The Search of the Path MTU with QUIC

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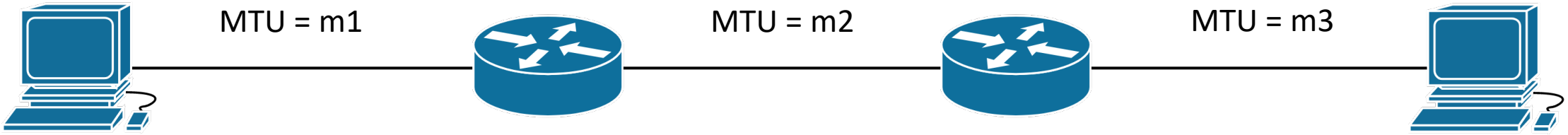
Agenda

1. Introduction
2. PMTUD Framework and QUIC
3. PMTU Search
4. Evaluation
5. Conclusion

Introduction

Path MTU



MTU = Maximum Transmission Unit

= IP packet size limit for a link

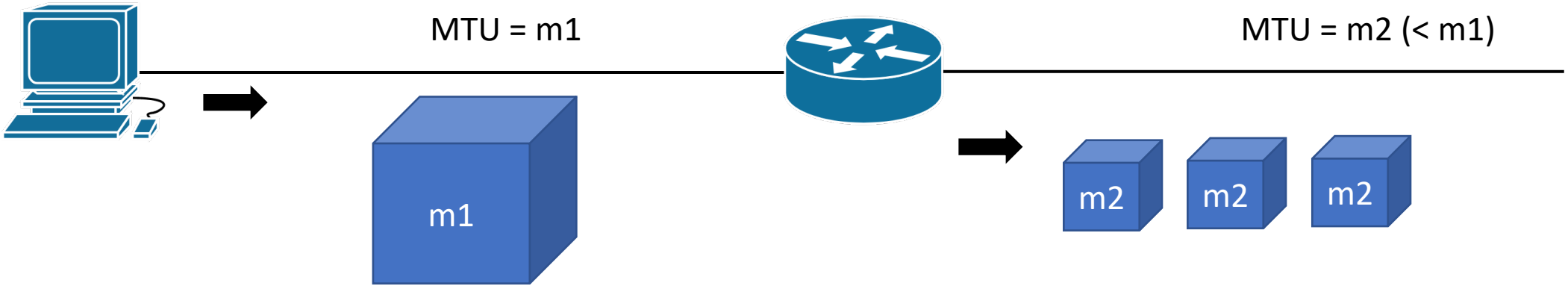
PMTU = Path MTU

= IP packet size limit for the path

= min(m1, m2, m3)

Why care about the PMTU?

- Limit size of outgoing packets only by the local link MTU (m1)
- Let router do IP fragmentation if necessary
  - Only possible with IPv4
  - IP Fragmentation considered harmful[1]

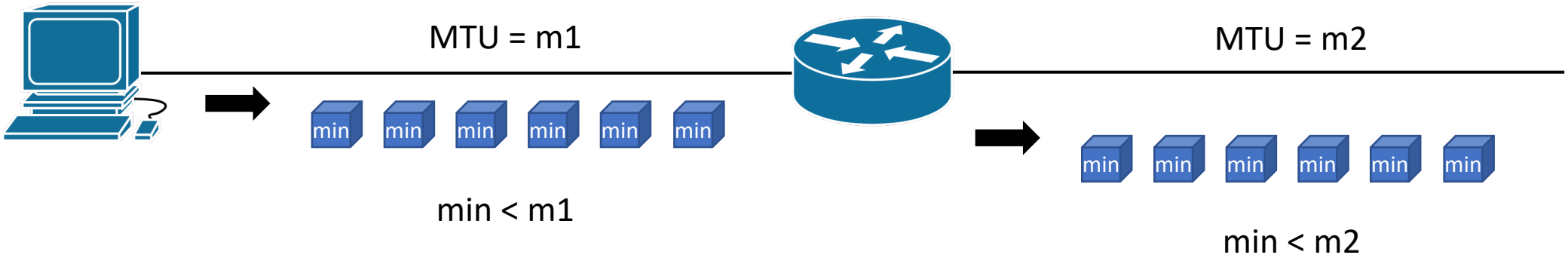


[1]Christopher A. Kent and Jeffrey C. Mogul. Fragmentation Considered Harmful. ACM SIGCOMM '87

Why care about the PMTU?

- Send IP packets small enough to avoid size constraints
  - Requires more packets
  - Increases overhead
  - Consumes more processing power

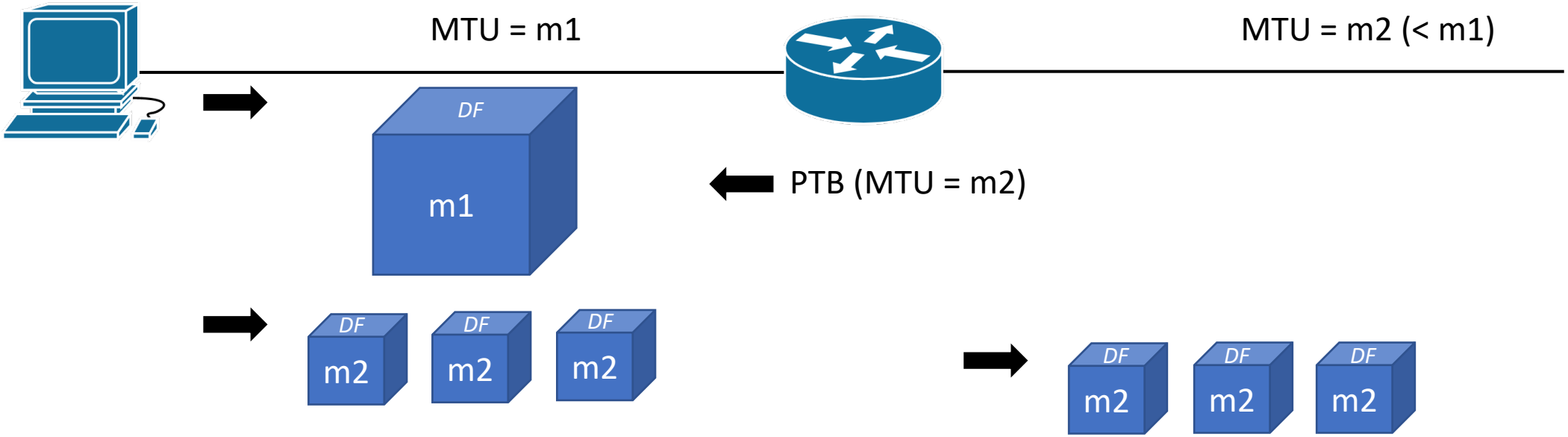
  → Reduces throughput[1]



[1]Kazuho Oku and Jana Iyengar. 2020. Can QUIC match TCP's computational efficiency? https://www.fastly.com/blog/measuring-quic-vs-tcp-computational-efficiency

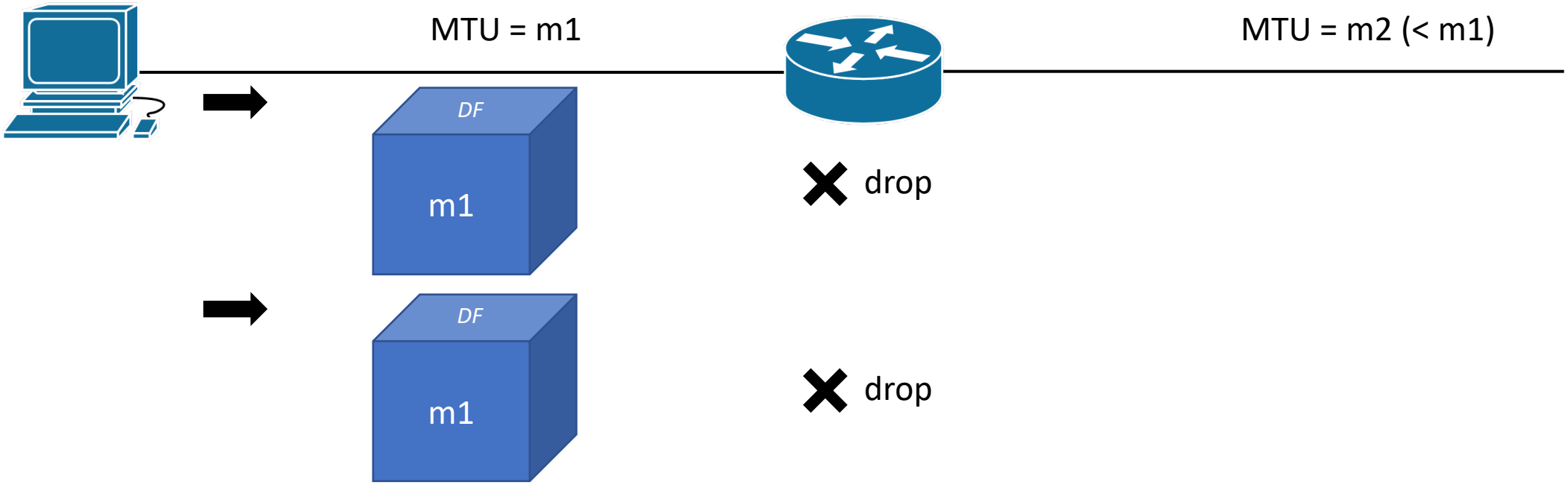
PMTU Discovery

- Limit size of outgoing packets only by link local MTU (m1)
- Set Don’t Fragment bit (implicit for IPv6)
- Rely on router to respond with Packet Too Big (PTB) message



PMTU Discovery Problem

- In the Internet, a Sender can’t rely on receiving a PTB
- E.g., because a Router silently drops packets that are too large
- Results in a Black Hole situation



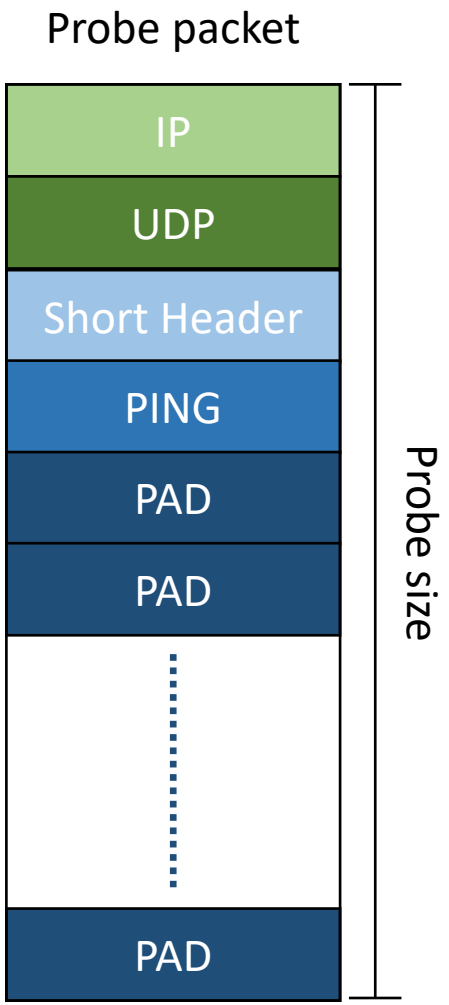
PMTU Discovery for Packetization Layer

- Don’t depend on a signal from the network
- Instead of IP, use an acknowledged Packetization Layer (PL) protocol
- IETF recently standardized this (RFC8899) for PL protocols like QUIC
- Describes the framework
- Does not contain details of how to search for the PMTU

PMTUD Framework and QUIC

PMTU Probe

- Estimate PMTU
- Begin with a small value
- Send packets to probe the network path



PMTU Probe Events

- Acknowledgement
  - Estimated PMTU = probe packet size
  - Received after approx. one RTT (+ max_ack_delay)
- Loss (use QUICs loss detection)
  - Resend probe packet
  - Consider probe as failed after MAX_PROBES lost probe packets
- PTB (valid)
  - Consider probe as failed

PMTU Search

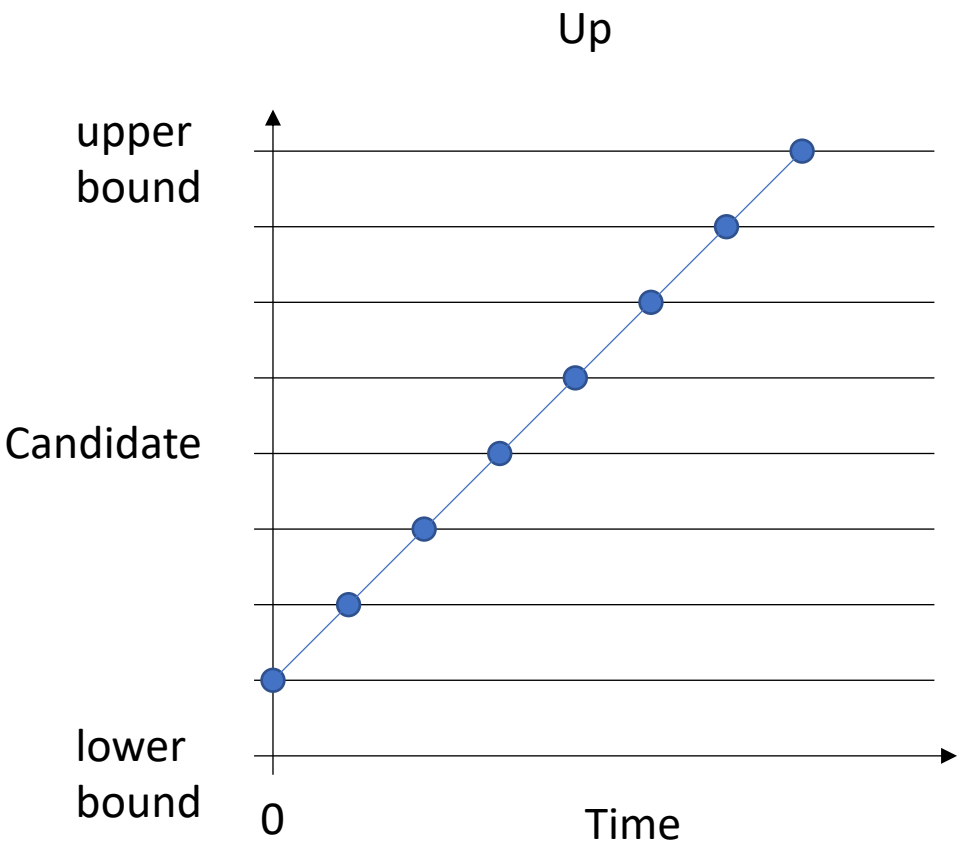
PMTU Candidates

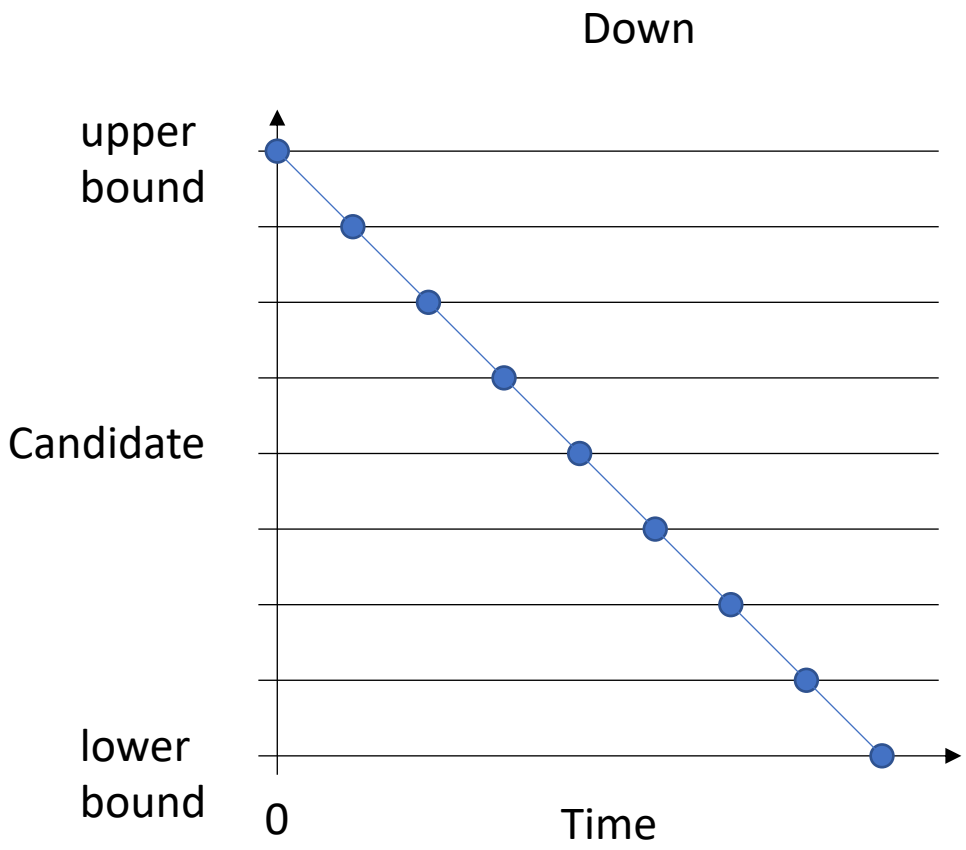
- Lower Bound: 1280 B (use this size for QUIC's path validation)
  - RFC9000: QUIC assumes each path supports this size
- Upper Bound: Minimum of these
  - Maximum IP packet size (65,535 B for IPv4 or 65,575 B for IPv6)
  - MTU specified for local network interface
  - MTU learned from another network device (Router)
  - MRU declared by the remote endpoint (max_udp_payload_size)
- Precision:
  - Consider only a subset of candidates by accepting a lower precision
  - We choose to consider only multiples of four

Candidate Sequence

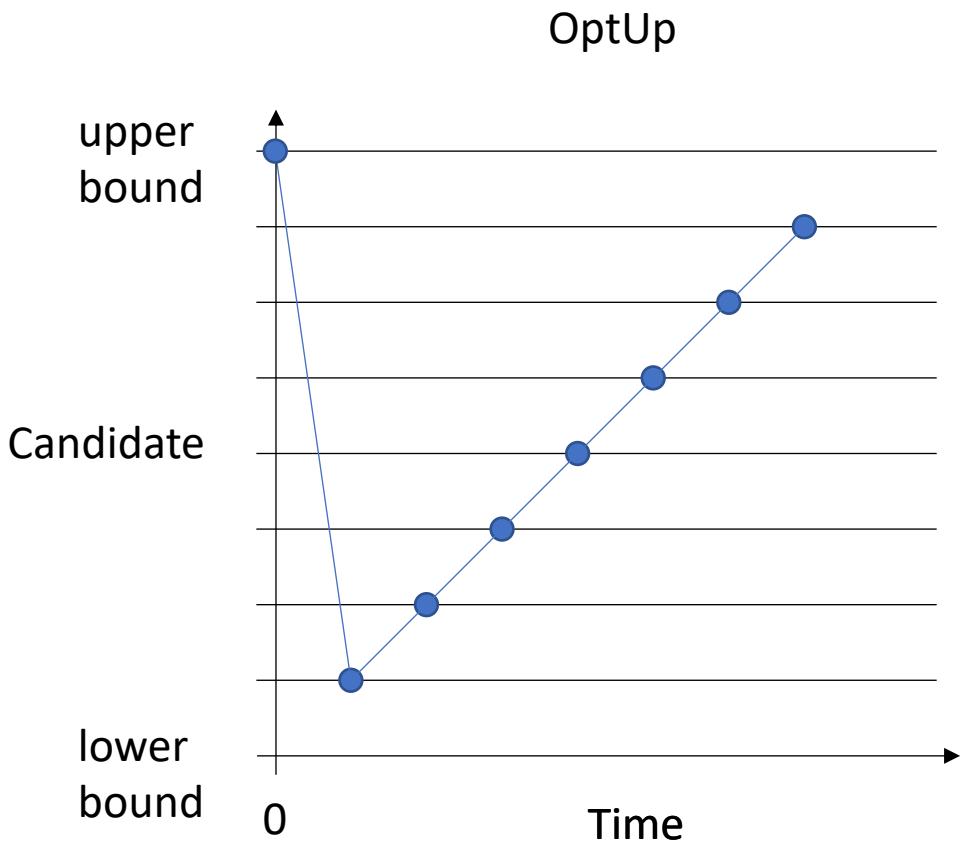
- Specifies the order of candidates to probe
- We consider 7 candidate sequences

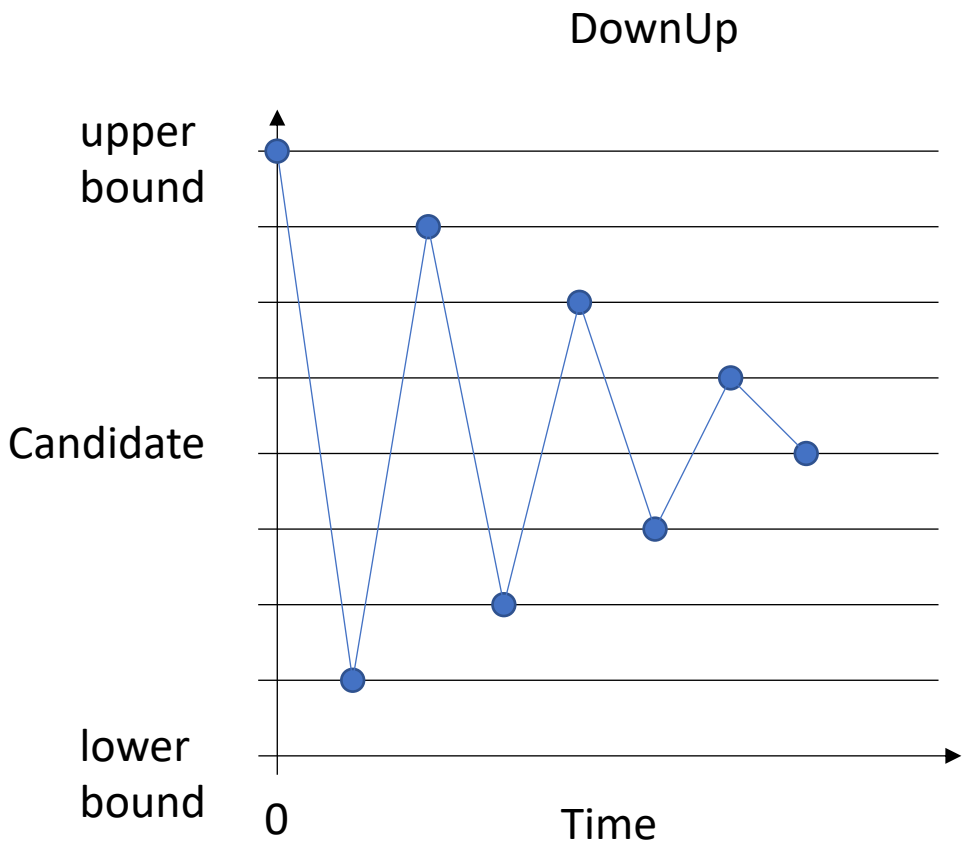
Candidate Sequences



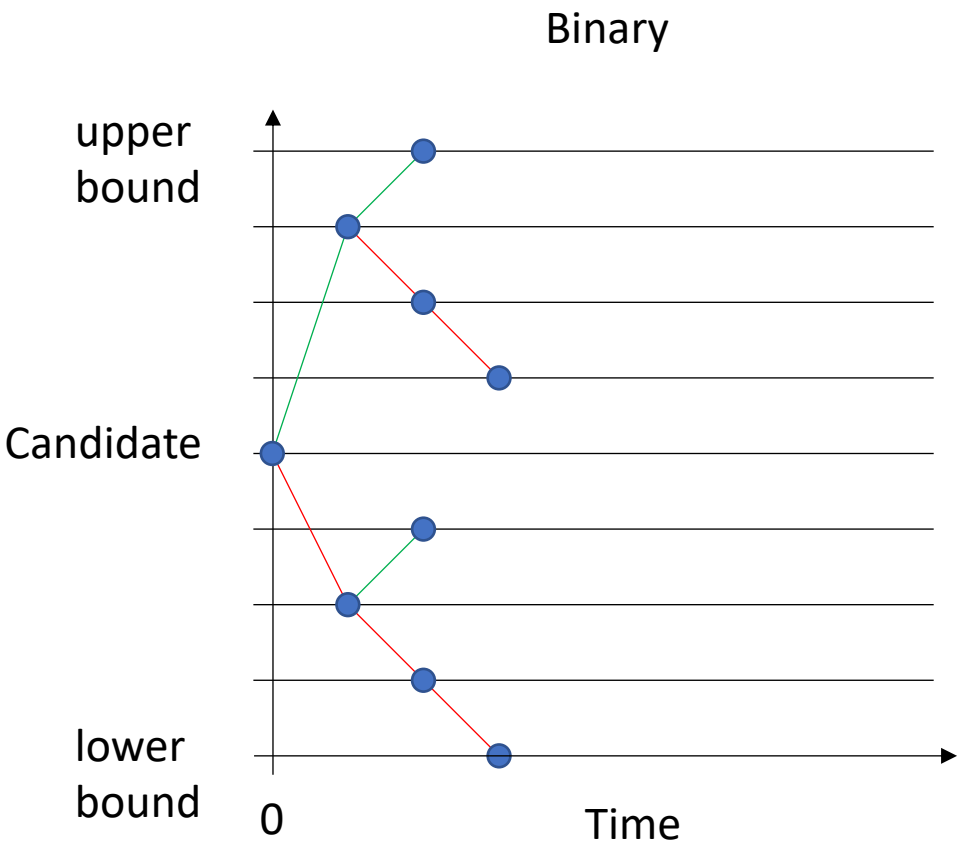


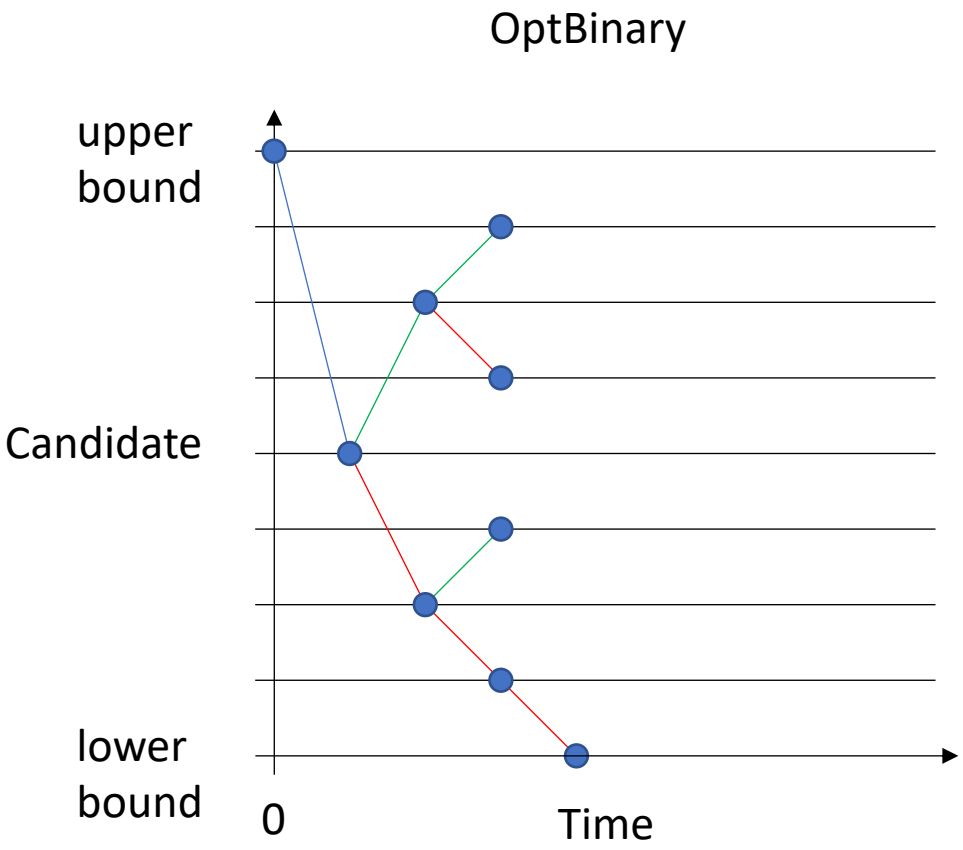
Candidate Sequences



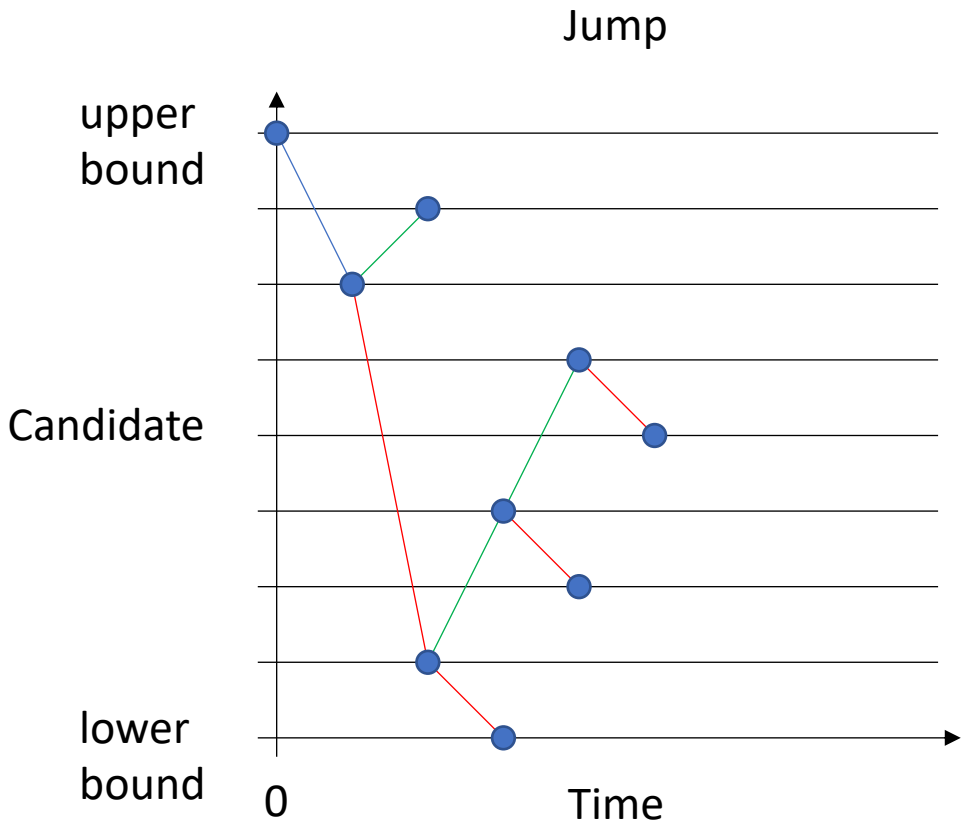


Candidate Sequences



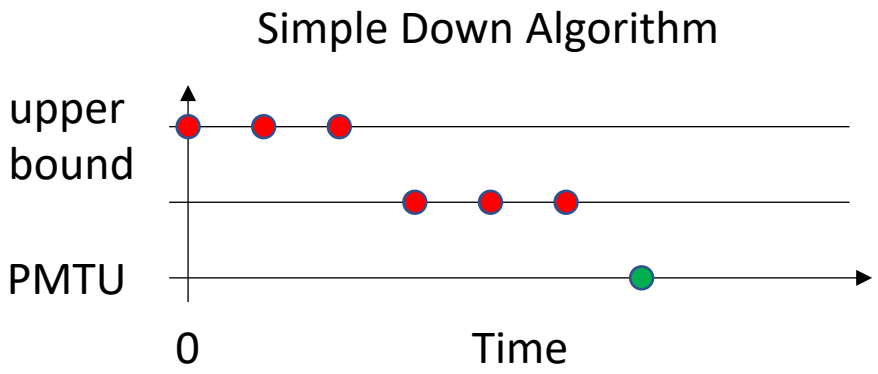


Candidate Sequences



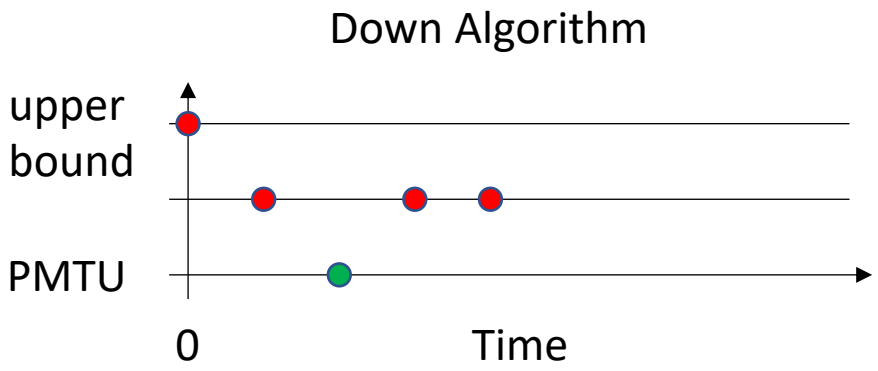
Search Algorithm

- Decides when to
  - select the next candidate
  - retransmit
  - terminate
- Simple algorithm would check one candidate after the other



Search Algorithm

- Start probe for a smaller candidate instead of rtx
- Postpones decision for previous candidate
- Successful Probe: Starts rtx if no larger candidates are available
- Failed Probe: Lets all other probes for larger candidates fail as well



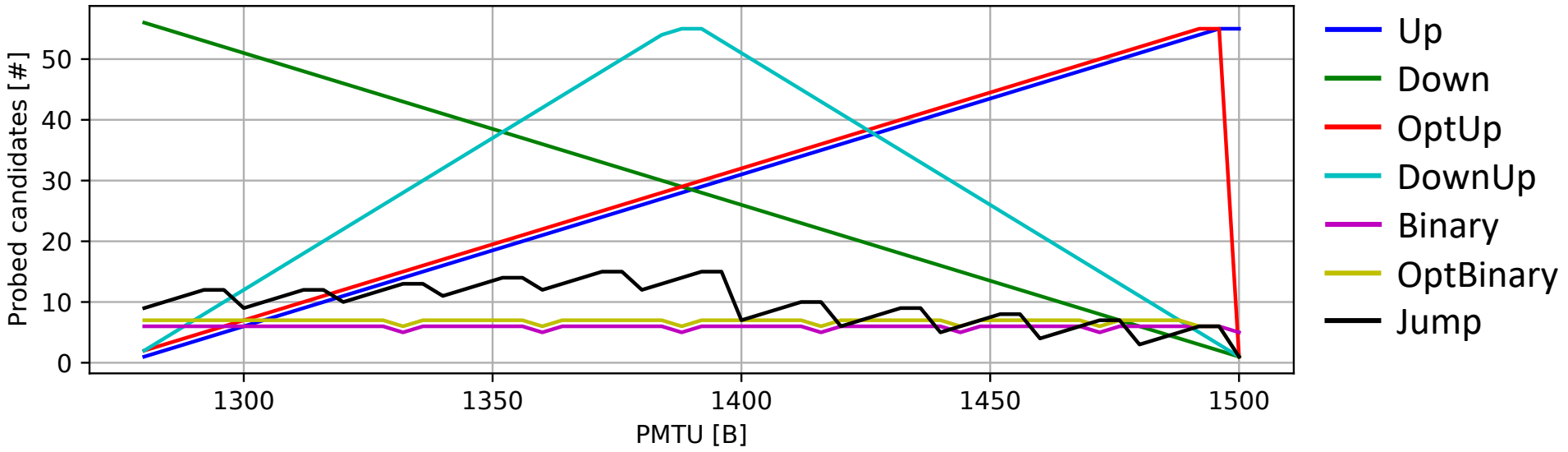
Evaluation

Analytical

- 4 Metrics
- Compare algorithm with each candidate sequence
- Consider network endpoint searches the PMTU
- Candidates: multiples of 4 between 1280 B and 1500 B
- Assume no packet loss due to another reason than packet size
- No PTB

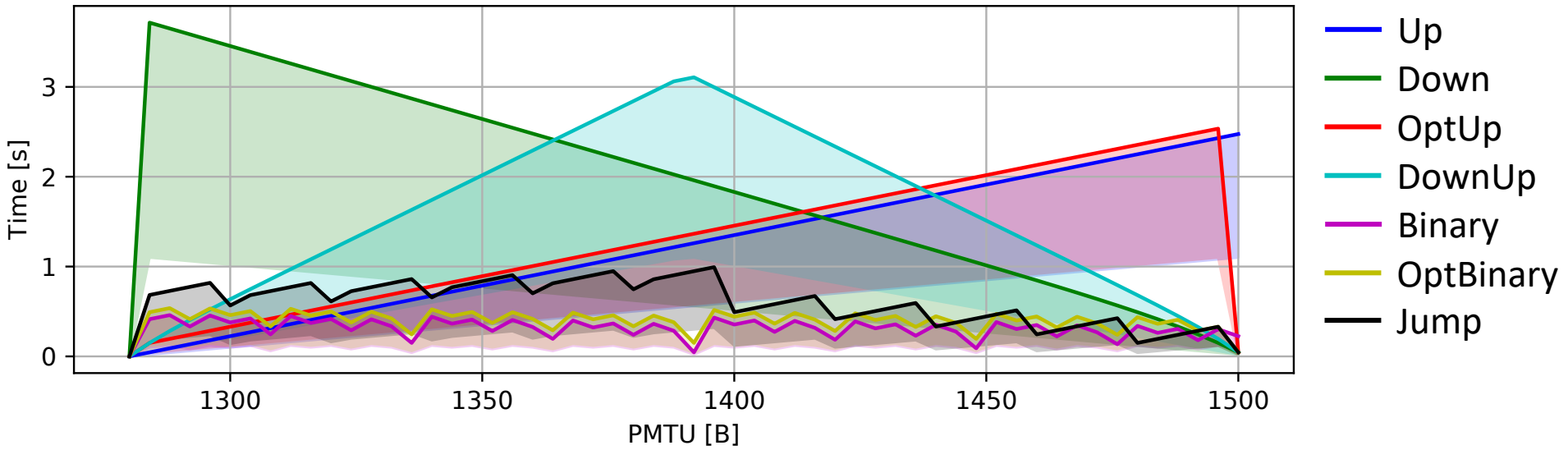
Number of probed PMTU candidates

- Number of candidates the algorithm probes
- Until it finds the PMTU and terminates



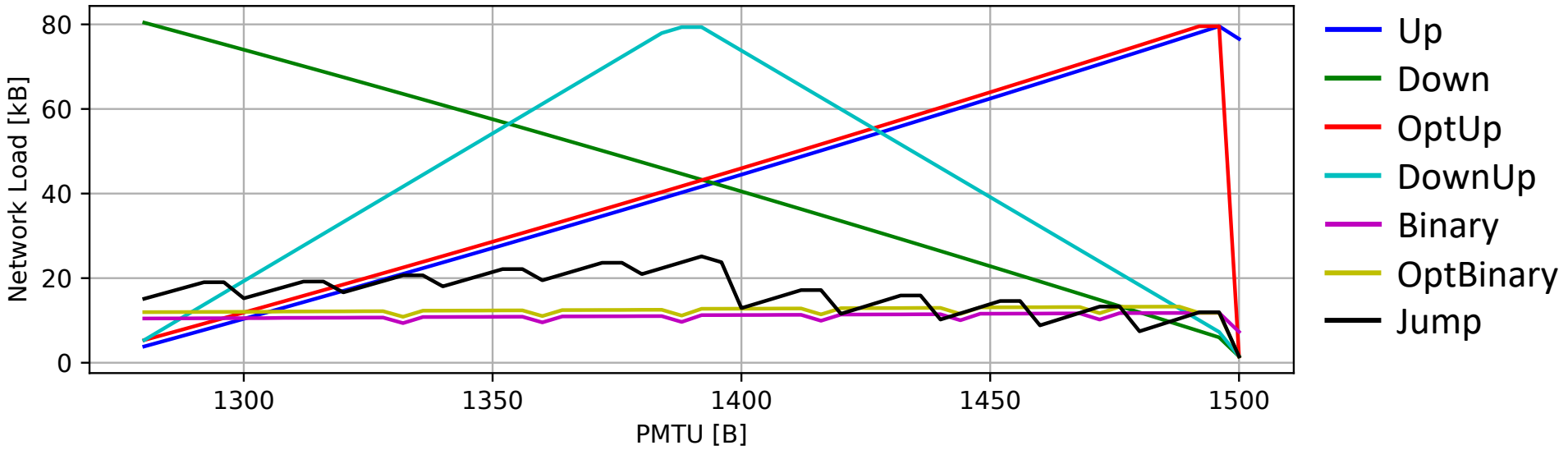
Time

- Time needed
- Until it finds the PMTU
- RTT = 20 ms, max_ack_delay = 25 ms



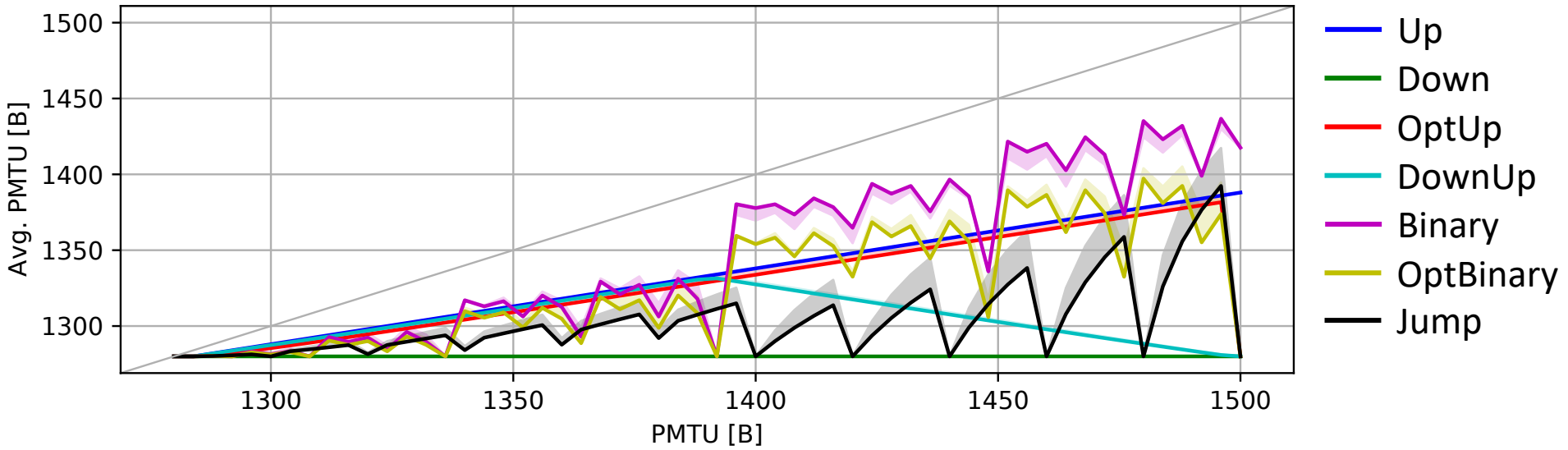
Network Load

- Load produced by probe packets
- Until it finds the PMTU and terminates
- MAX_PROBES = 3



Average PMTU Estimation

- Average PMTU estimation during search
- Before it finds the PMTU
- RTT = 20 ms, max_ack_delay = 25 ms



Result

Top 3

1. Binary
2. OptBinary
3. Jump

- Prefer OptBinary because it
  - immediately finds the PMTU or
  - triggers a PTB
- Jump depends on the initial set of candidates

Conclusion

Conclusion

- Search algorithm for PMTUD framework (RFC8899)
- Defined 4 metrics
- Analysed algorithm with different candidate sequences
- Implemented PMTUD in QUIC simulation model
- Used simulation to further evaluate search algorithm