Making Byzantine Fault Tolerant Systems Tolerate Byzantine Failures

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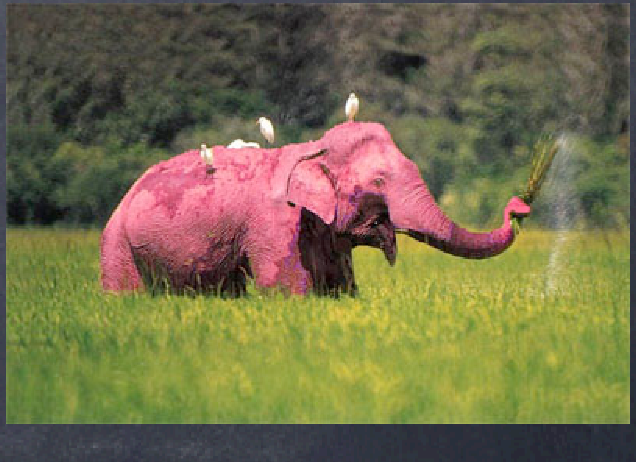

BFT Systems

- PBFT [OSDI 98]
- HQ [OSDI 06]
- Zyzzyva [SOSP 07]
- HT BFT [DSN 04]
- QU [SOSP 05]
- BFT Under Attack [NSDI 08]
- Commit Barrier Scheduling [SOSP 07]
- Low Overhead BFT [SOSP 07]
- Attested Append Only Memory [SOSP 07]
- Beyond 1/3 Faulty in BFT [SOSP 07]
- BASE [OSDI 02]
- SafeStore [USENIX 07]
- Separating Agreement from Execution [SOSP 03]
- SUNDR [OSDI 04]
- ...

System Throughput

	Best Case
PBFT	62k
Q/U	24k
HQ	15k
Zyzzyva	65k

ops/sec

System Throughput

	Best Case	Faulty Client	Client Flood	Faulty Primary	Faulty Replica
PBFT	62k	0	crash	1K	250
Q/U	24k	0	crash	NA	19k
HQ	15k	NA	4.5k	NA	crash
Zyzzyva	65k	0	crash	crash	0

ops/sec

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PBFT	62k	0	crash	1K	250
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Zyzzyva	65k	0	crash	crash	0
Aardvark	39k	39k	7.8k	37k	11k

ops/sec

Outline

- Robust BFT: The case for a new goal
- Aardvark: Designing for RBFT
- Evaluation: RBFT in action

Paved with good intentions

- No BFT protocol should rely on synchrony for safety
- FLP: No consensus protocol can be both safe and live in an asynchronous system!
  - All one can guarantee is eventual progress
- "Handle normal and worst case separately as a rule, because the requirements for the two are quite different:
  the normal case must be fast;
  the worst case must make some progress"
  -- Butler Lampson, "Hints for Computer System Design"

Recasting the problem

- Maximize performance when
  - the network is synchronous
  - all clients and servers behave correctly
- While remaining
  - safe if at most f servers fails
  - eventually live

Recasting the problem

- Misguided
- Dangerous
- Futile

Recasting the problem

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  - it encourages systems that fail to deliver BFT
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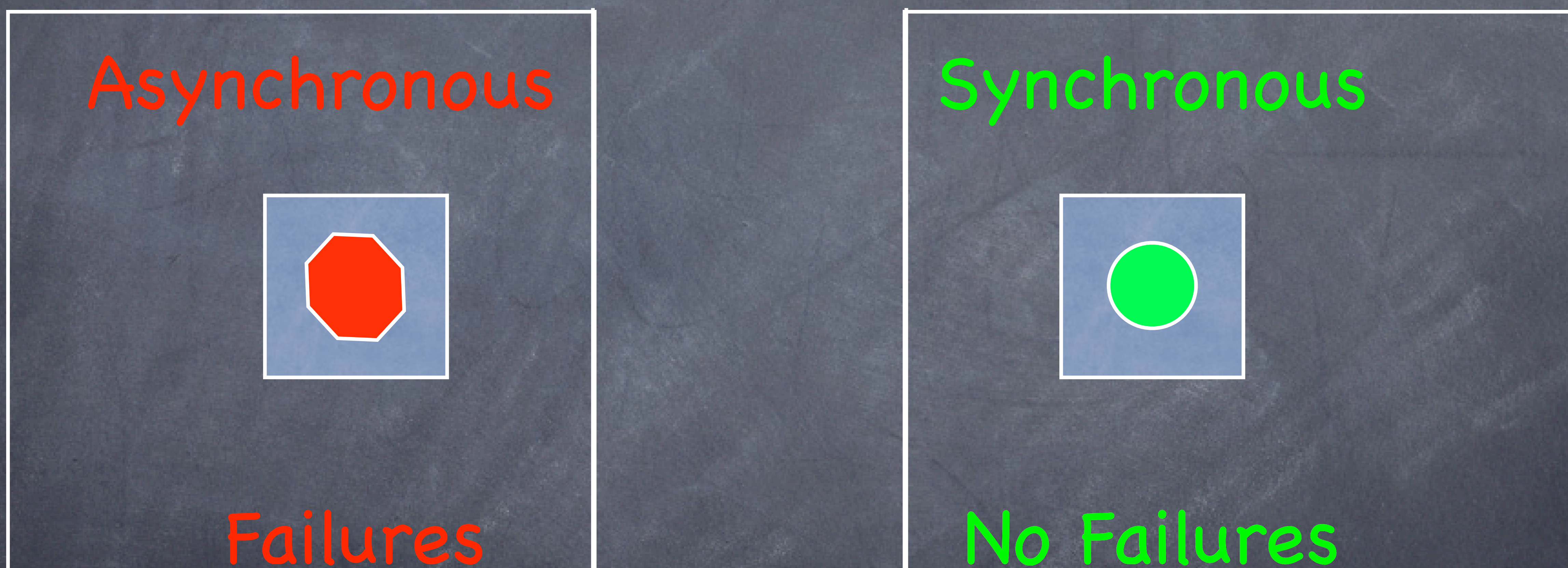
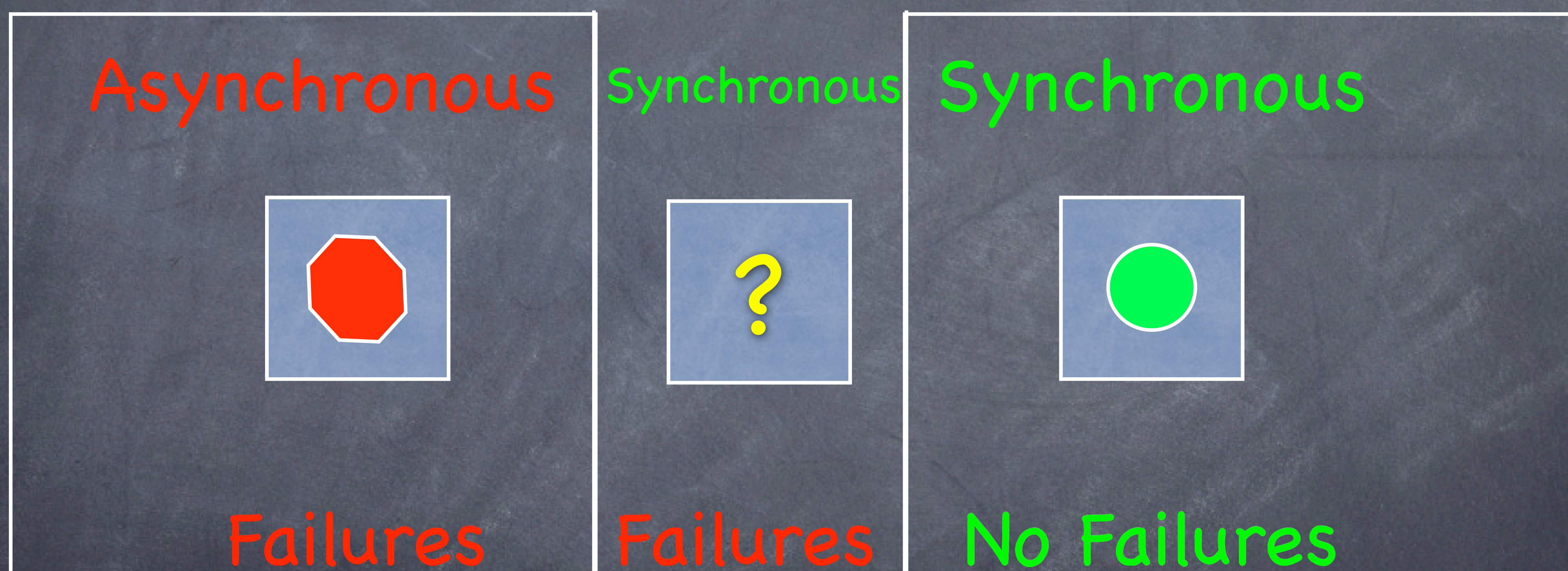
- Misguided
  - it encourages systems that fail to deliver BFT
- Dangerous
  - it encourages fragile optimizations
- Futile
  - it yields diminishing return on common case

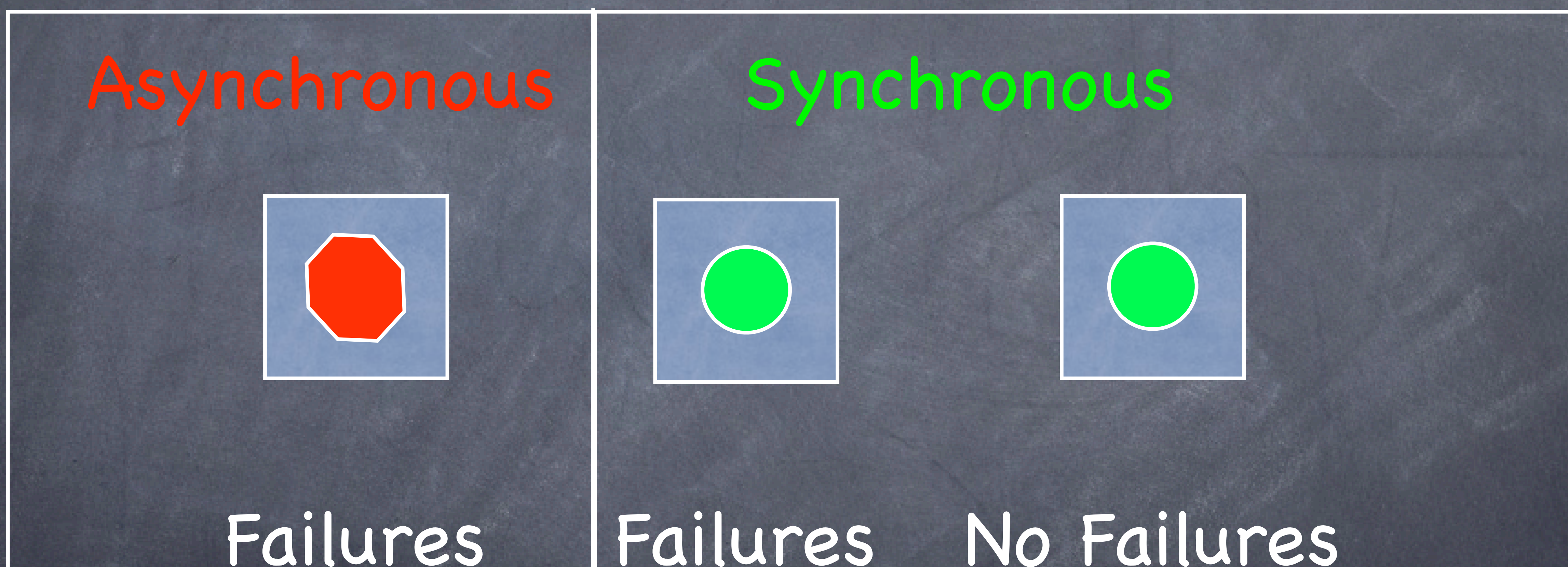
A New Goal



A New Goal


Asynchronous
Synchronous
Synchronous
?
Failures
Failures
No Failures

A New Goal



Robust BFT

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  - at most f servers fail
- While remaining
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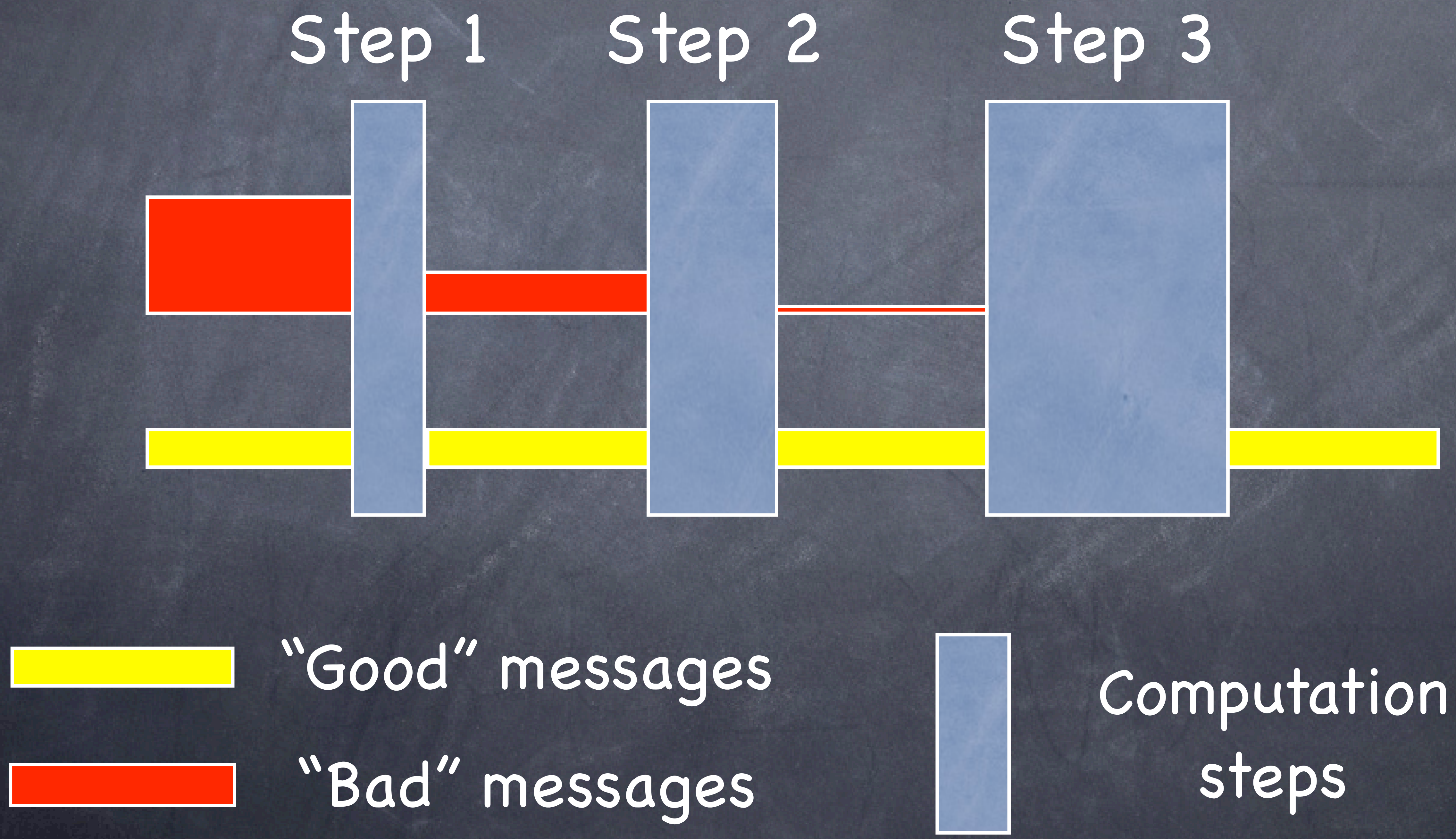
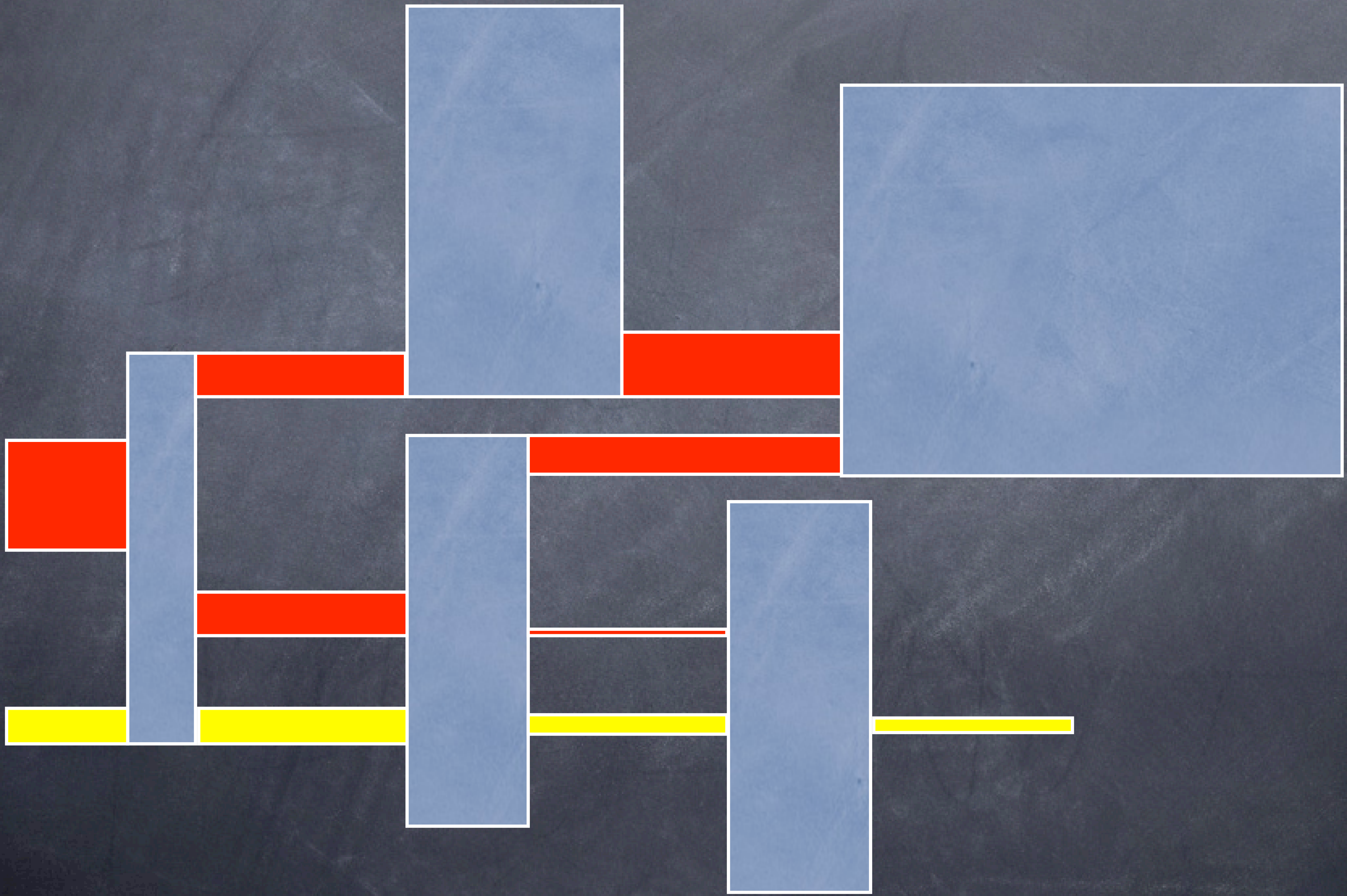
Protocol Structure



Fragile Optimizations



Revisiting conventional wisdom

- Signatures are expensive - use MACs
- View changes are to be avoided
- Hardware multicast is a boon

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- View changes are to be avoided
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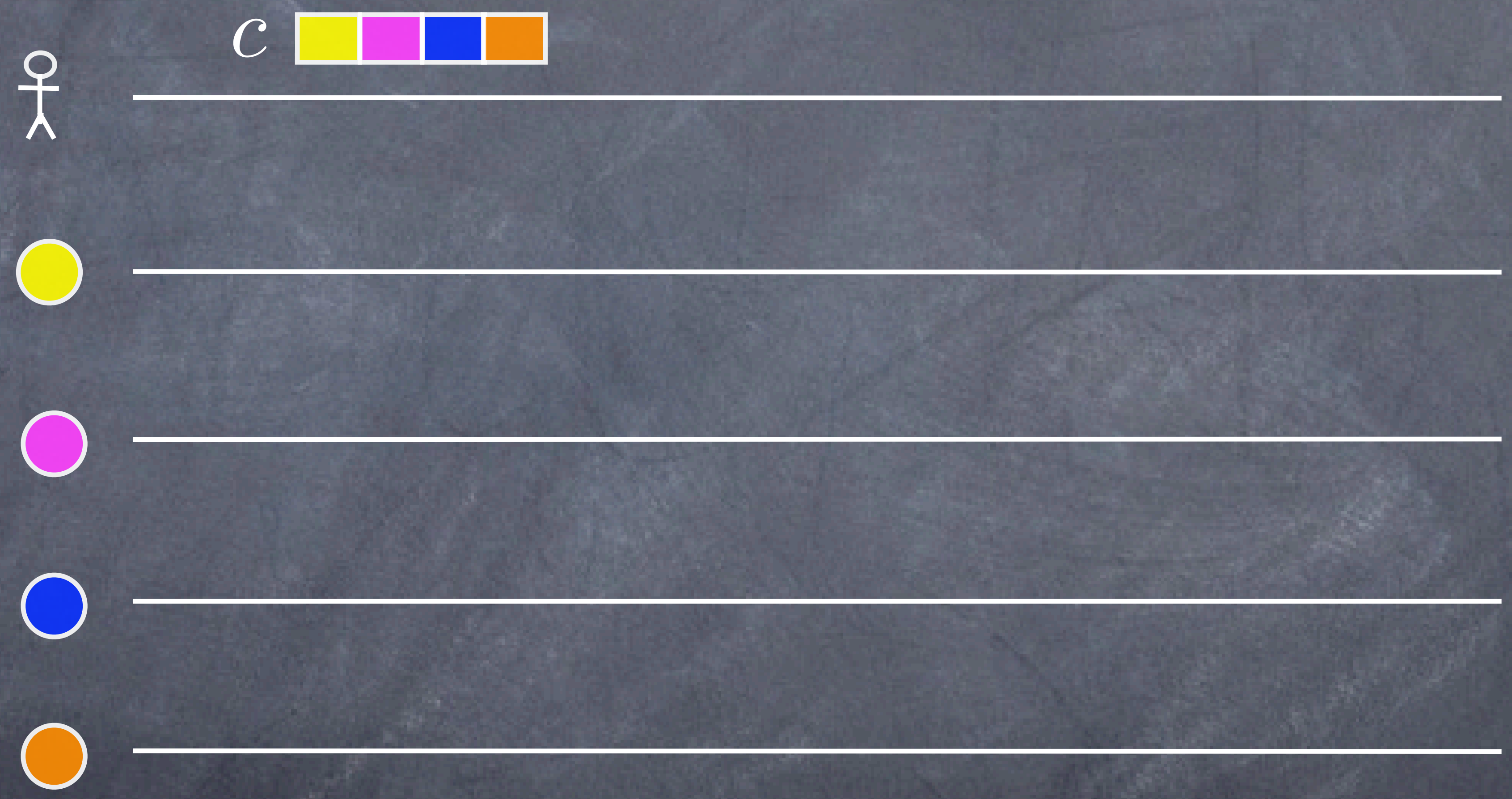
- Hardware multicast is a boon
  - Aardvark uses separate work queues for clients and individual replicas

Big MAC Attack



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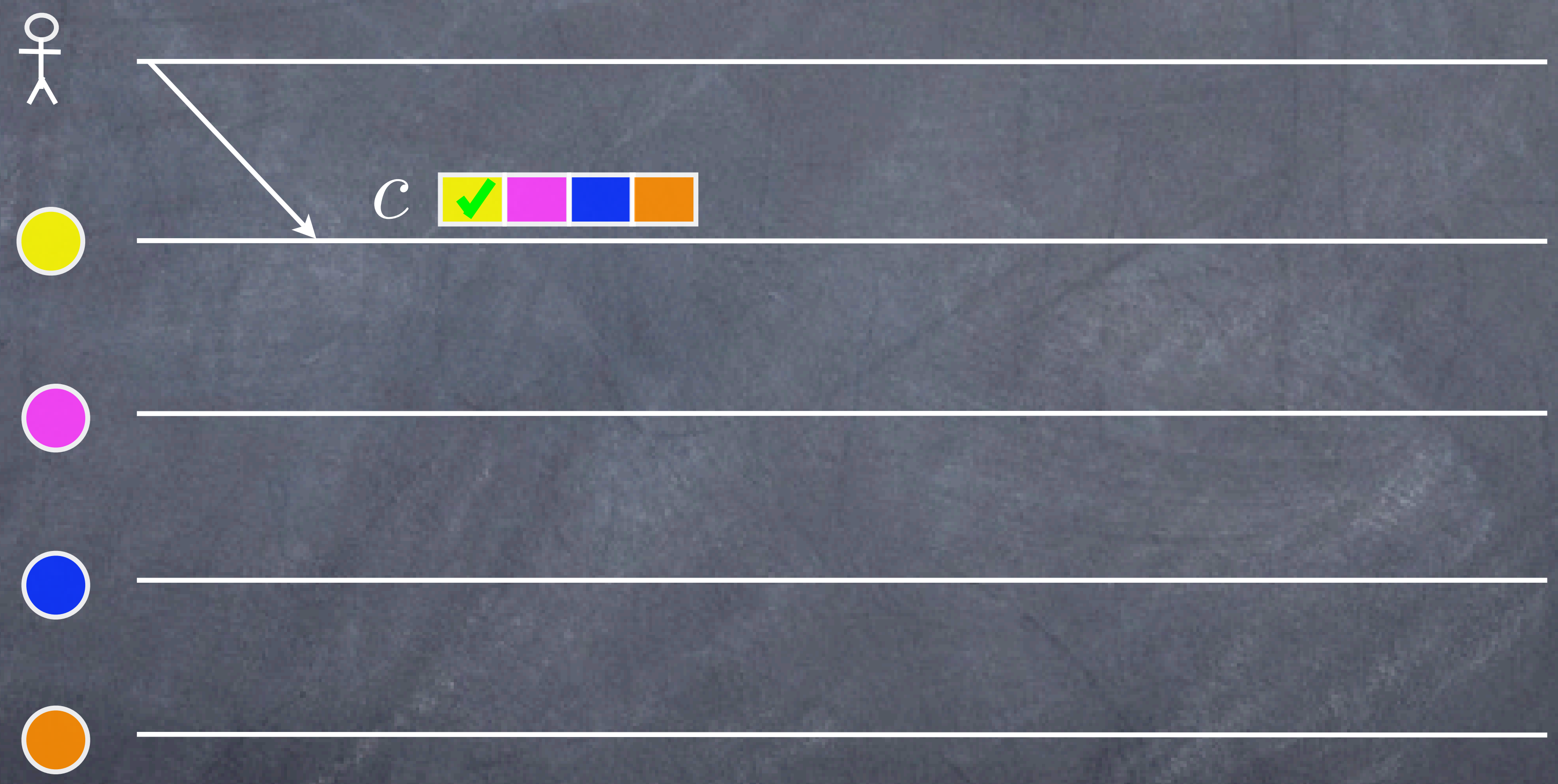

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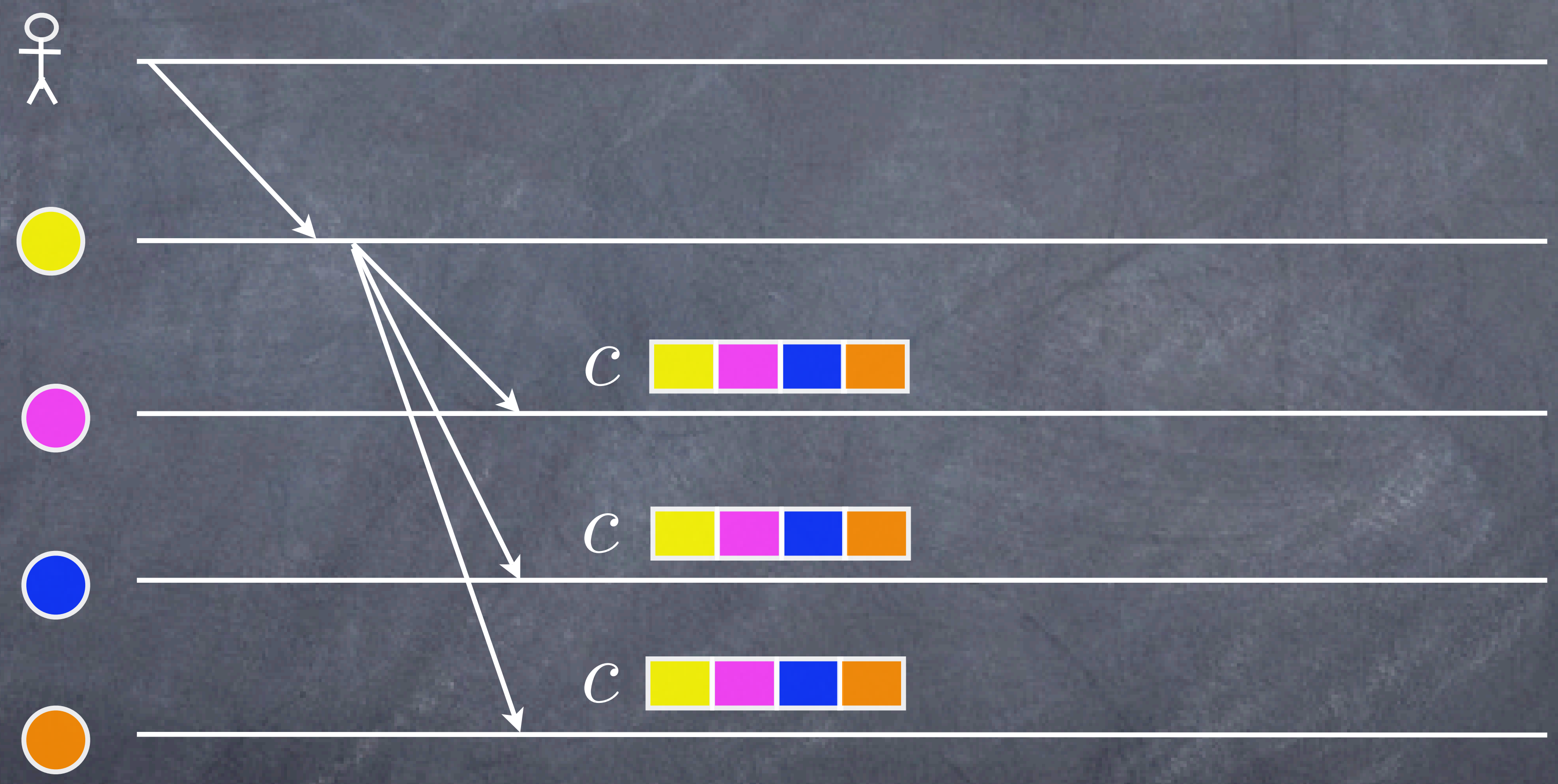

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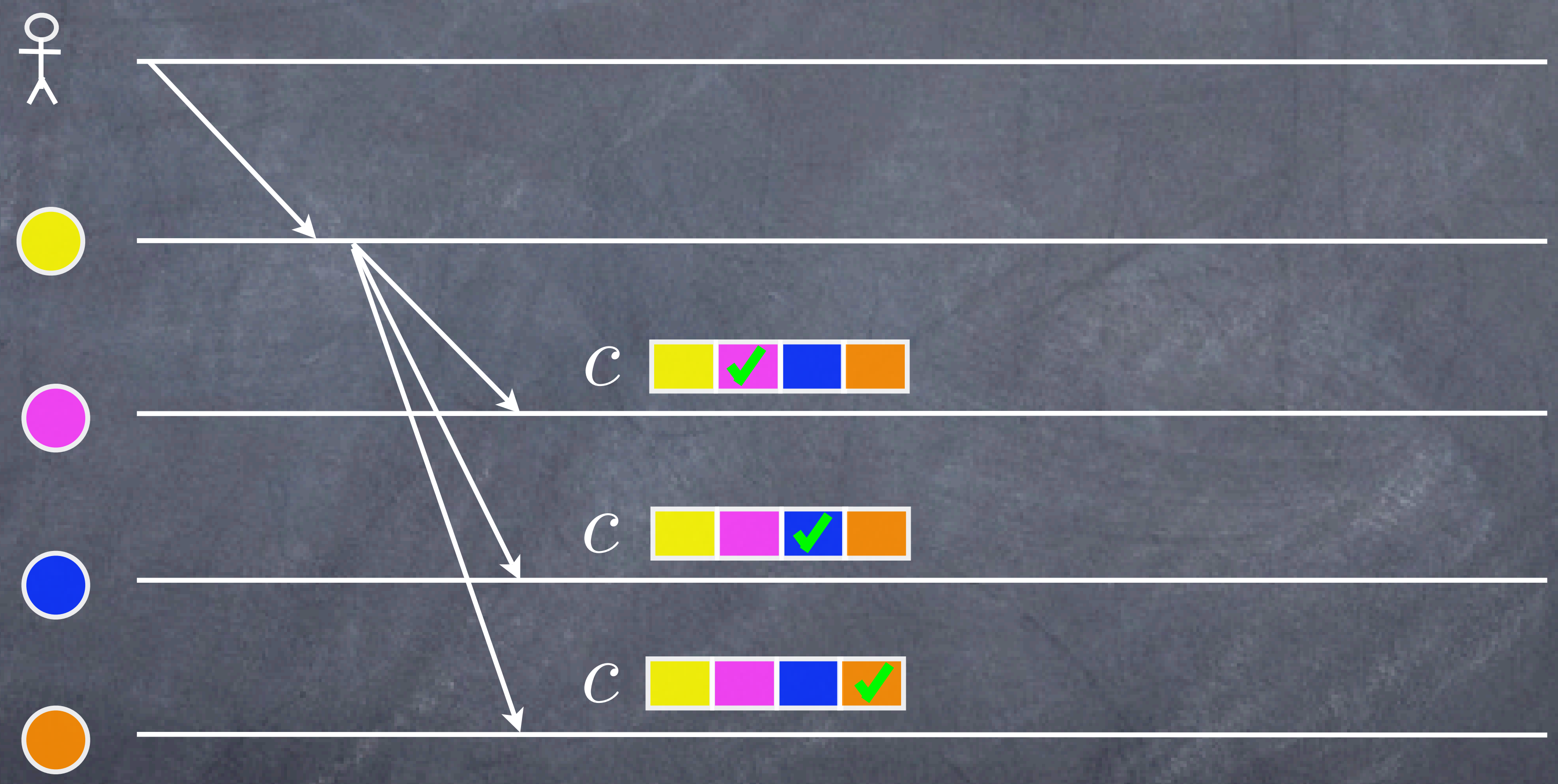

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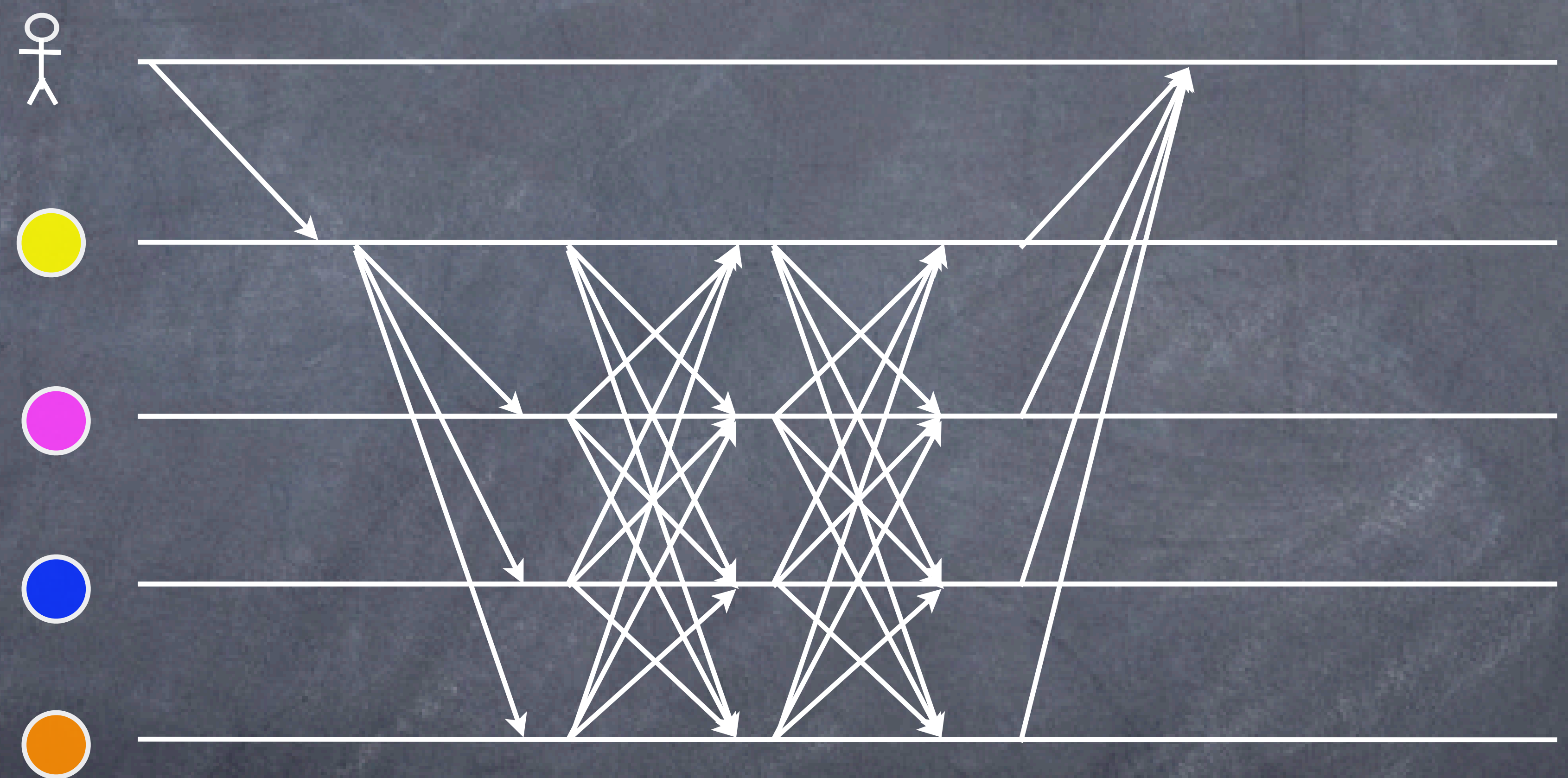

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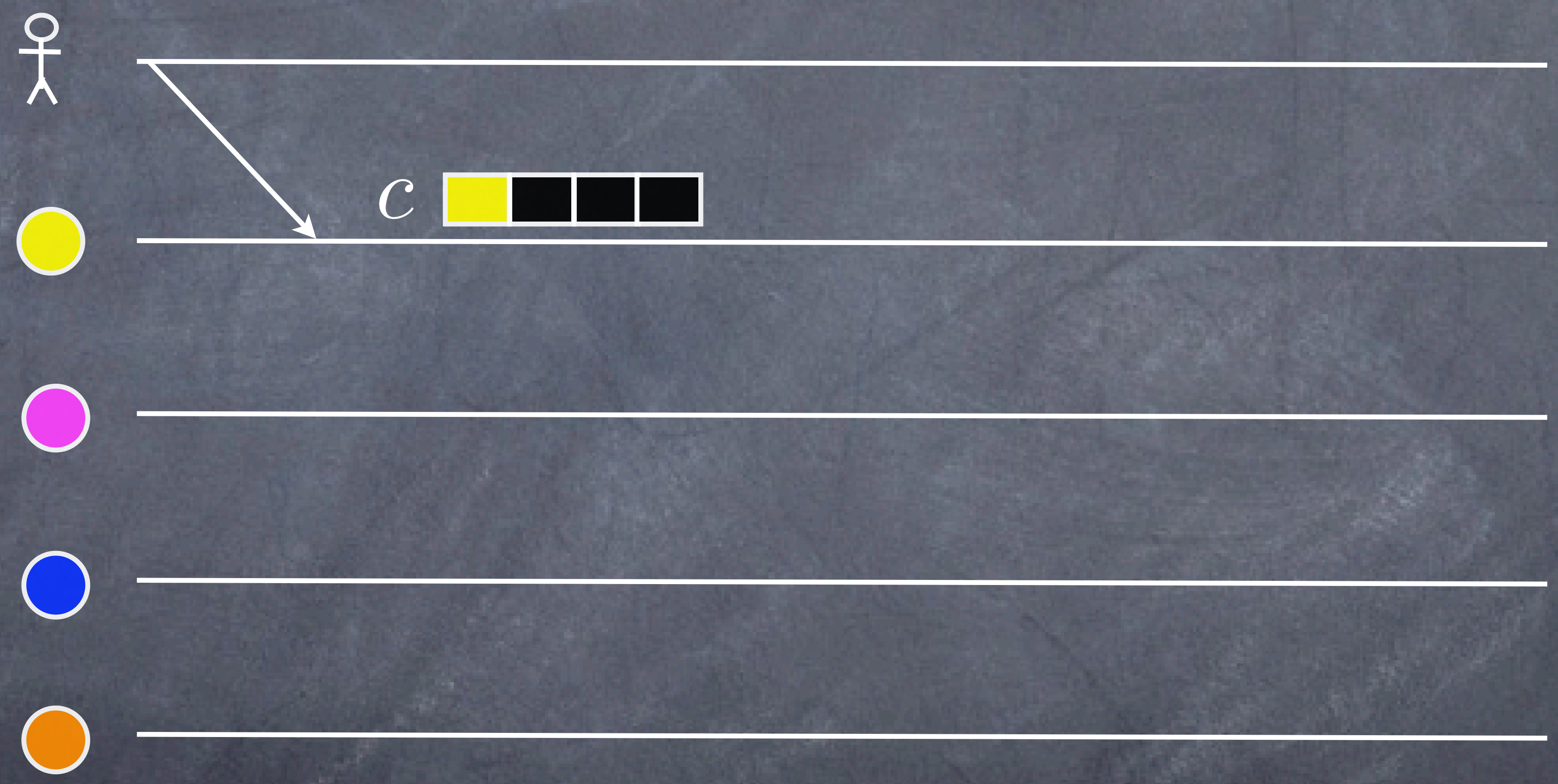

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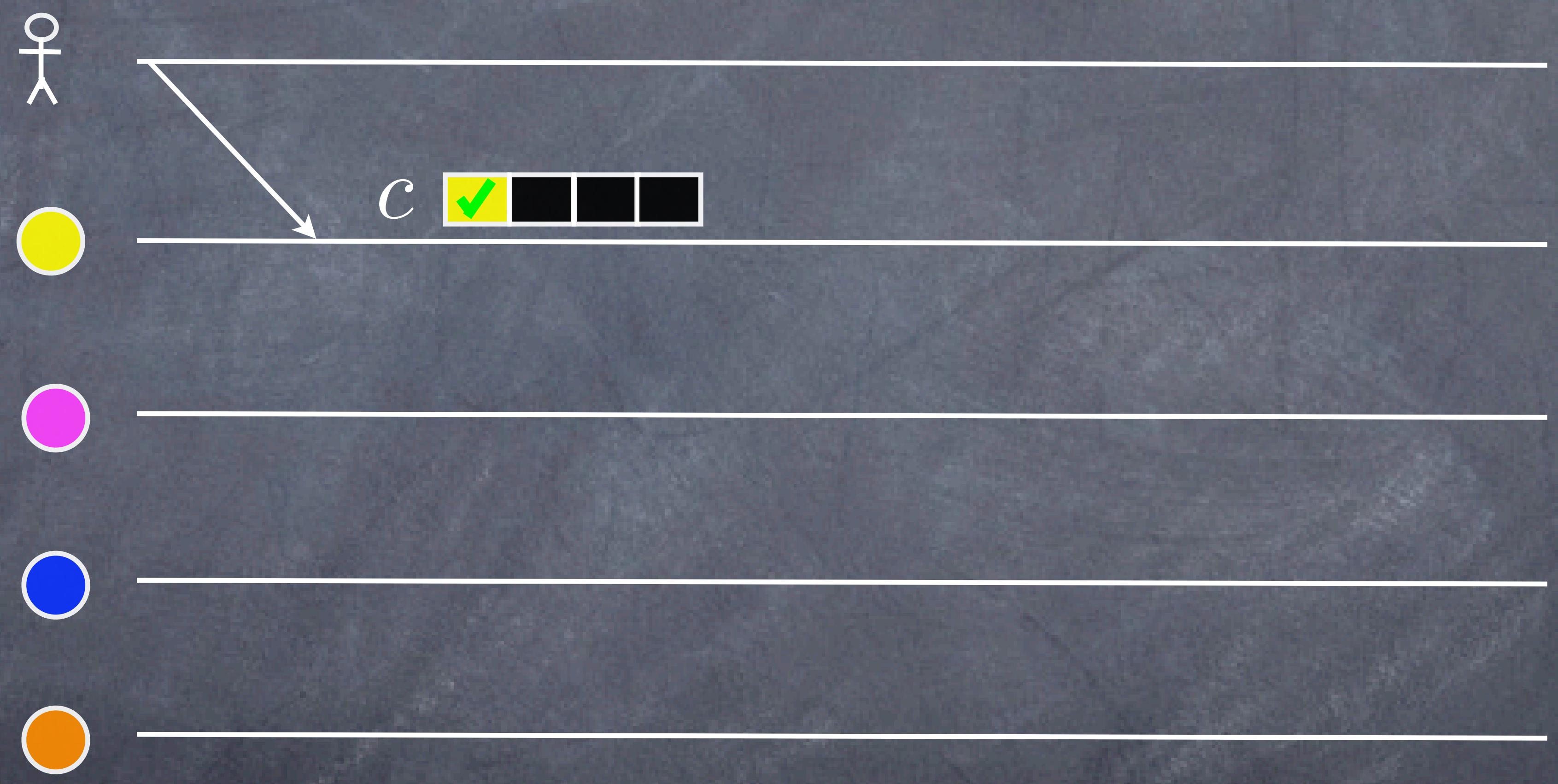

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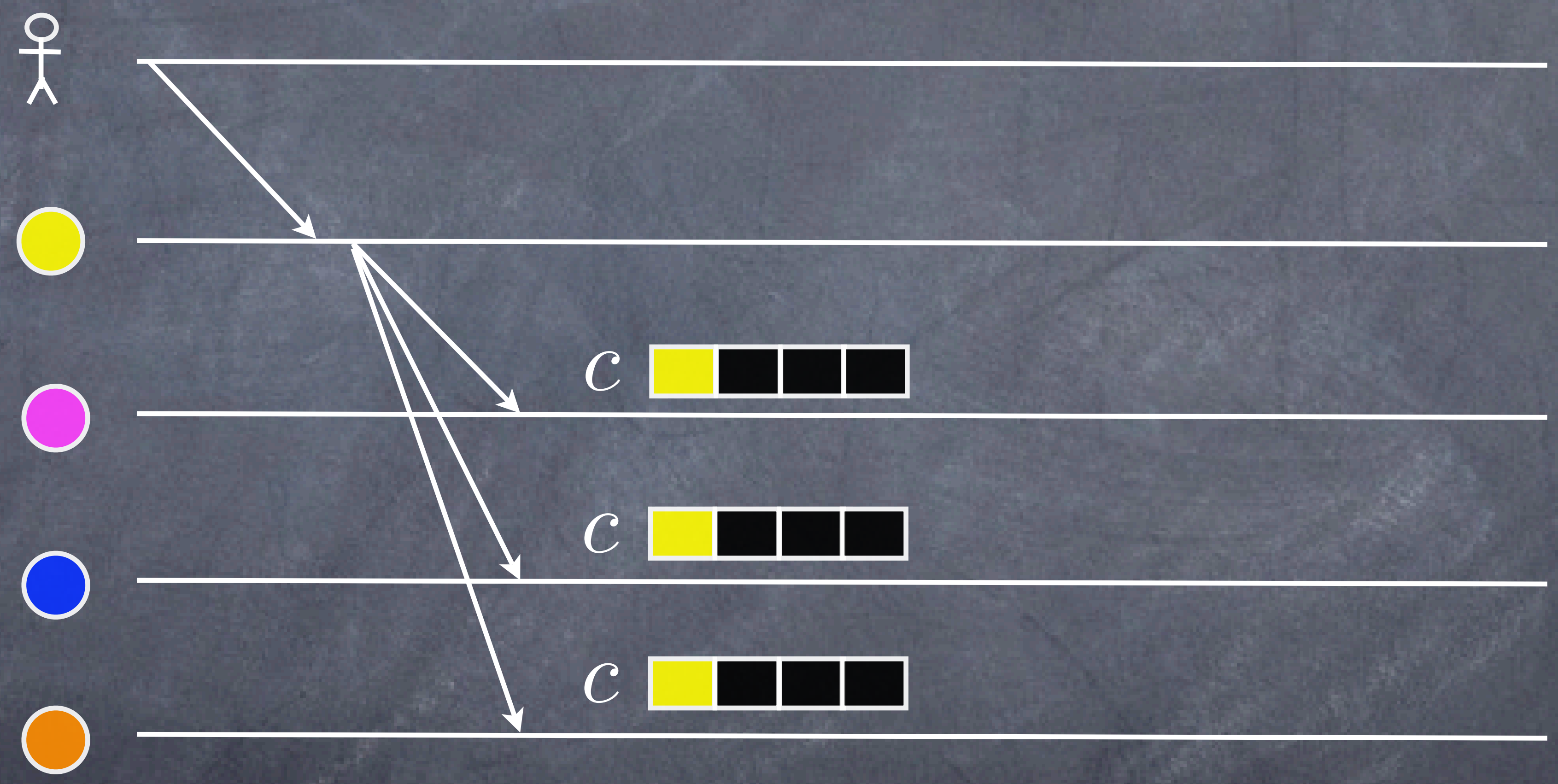

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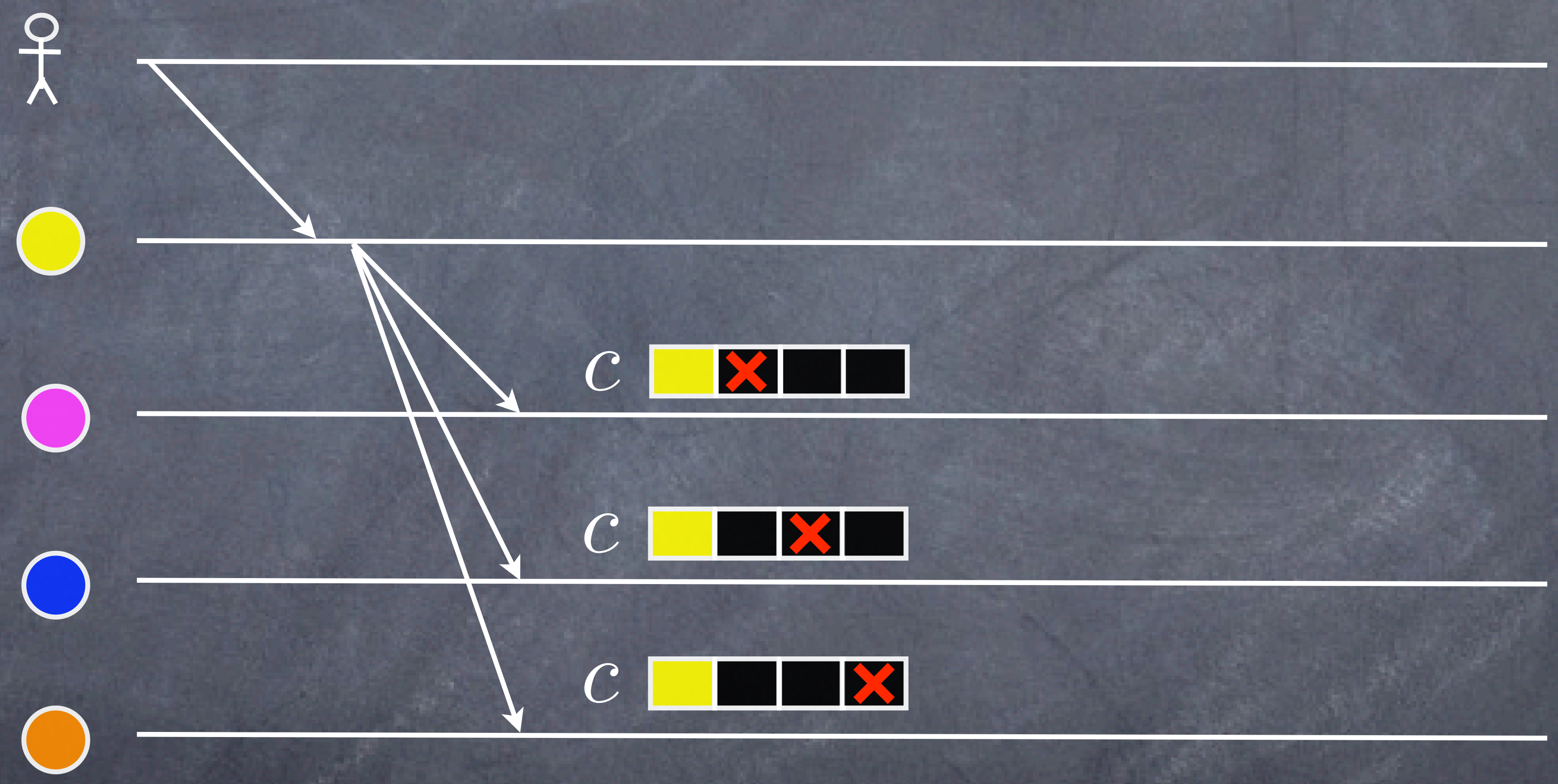

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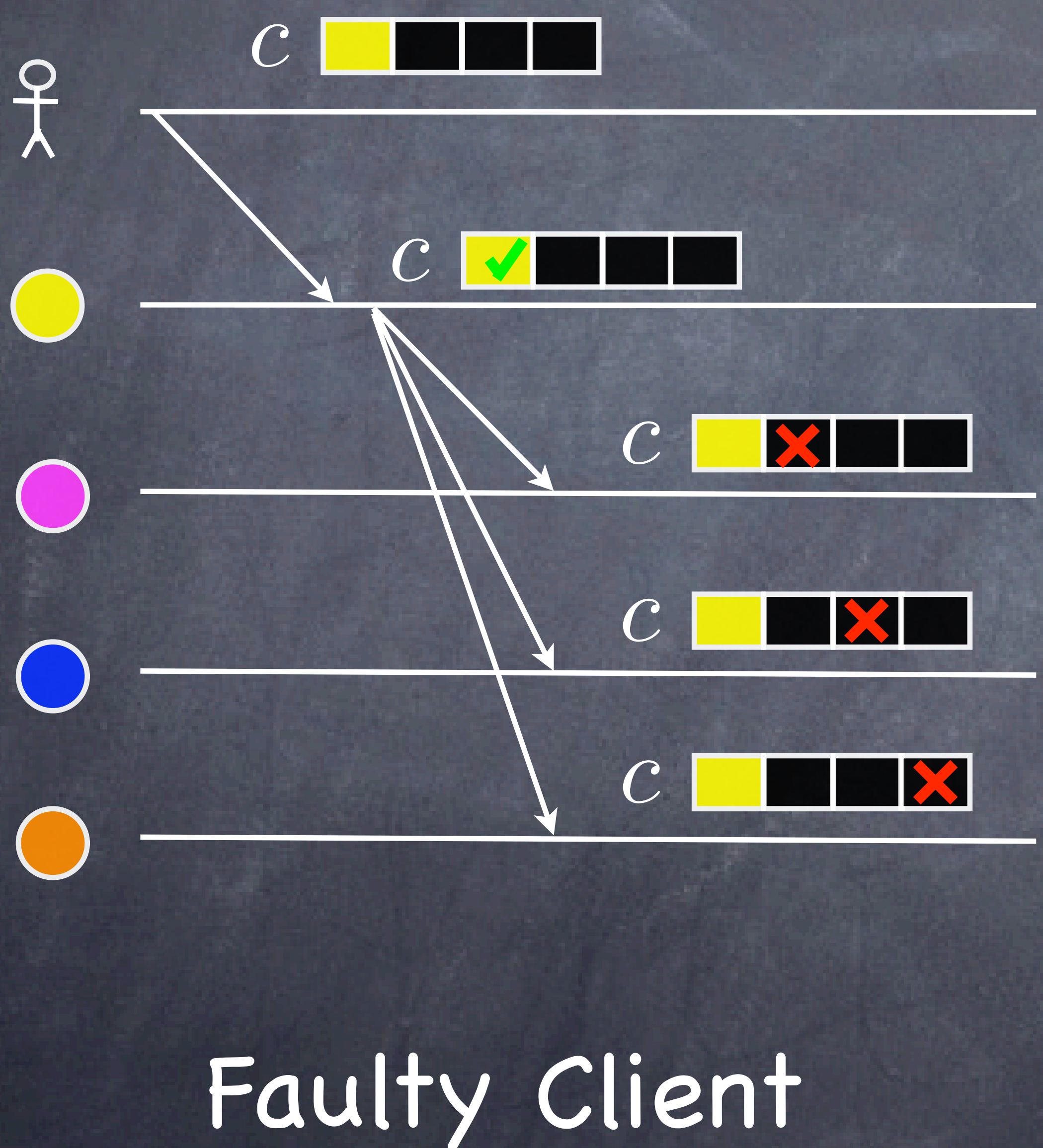

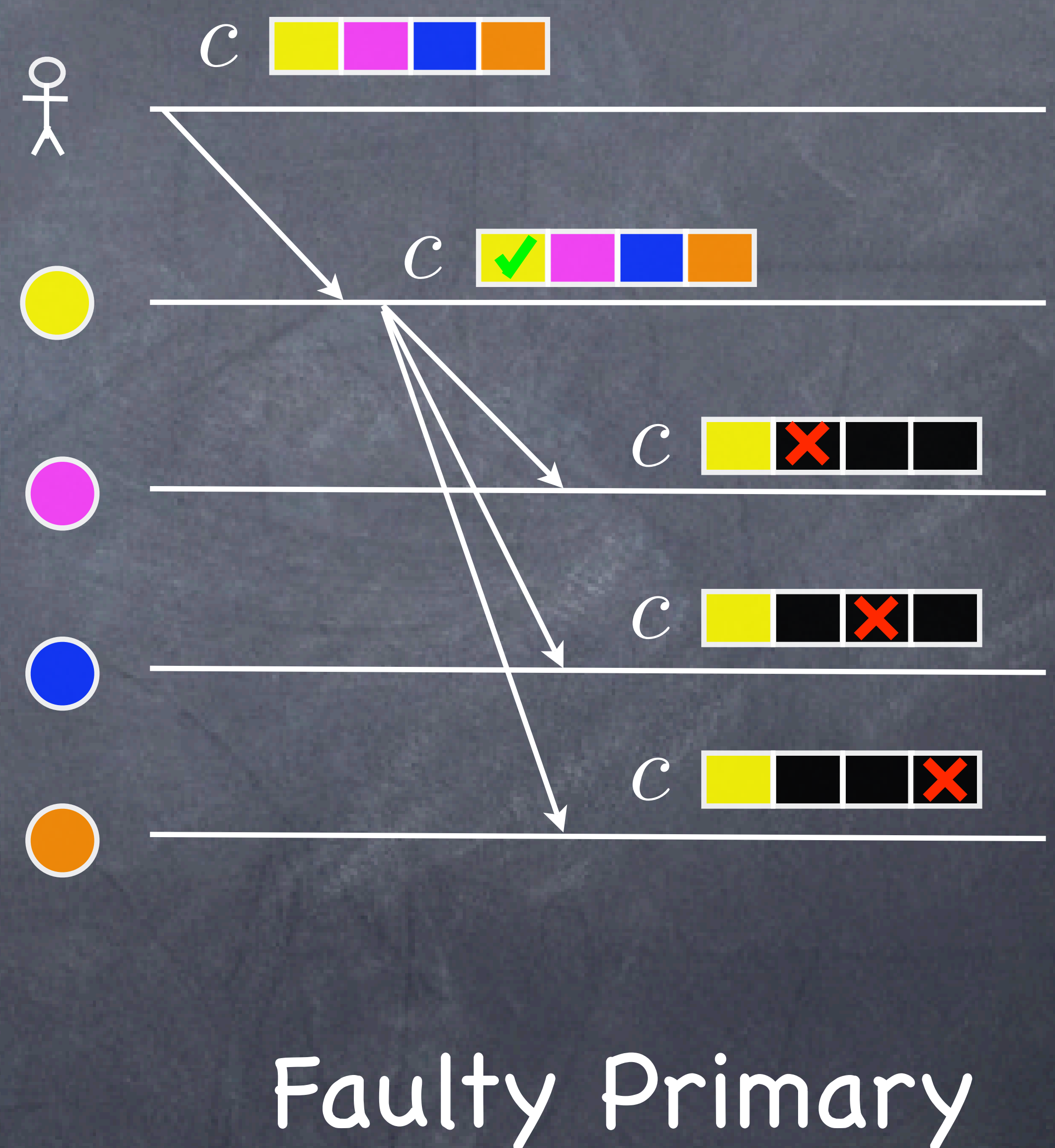

Hybrid MAC/Signatures

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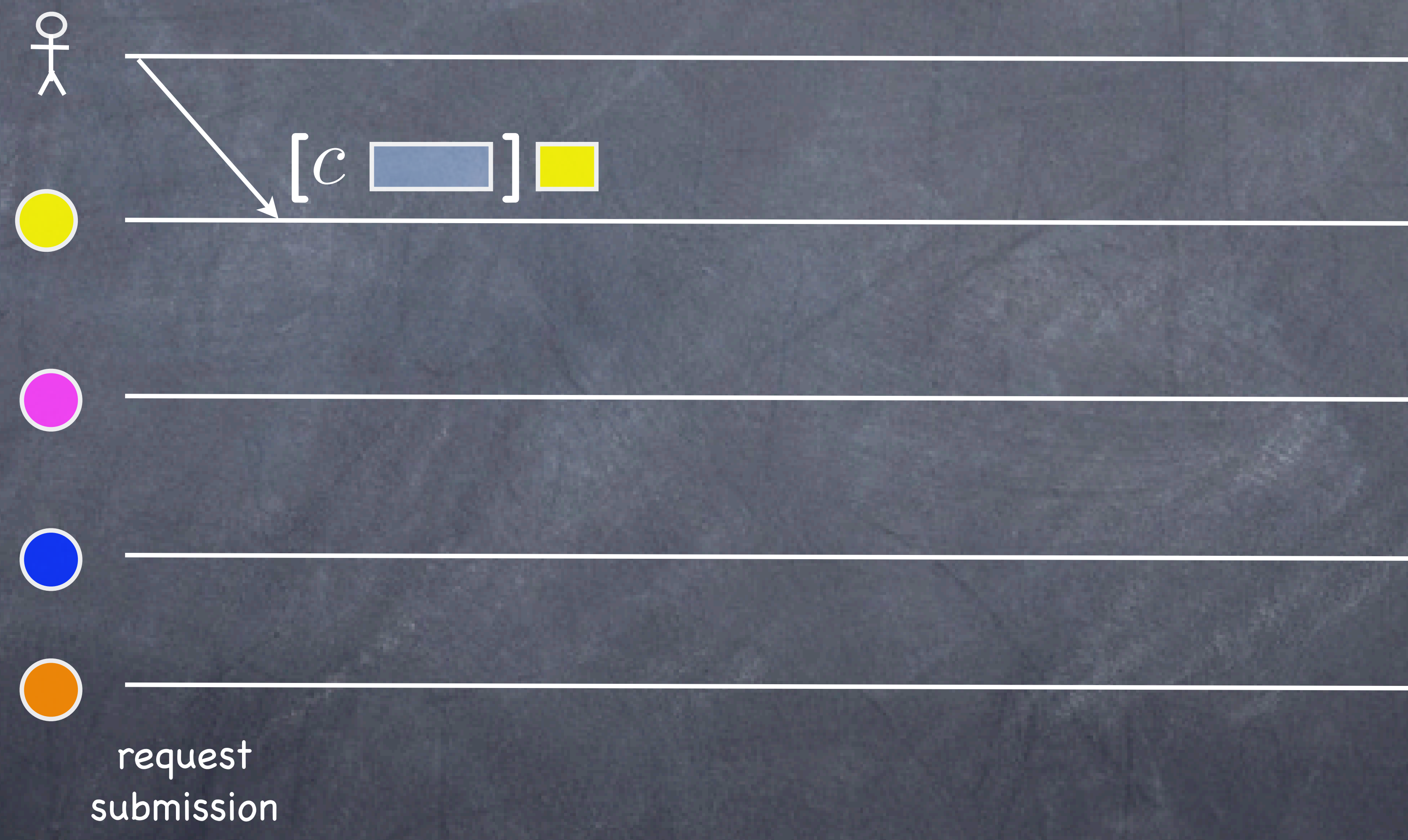

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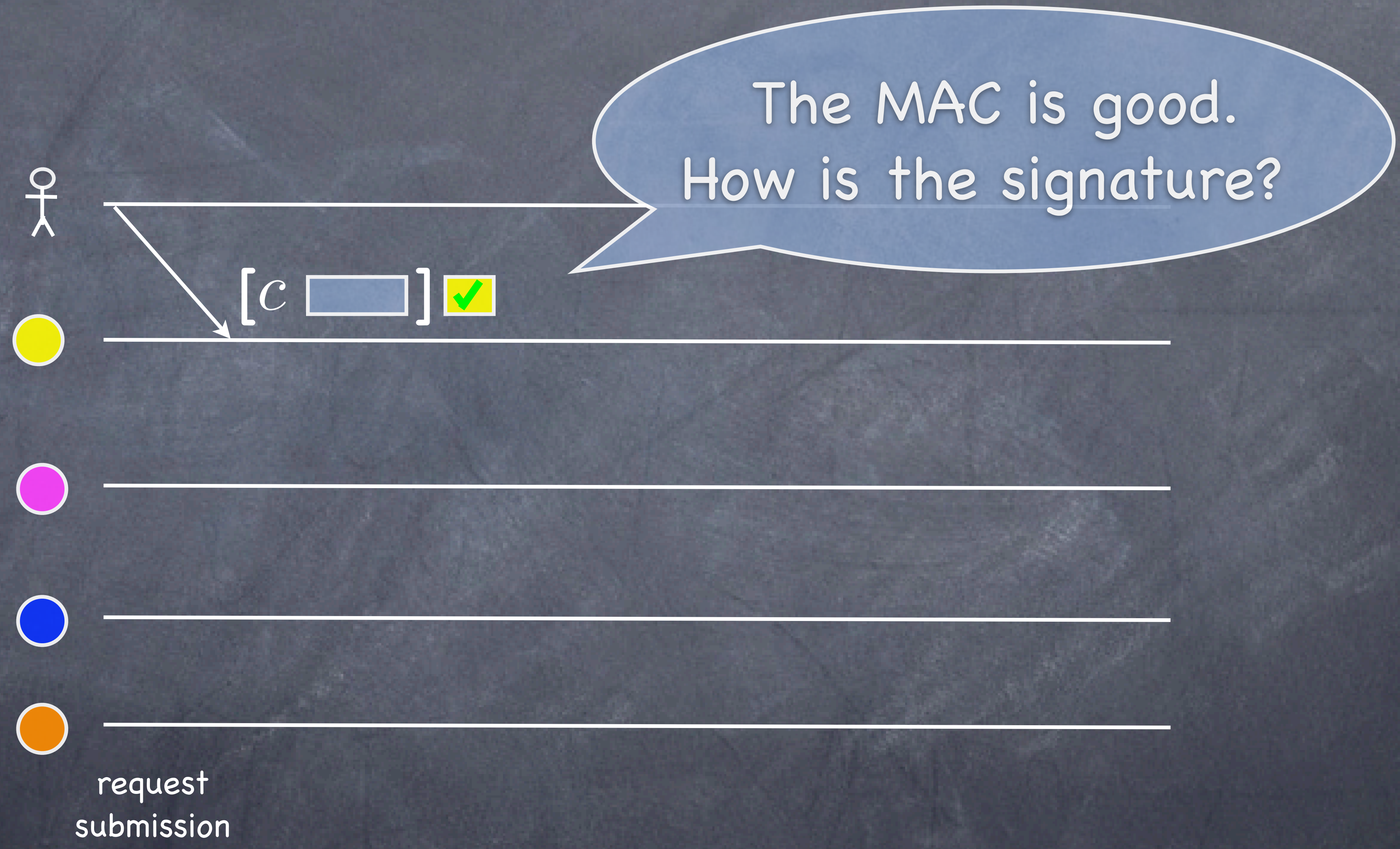

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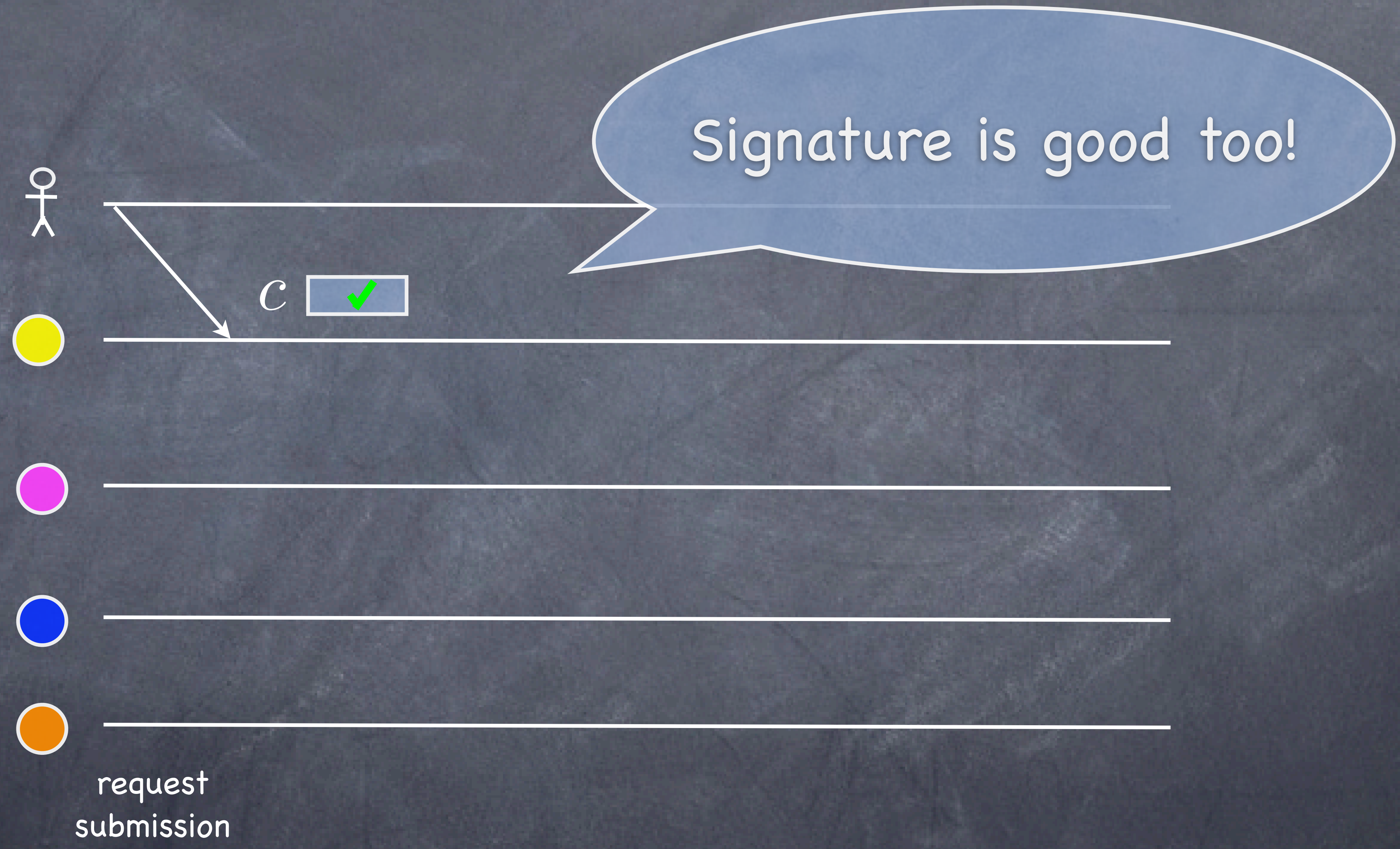

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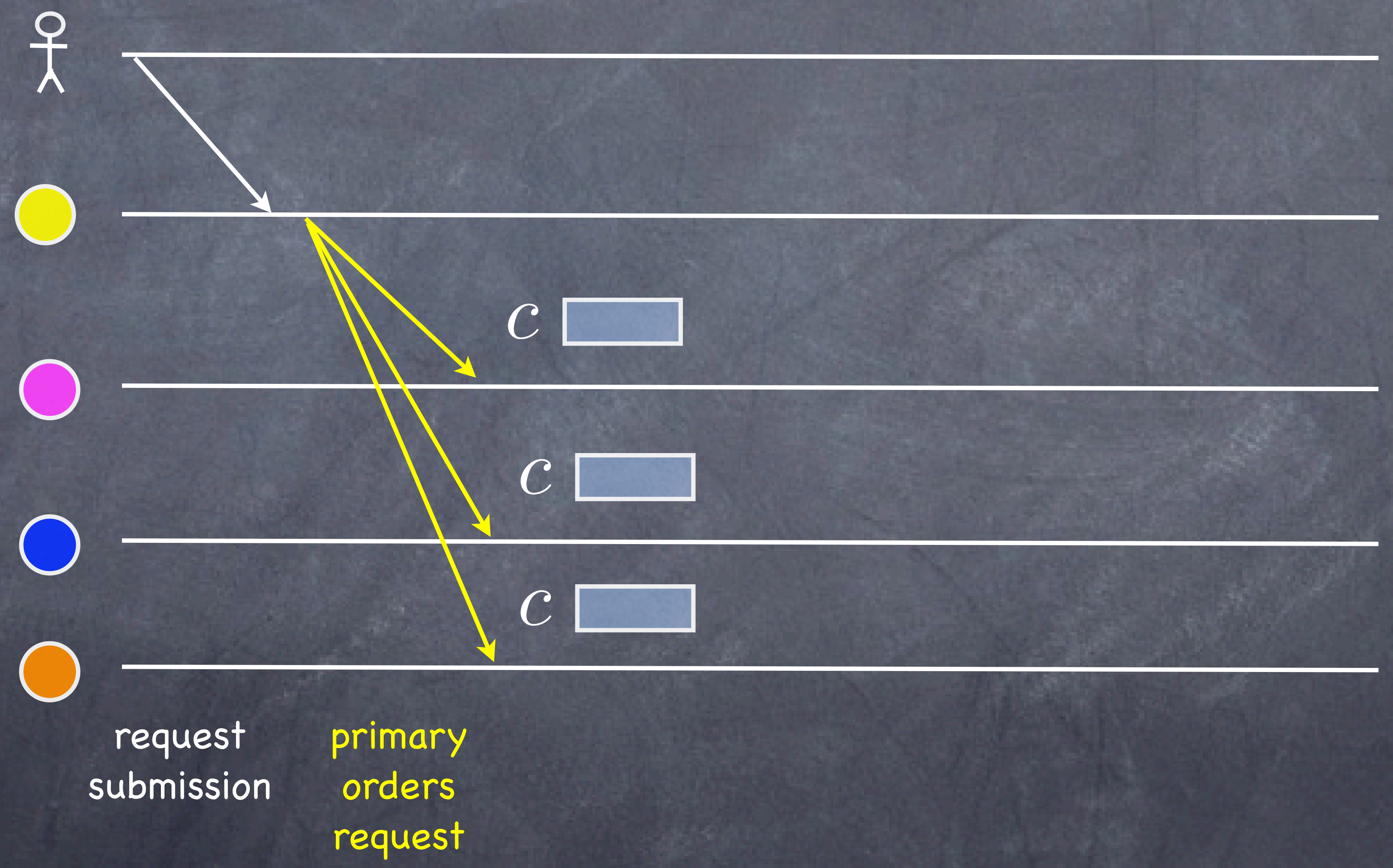

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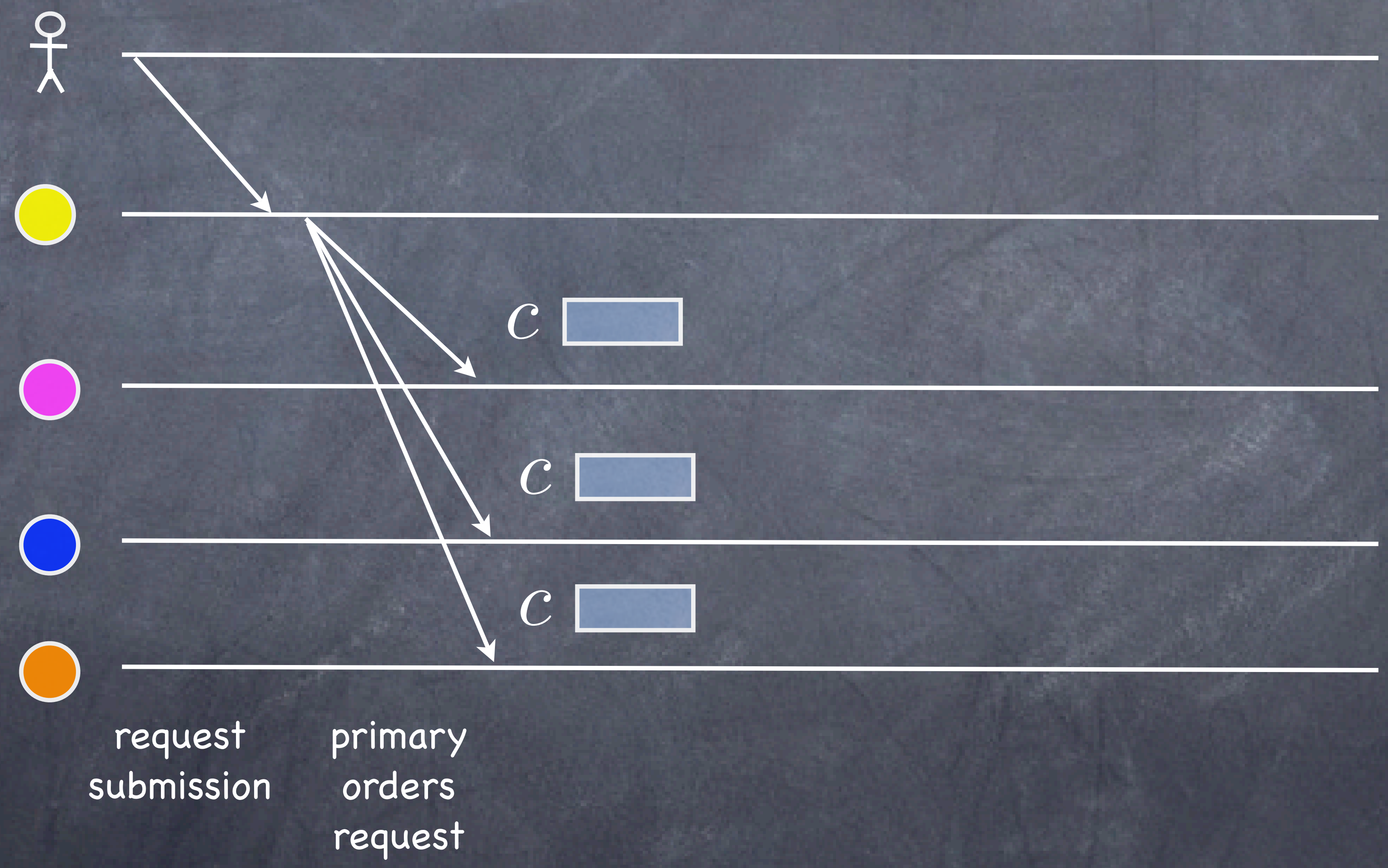

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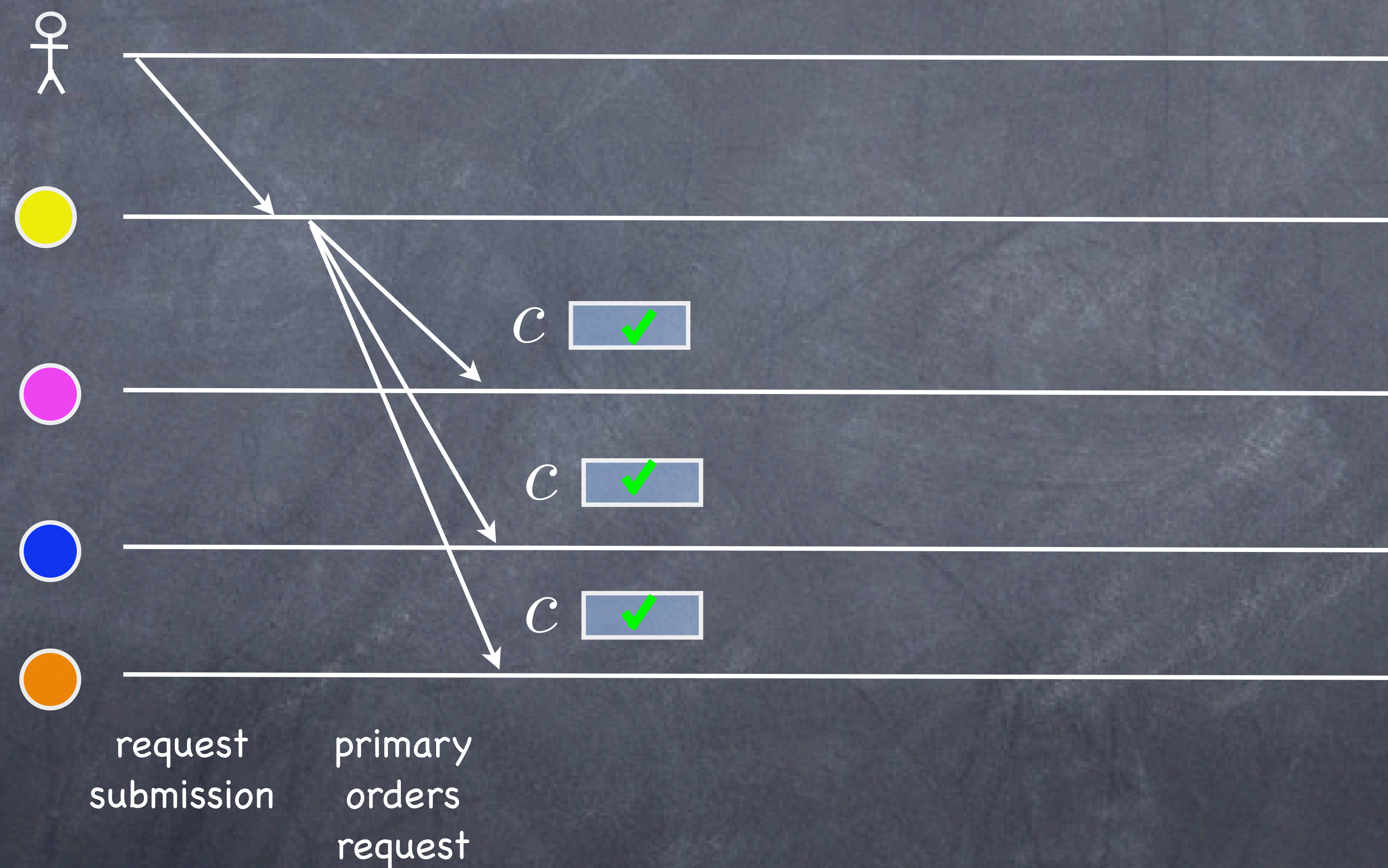
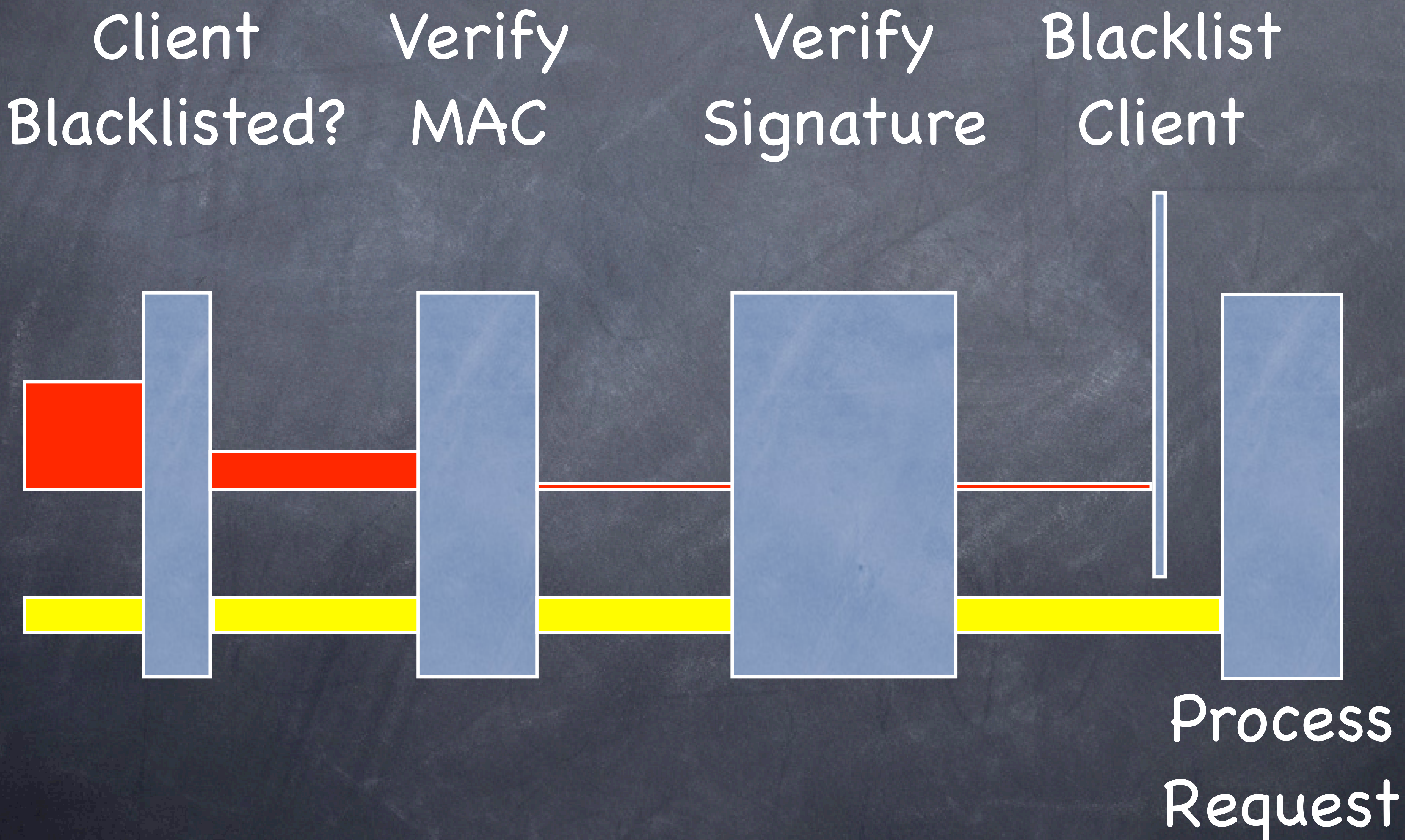


Signed Request Filtering



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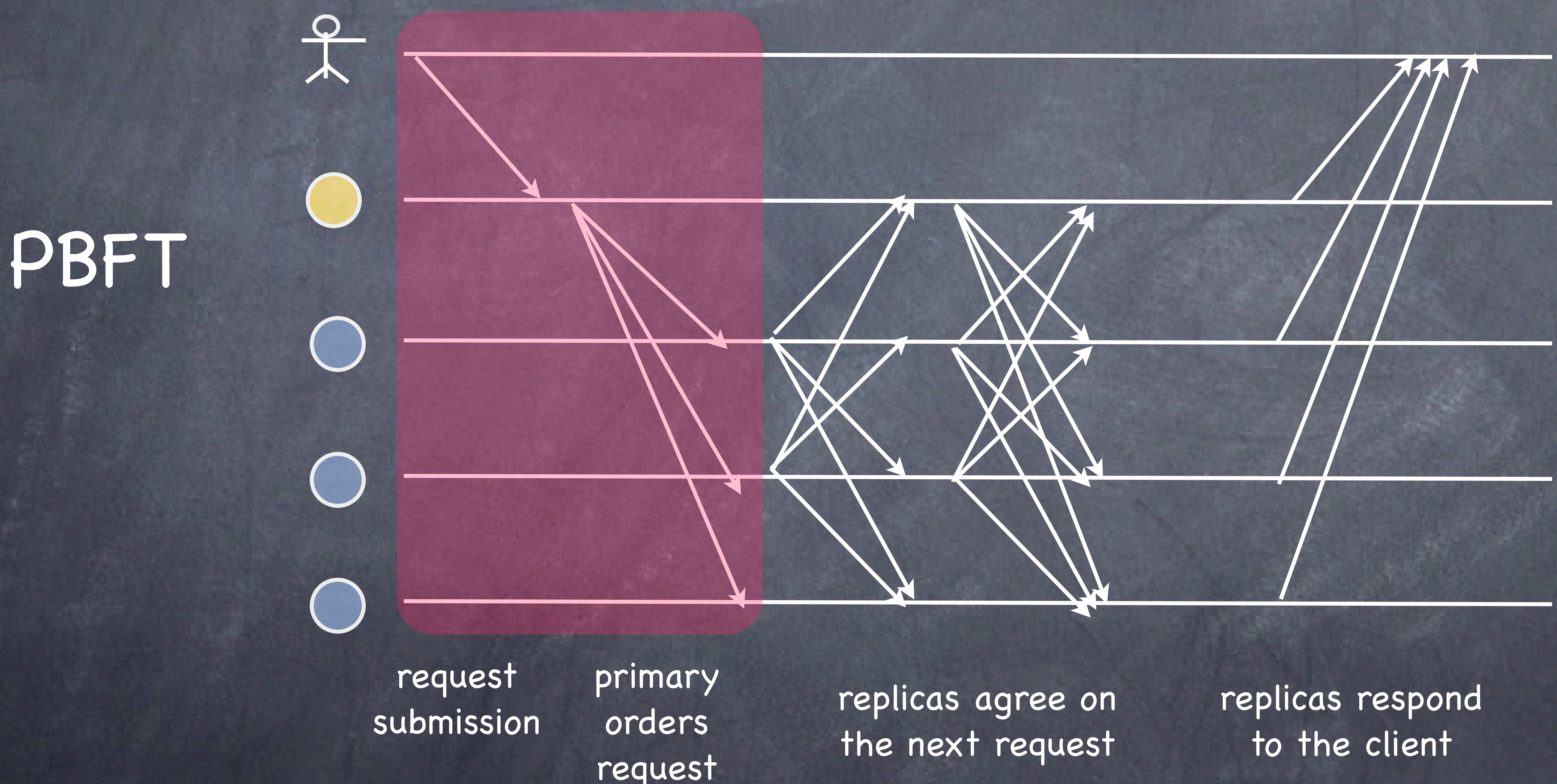
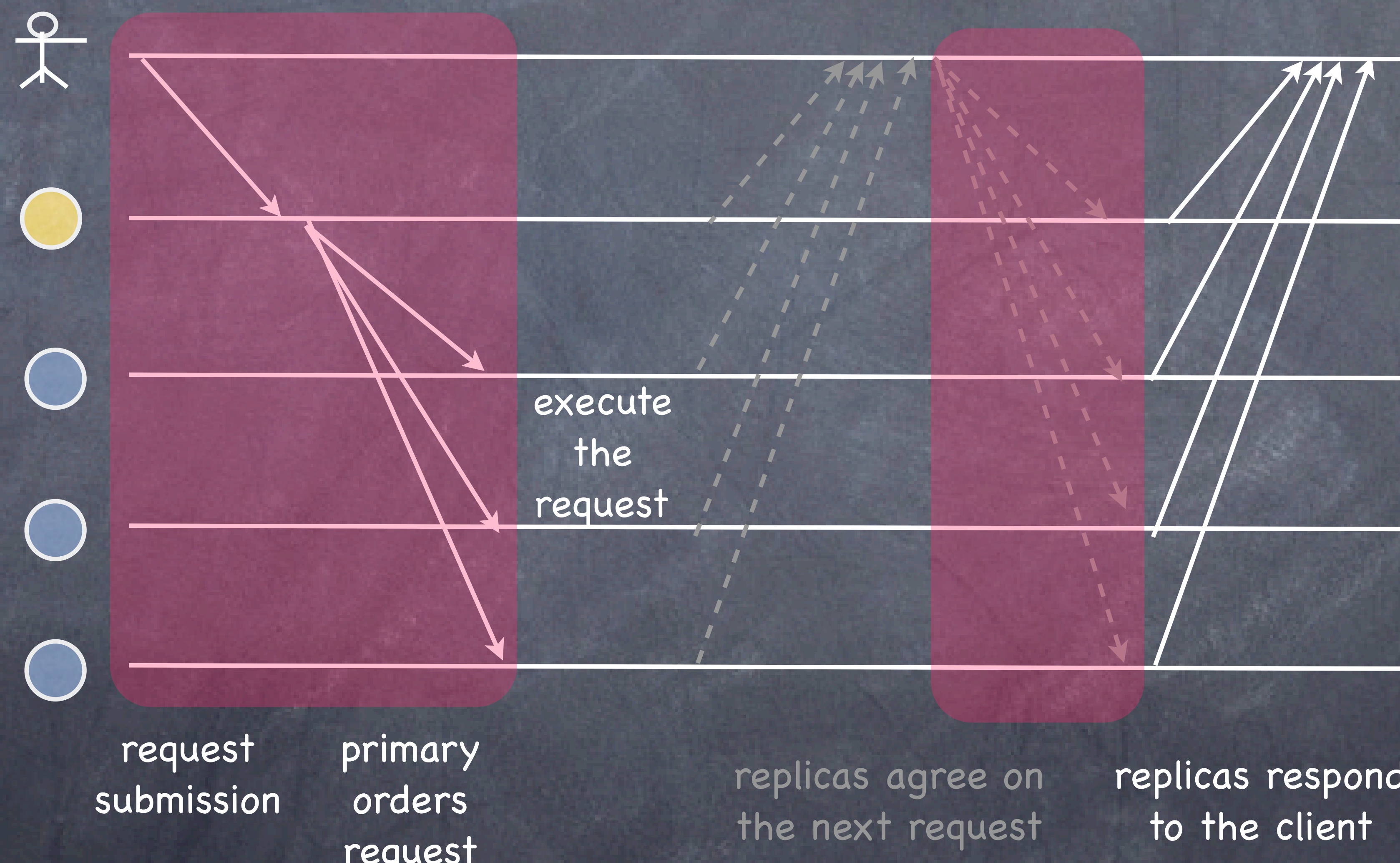


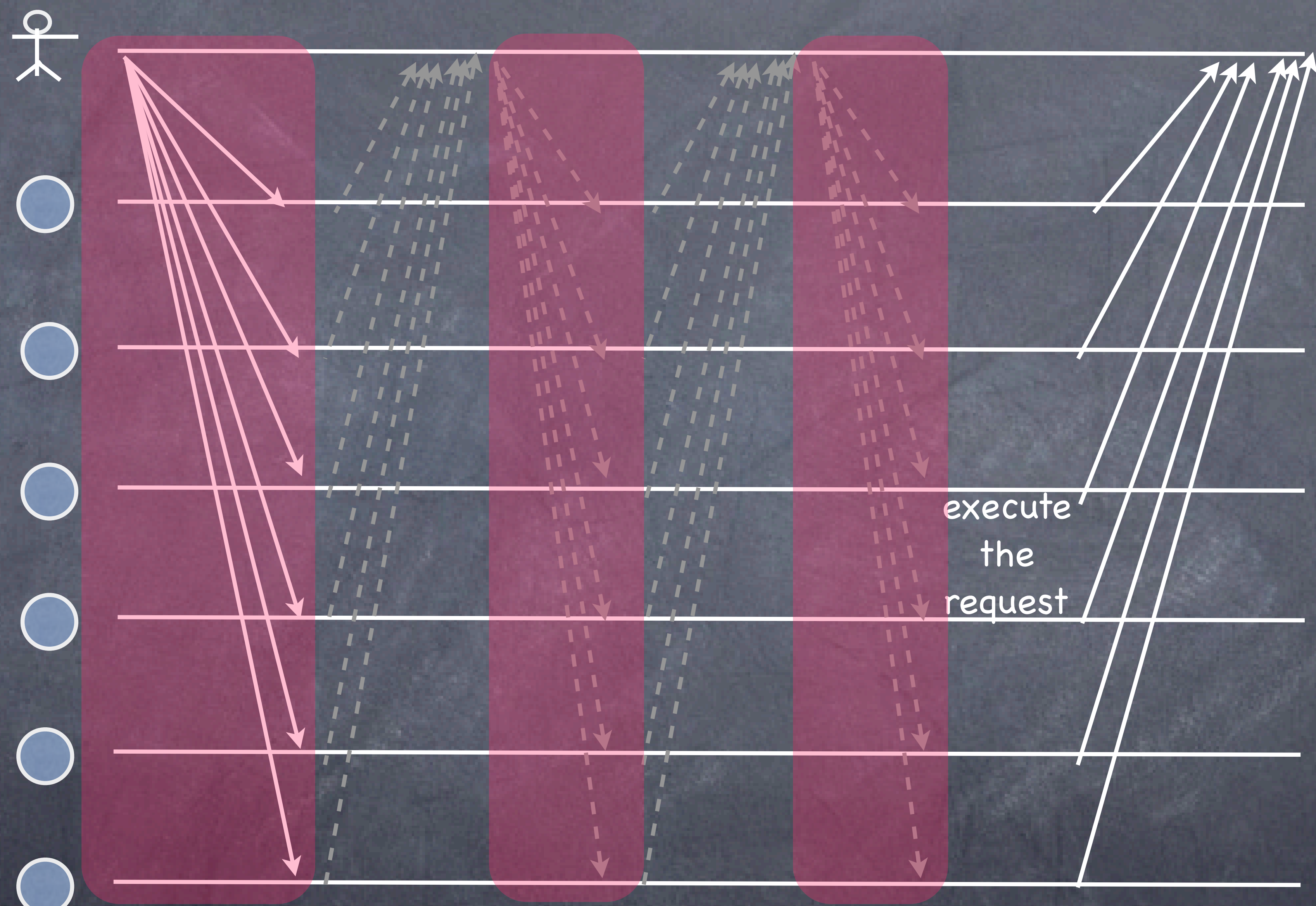
Big MAC Attack

Zyzzyva



Big MAC Attack

Q/U



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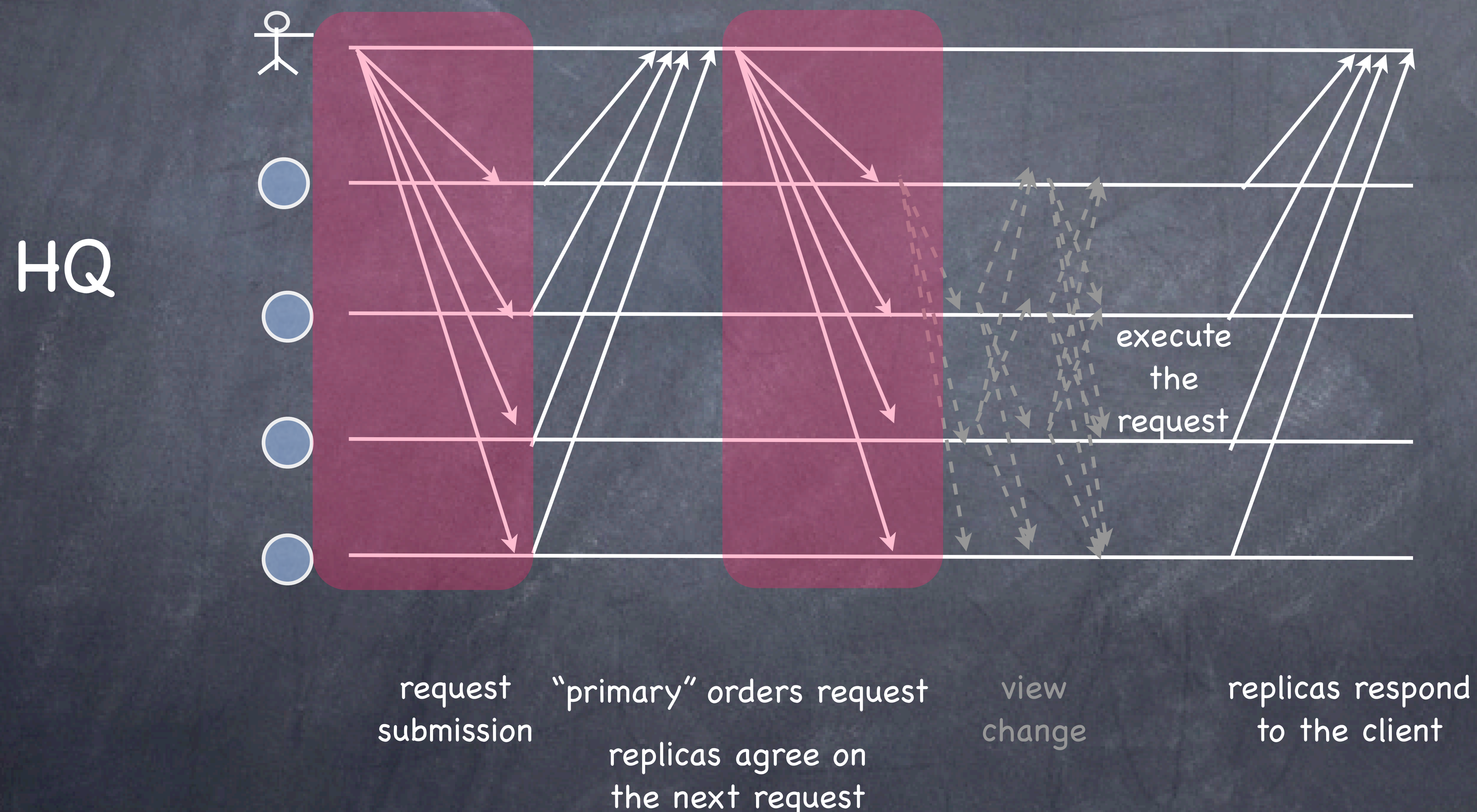

Slow Primary

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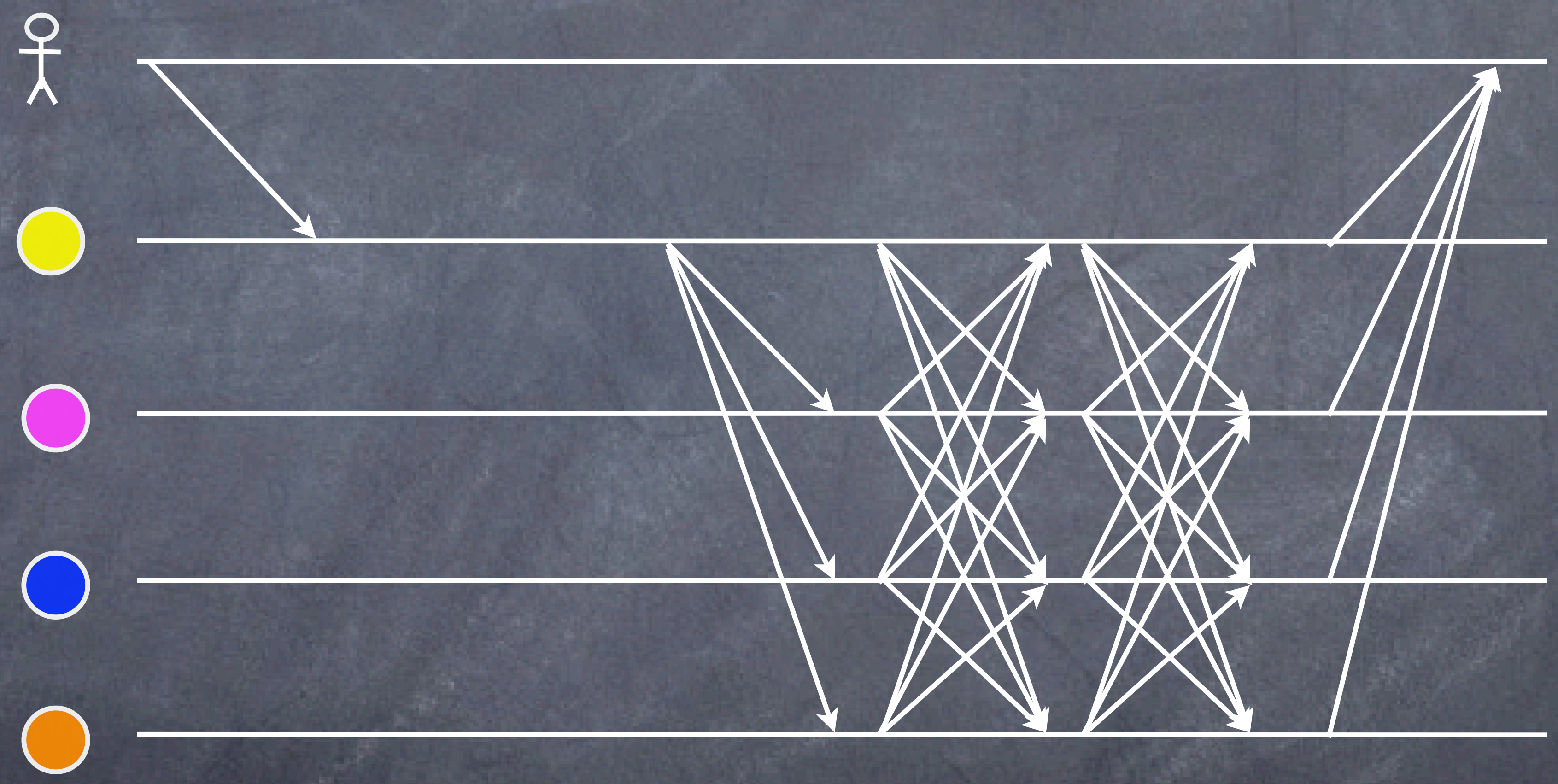
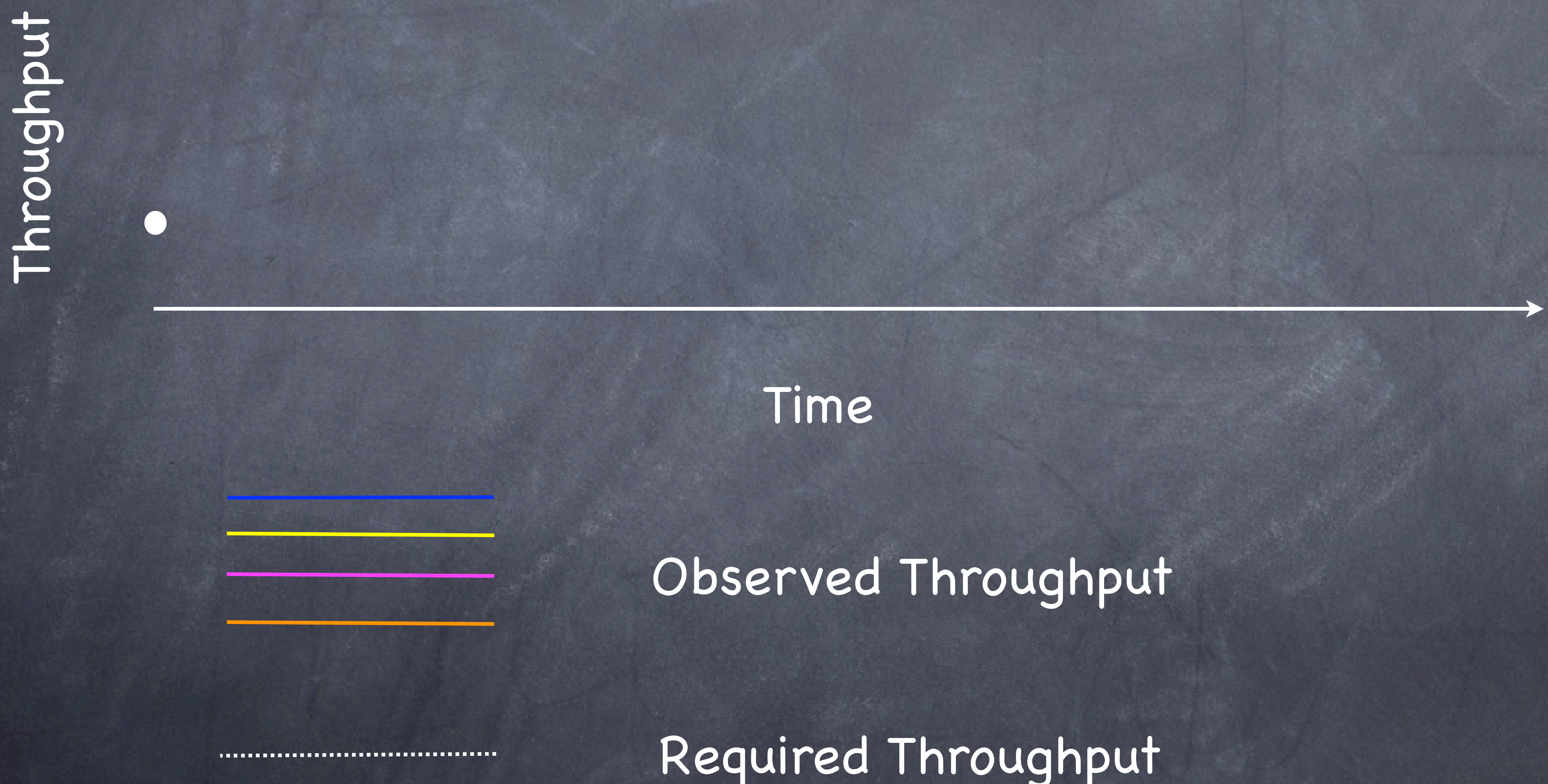


Adaptive View Changes



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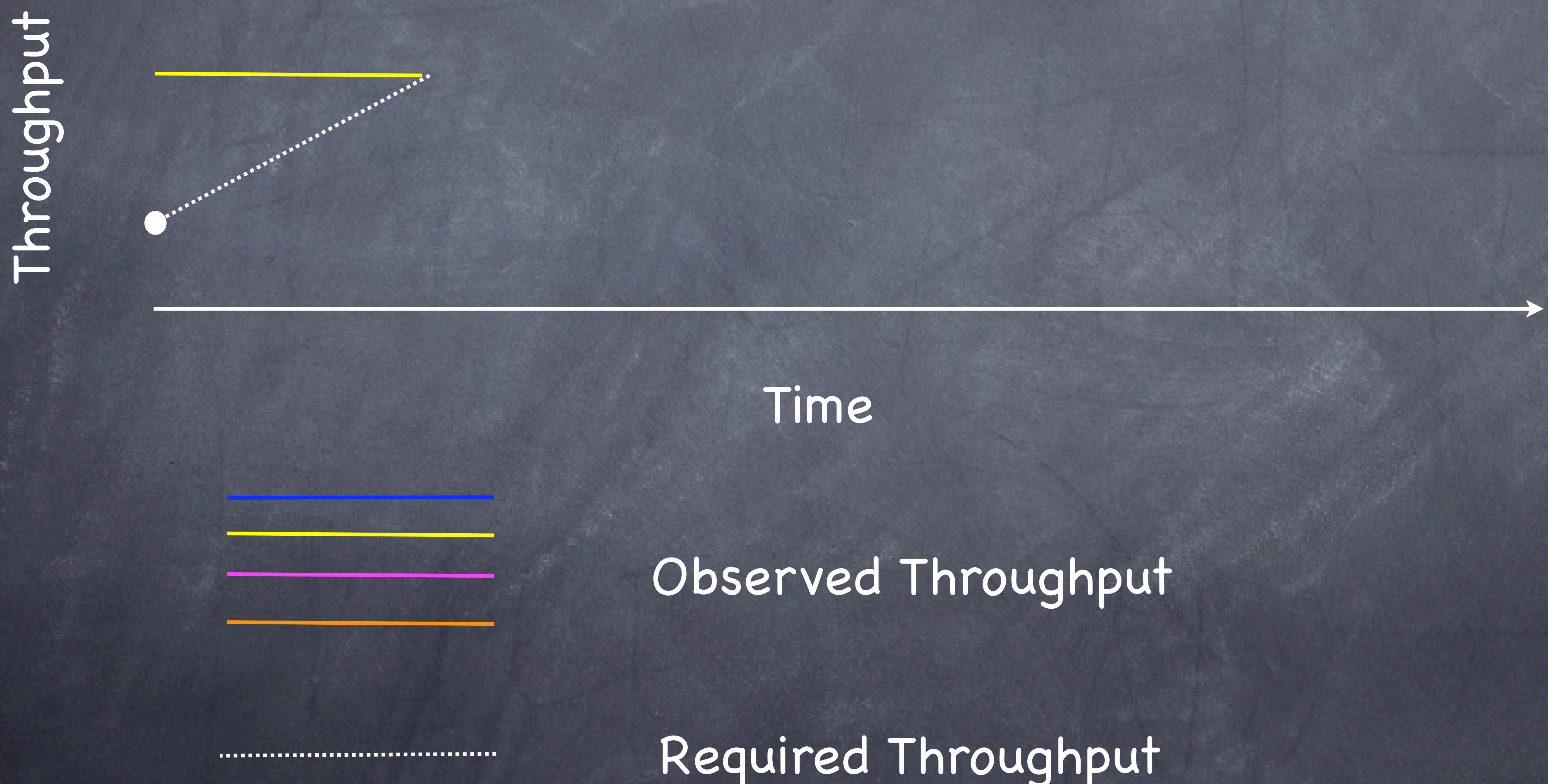

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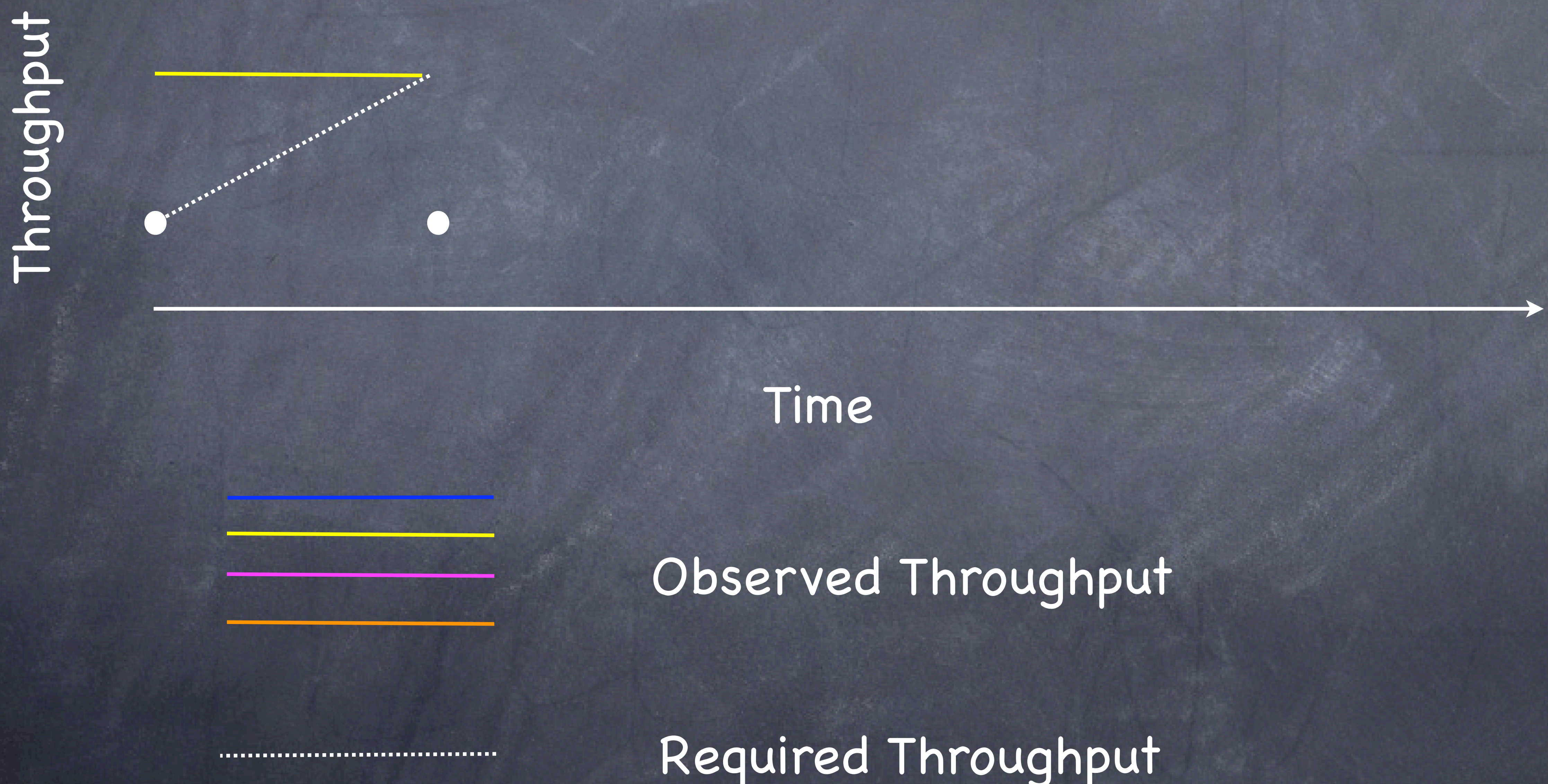

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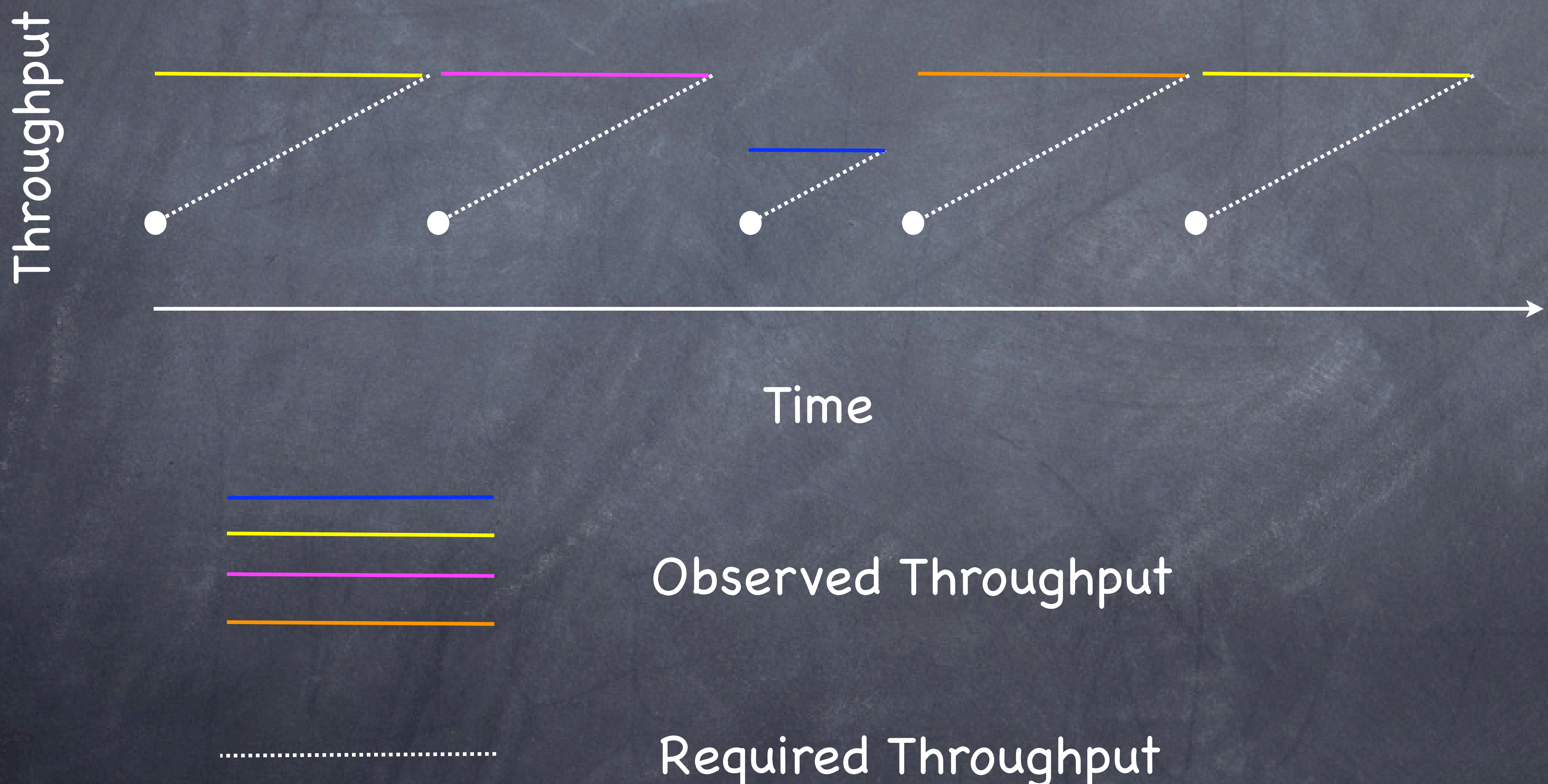


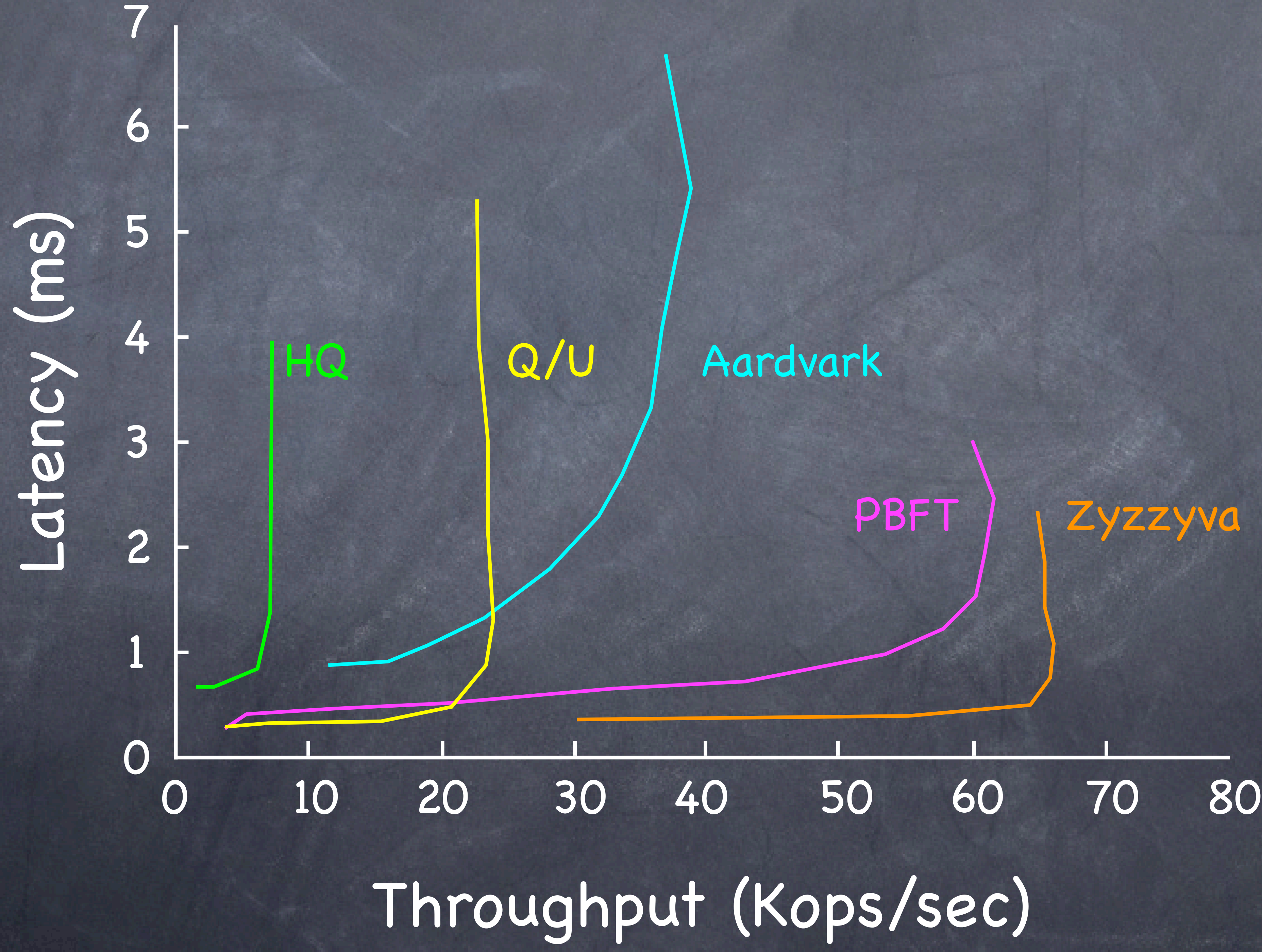
Implementation details

- Sign client requests
- Adaptive view change
- Separate network channels
- Fair scheduling
  - clients -v- replicas
  - replicas -v- replicas
- Exploit multicore architectures

Outline

- Robust BFT: The case for a new goal
- Aardvark: Designing for RBFT
- Evaluation: RBFT can work

Throughput -v- Latency



Aardvark, Incrementally

	MAC Client Request	Sign Client Request	Adaptive View Change
PBFT	62k	30k	-
Aardvark	58k	39k	39k

Performance with failures

- Byzantine failures are arbitrary
- Good faith effort

Big MAC Attack

	Peak	Faulty Client
PBFT	62k	0
Q/U	24k	0
HQ	7.6k	-
Zyzzyva	65k	0
Aardvark	39k	39k

Slow Primary

	Peak	1ms delay	10ms delay	100ms delay
PBFT	62k	5k	5k	1k
Zyzzyva	65k	28k	5k	crash
Aardvark	39k	38k	37k	38k

Summary

- RBFT: a new goal for BFT systems
- Aardvark: rejecting conventional wisdom
- Evaluation: it works!