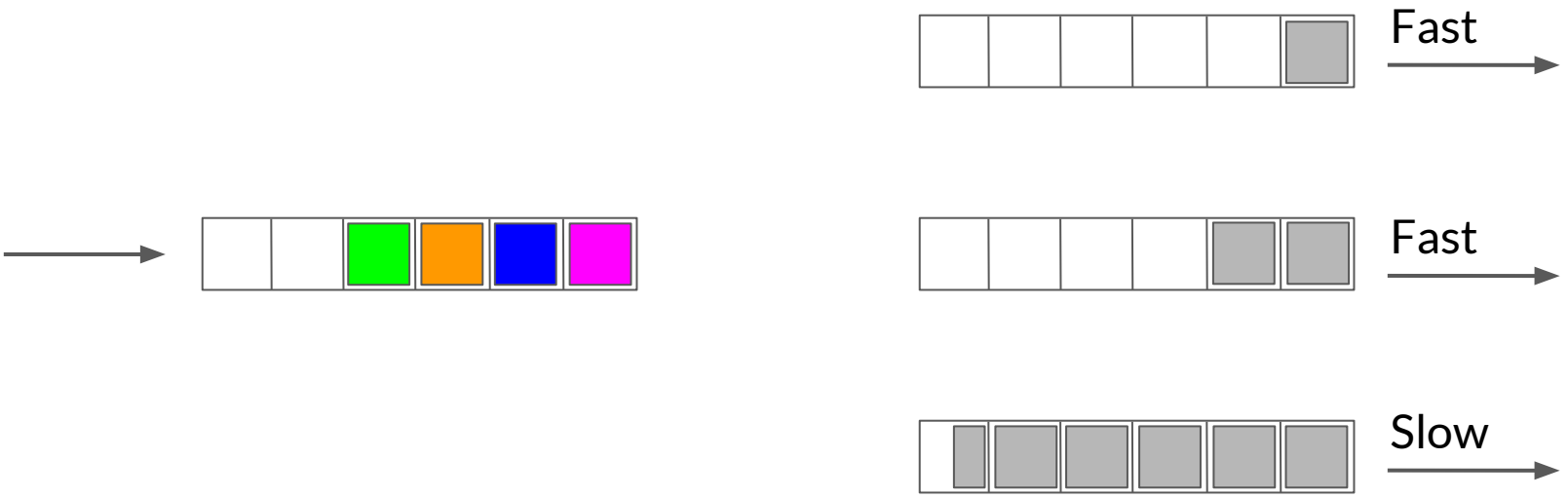
Shell command

lz4 - - | openssl ... | gsutil cp - gs://bucket/file

Problem: Split pipe and load-balance outputs

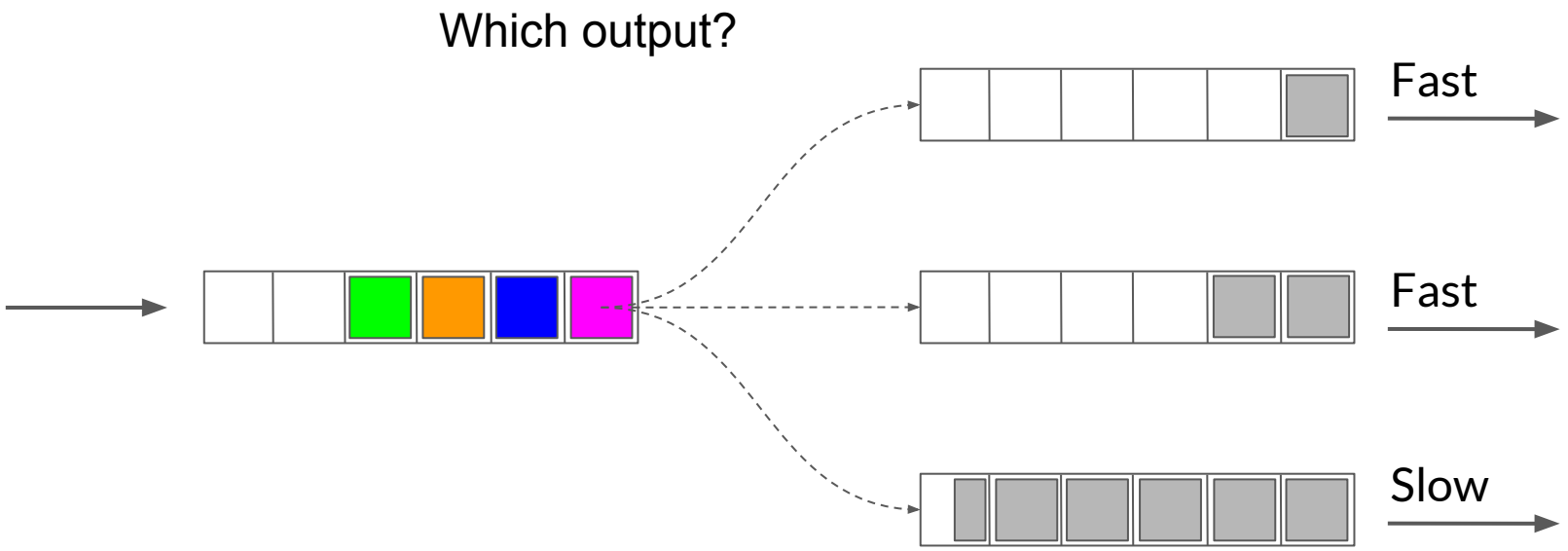


Split pipe and load-balance outputs



Kernel pipe buffers

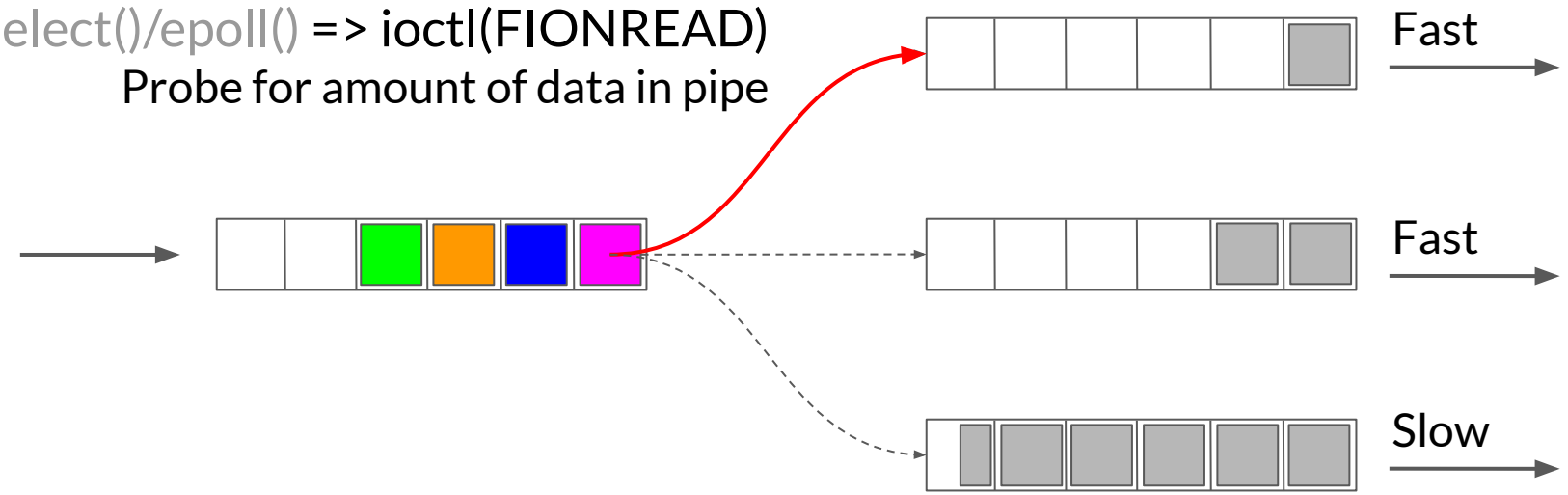
Split pipe and load-balance outputs



Split pipe and load-balance outputs

select()/epoll() => ioctl(FIONREAD)

Probe for amount of data in pipe



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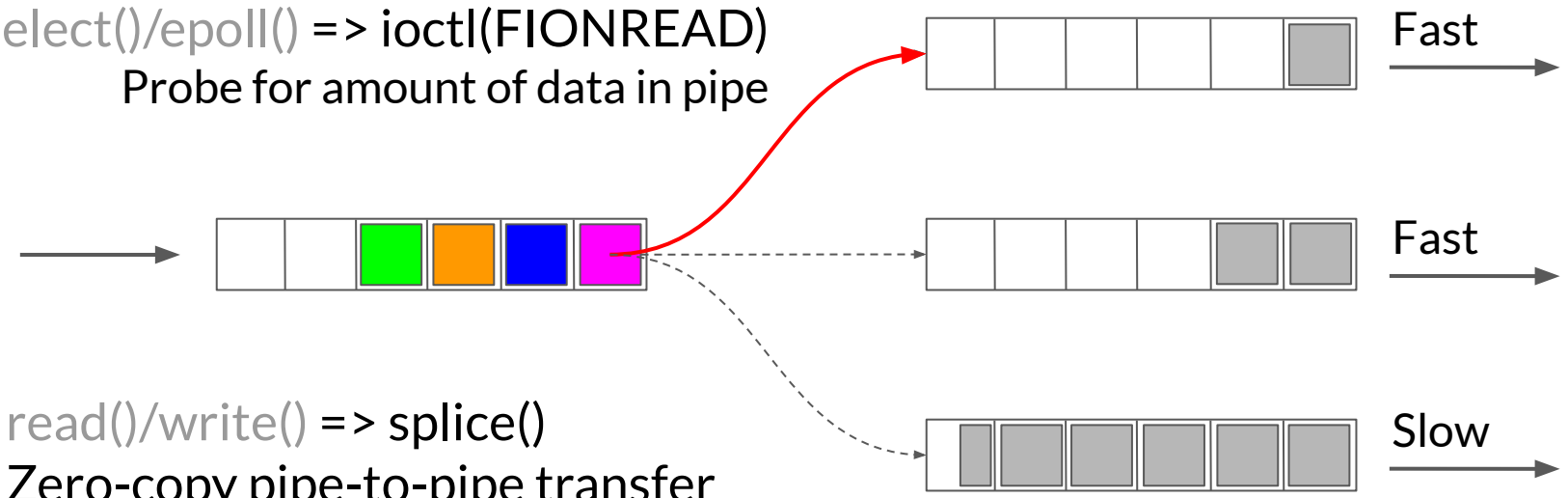
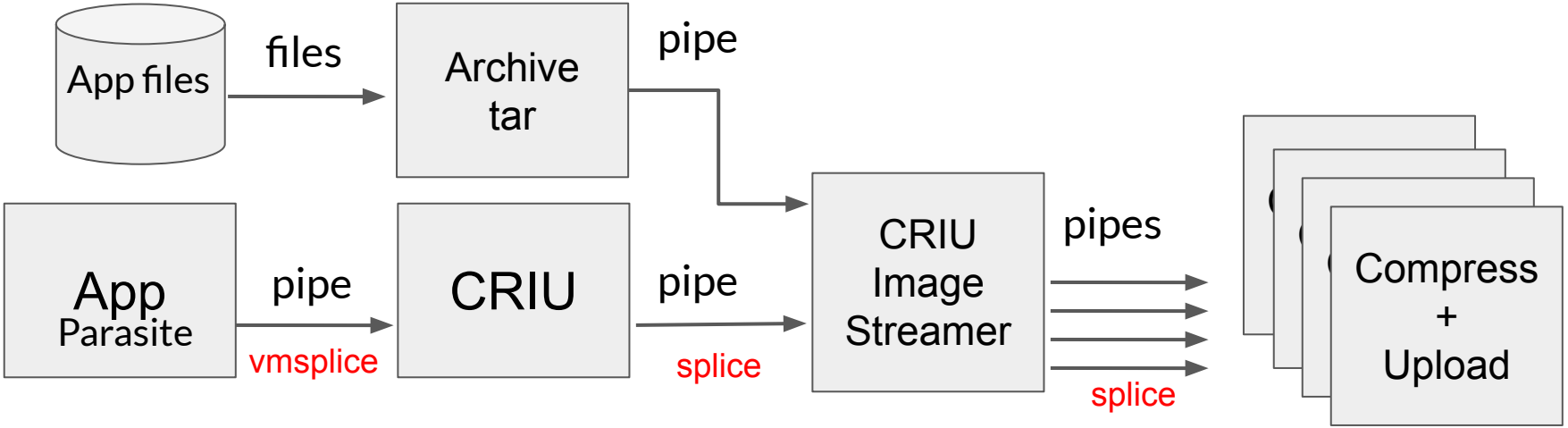
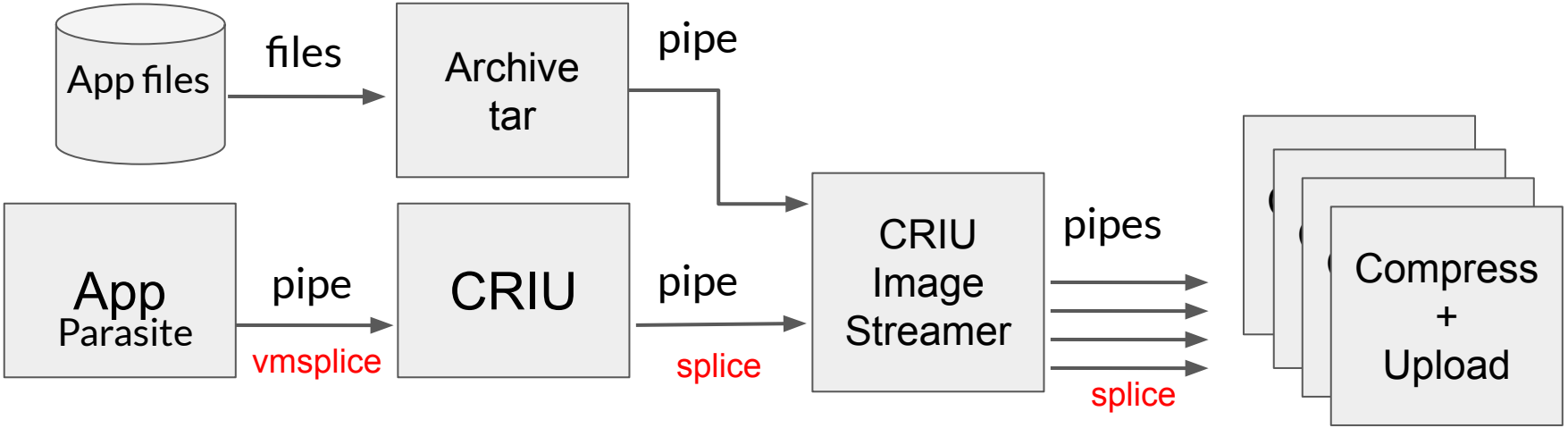


read()/write() => splice()
Zero-copy pipe-to-pipe transfer

Streaming Checkpointing



Streaming Checkpointing



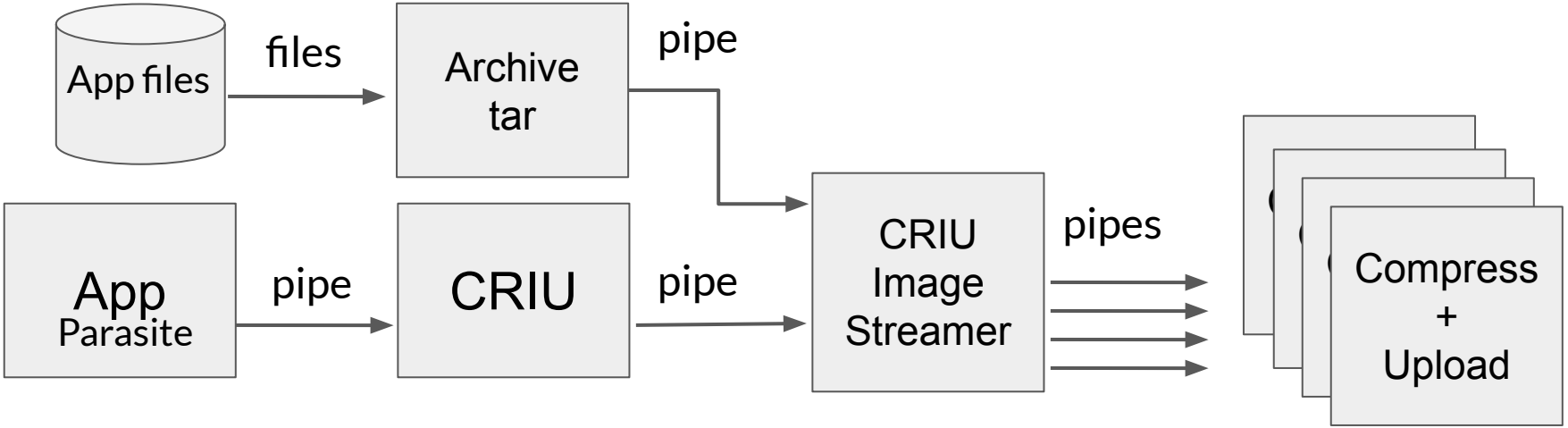
cat > /dev/null

15 GB/s

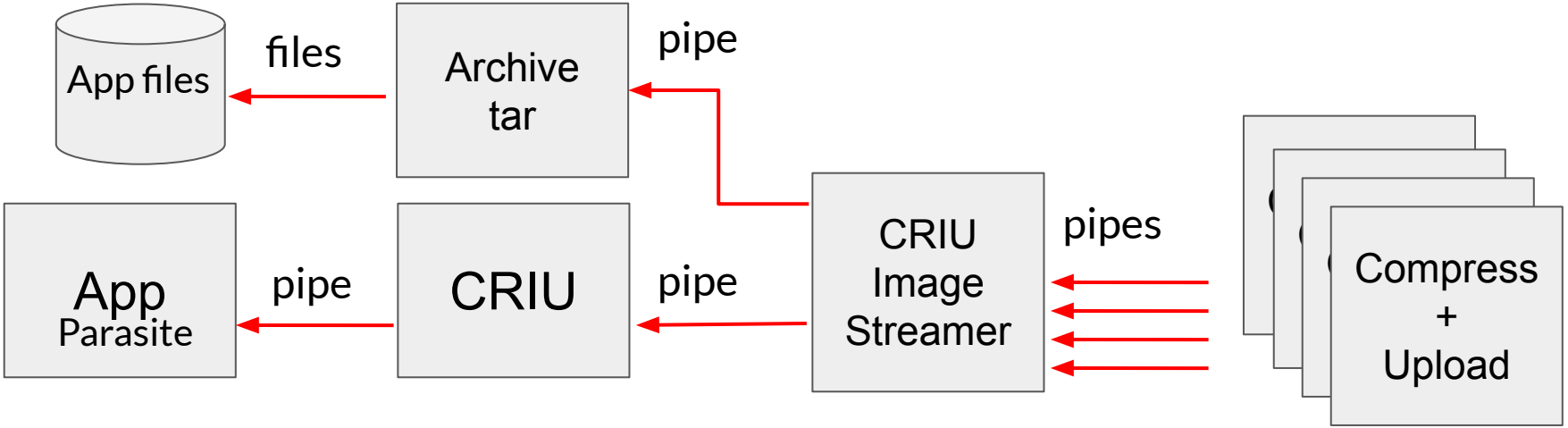
Performance Trade-off: CPU vs Network

Upload Protocol	HTTPS	HTTPS	HTTPS
Compression Algo	**None**	**lz4**	**zstd**
Compression Ratio (typical Java app)	1x	3x	5x
Throughput per CPU (before compression)	550 MB/s	350 MB/s	220 MB/s
Time to checkpoint (16 CPUs, 128GB RAM, 2GB/s NIC)	64s	24s	37s

Streaming Checkpoint



Streaming Restore



Problem: CRIU reads image out-of-order

- Writes `inventory.img` **at the end** of the stream
- Reads `inventory.img` **at the beginning** of the stream

Problem: CRIU reads image out-of-order

- Writes `inventory.img` **at the end** of the stream
- Reads `inventory.img` **at the beginning** of the stream

Solution

- Buffer the entire image in memory
- Let CRIU access image in arbitrary order
- 2x memory problem solved by deallocating after transferring data to CRIU

Checkpoint example, it’s Unix

```
exec 10> >(lz4 - - | gsutil cp - gs://bucket/img-1.lz4)
exec 11> >(lz4 - - | gsutil cp - gs://bucket/img-2.lz4)

exec 20< <(tar -C / -cpf - /scratch/app)

criu-image-streamer \
    --shard-fds 10,11 --ext-file-fds fs.tar:20 \
    --images-dir /tmp capture &
criu dump --images-dir /tmp --tree $APP_PID --stream
```

Live Migration

```
criu-image-streamer capture | ssh remote criu-image-streamer serve
```

Acknowledgements

- Two Sigma
  - Vitaly Davidovich
  - Peter Burka
- CRIU team
  - Andrei Vagin, Google
  - Radostin Stoyanov, Cambridge
  - Mike Rapoport, IBM

Future Work

- Speed-up restore: zero-copy
- Support pre-dump
- Perform dedup
- Adaptive compression
- Add kernel pipe statistics

Conclusion

- We can checkpoint at 15GB/s
- Unix philosophy with performance
- `ioctl(FIONREAD)` and `splice` for zero-copy load-balancing

https://github.com/checkpoint-restore/criu-image-streamer

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