The Flexlab Approach To Realistic Evaluation of Networked Systems

Robert Ricci, Jonathon Duerig,
Pramod Sanaga, Daniel Gebhardt, Mike Hibler,
Kevin Atkinson, Junxing Zhang, Sneha Kasera, and
Jay Lepreau

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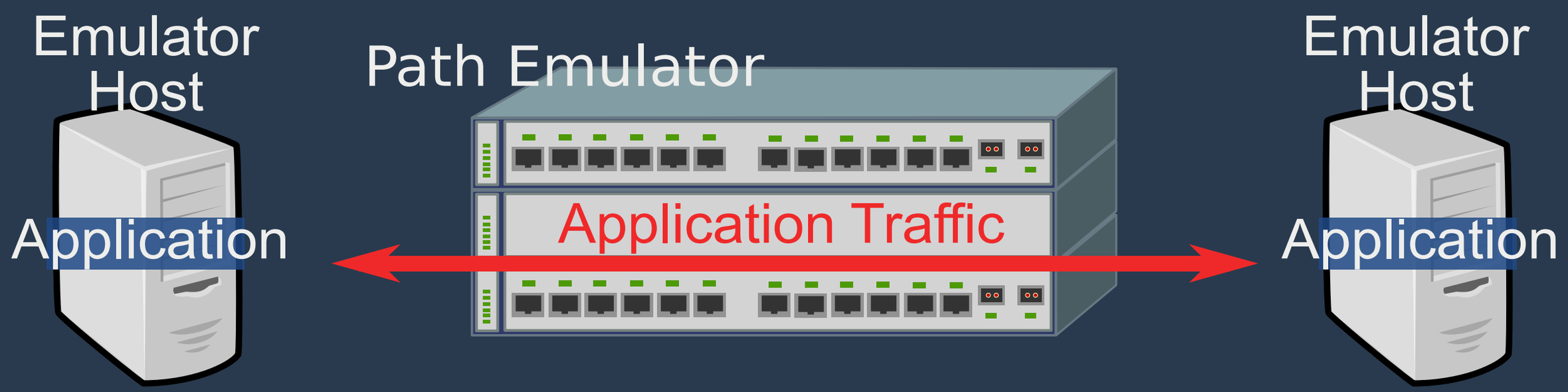
THE UNIVERSITY OF UTAH

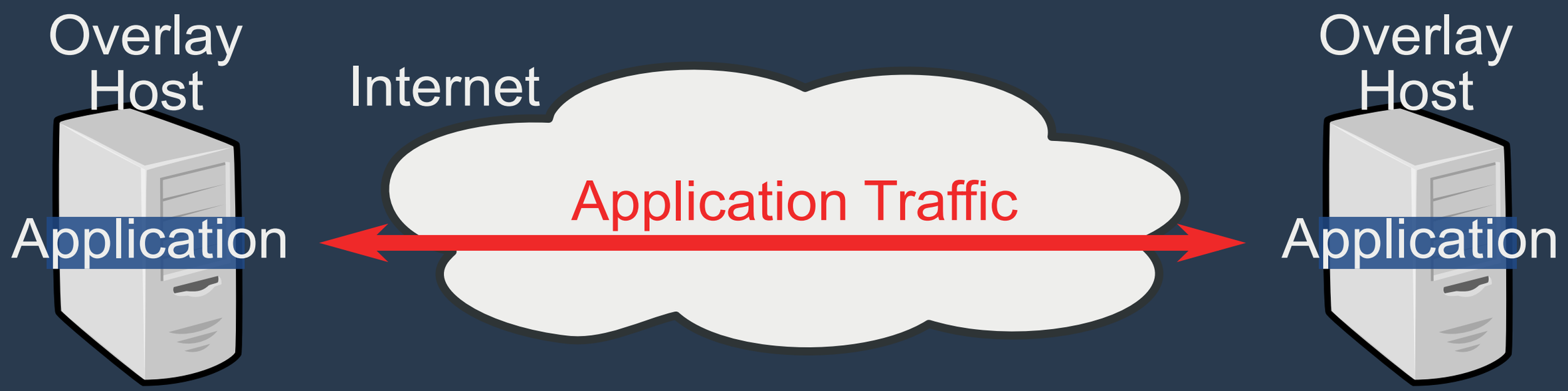
emulab.net

Emulators



- Examples: ModelNet and Emulab
- The Good: Control, repeatability, wide variety of network conditions
- The Bad: Artificial network conditions

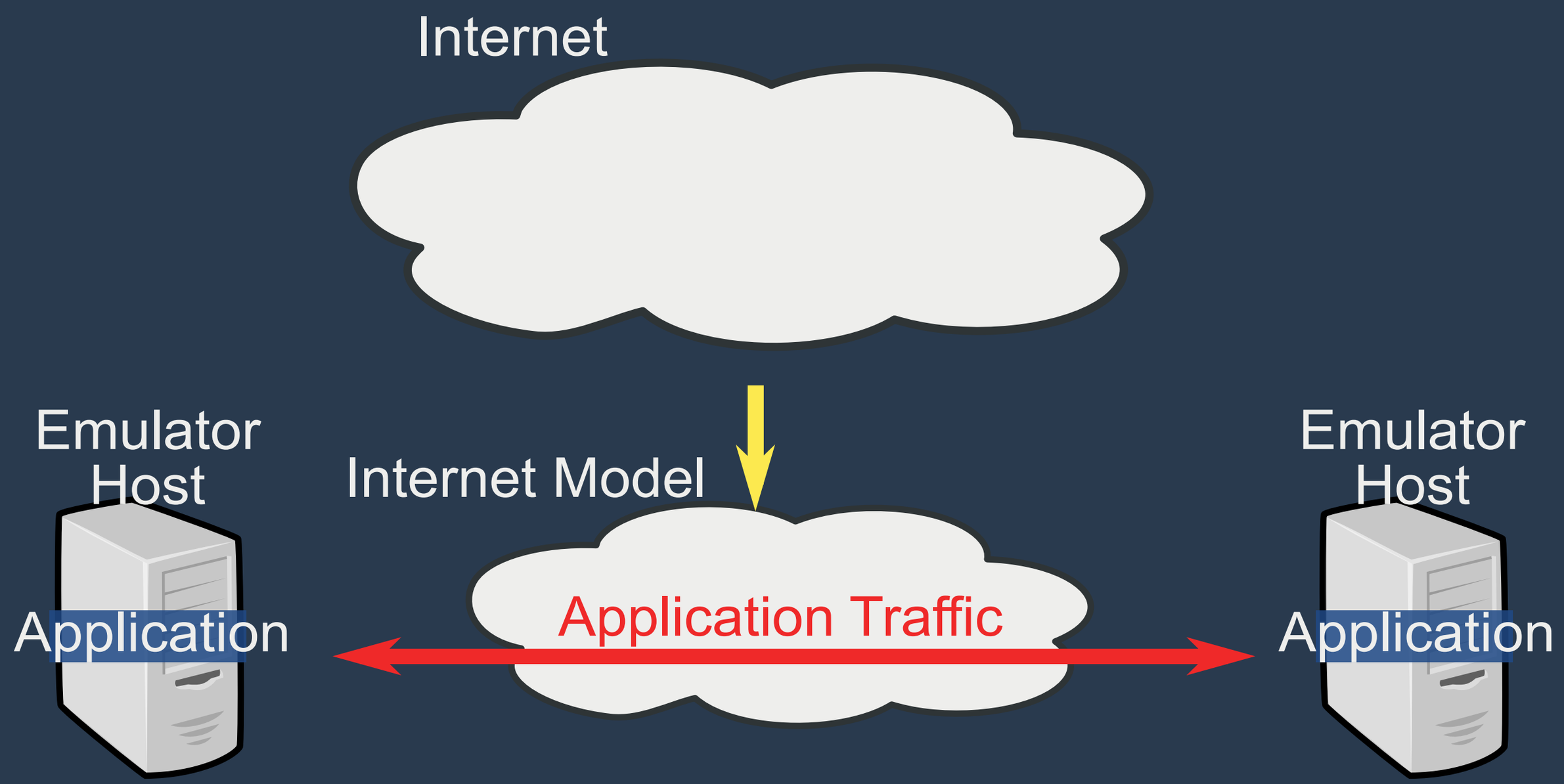
Overlay Testbeds



- Examples: RON and PlanetLab
- The Good: Real network conditions, deployment platform
- The Bad: Overloaded, few privileged operations, poor repeatability, hard to develop/debug on

Evaluating Networked Systems: Flexlab

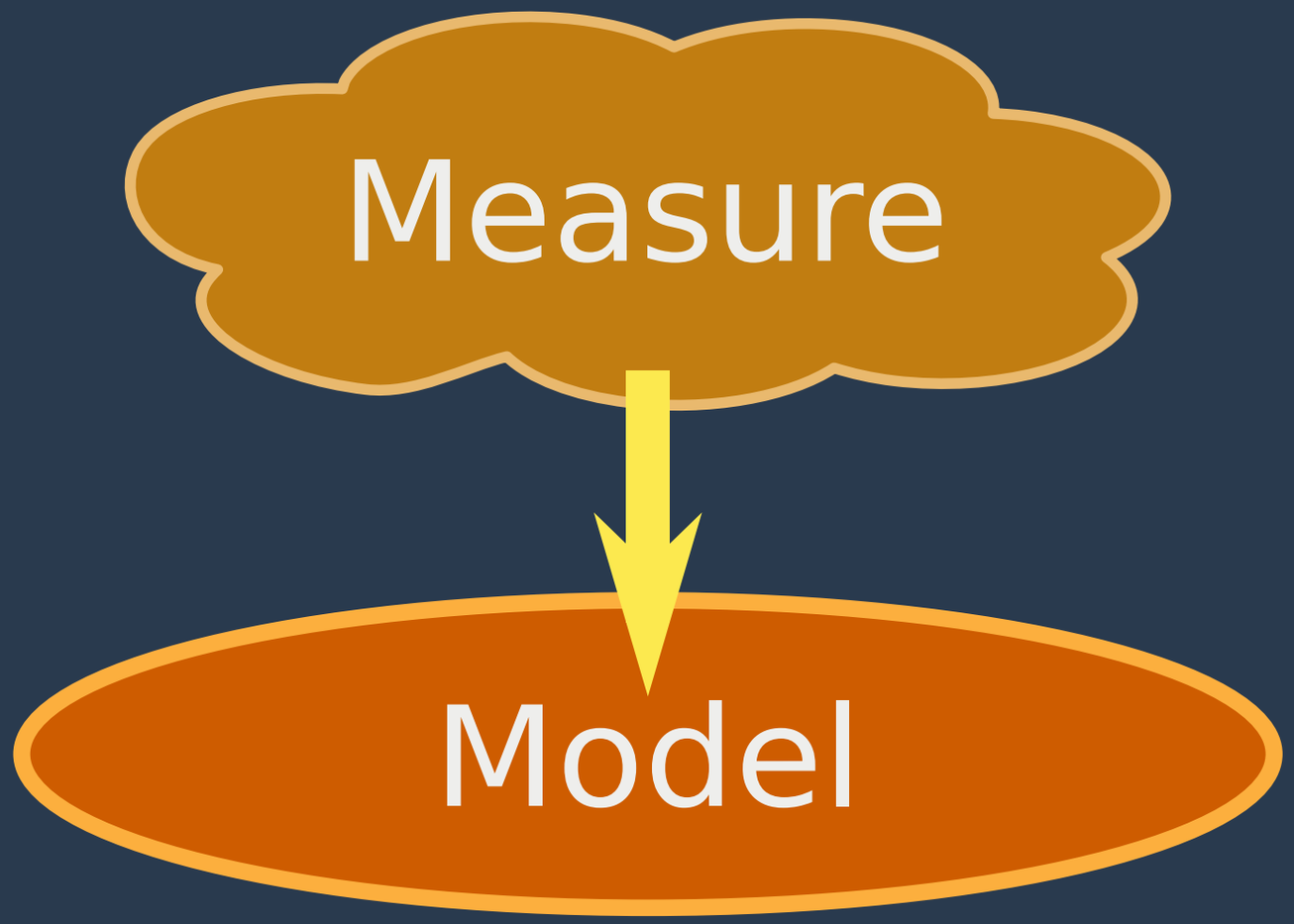
Goal: Real Internet within Emulator



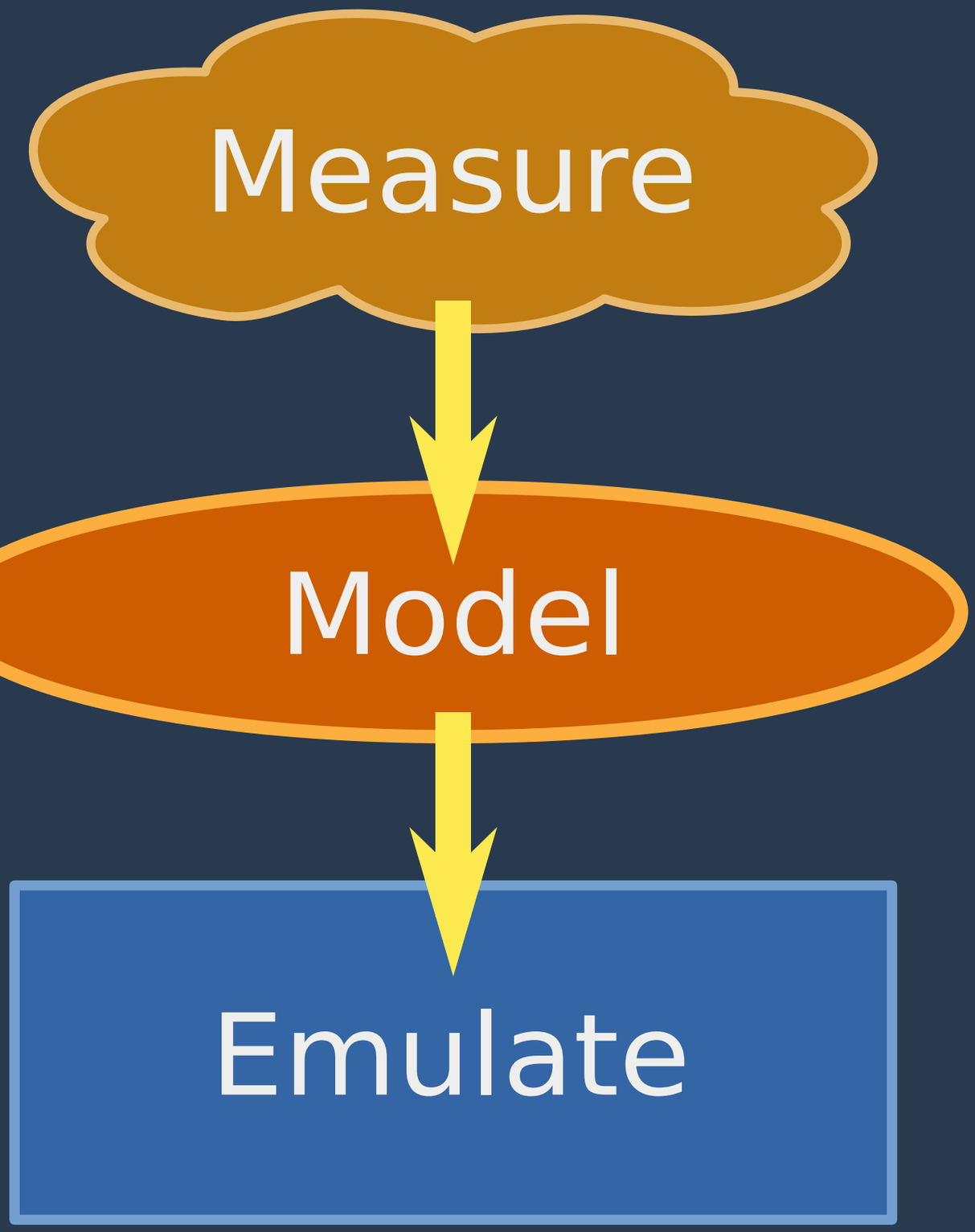
The Flexlab Approach

Measure

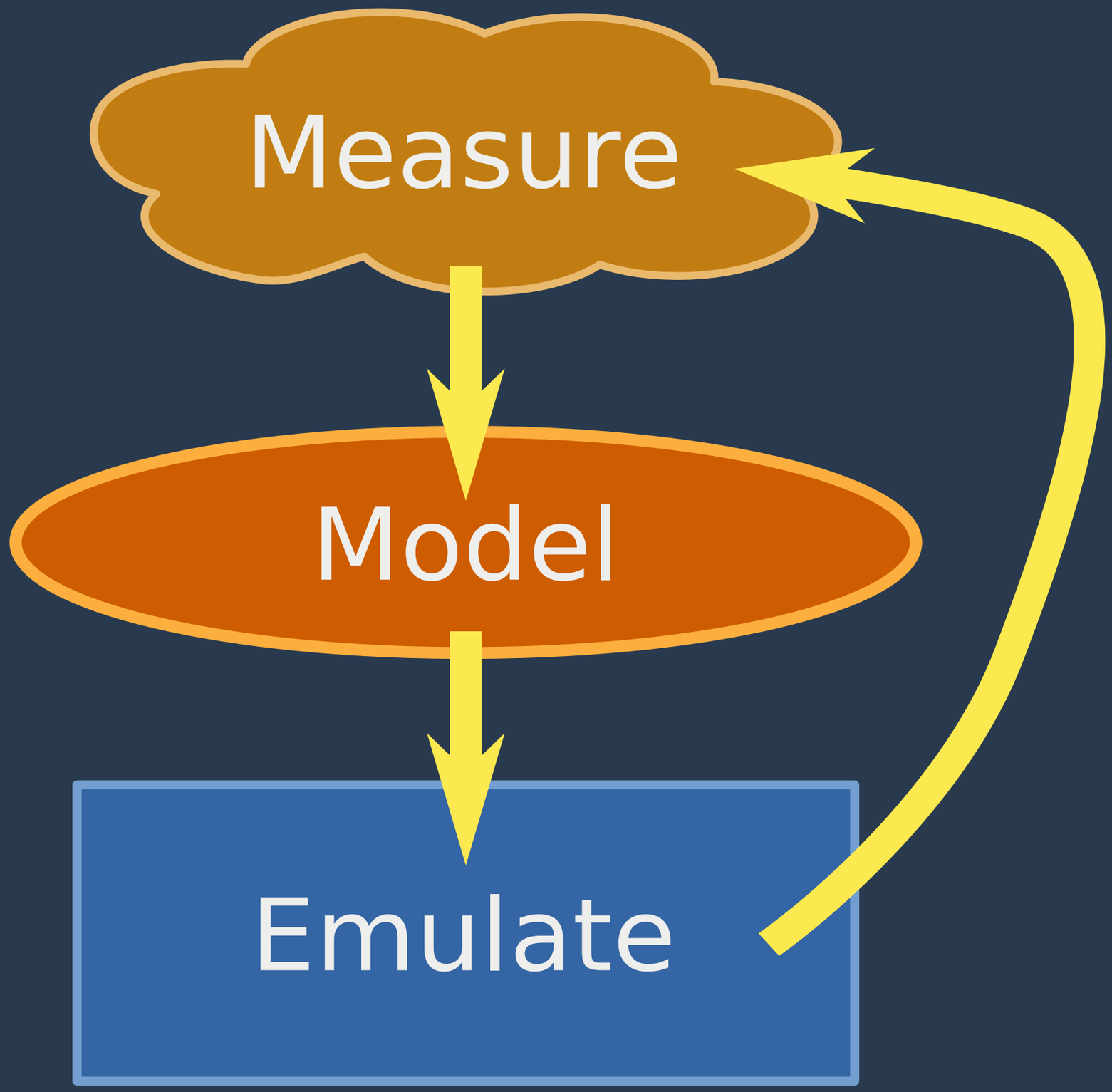
The Flexlab Approach



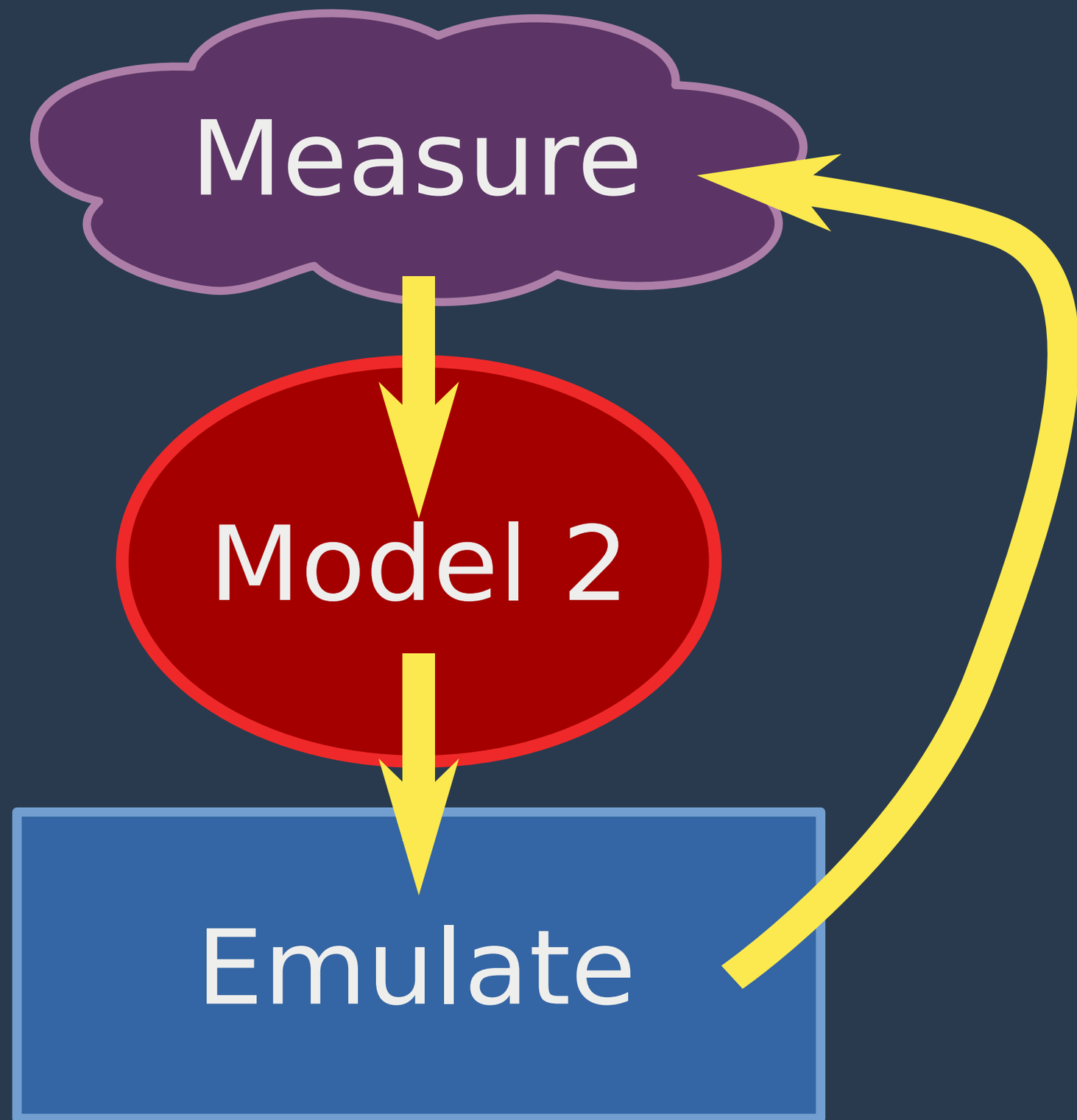
The Flexlab Approach



The Flexlab Approach



The Flexlab Approach



Key Points

- Software framework for pluggable network models
- Application behavior can drive measurements & model in real-time
- Application-Centric Internet Modeling
  - High fidelity measurement/ emulation technique
  - Includes new techniques for ABW measurement

More in the Paper

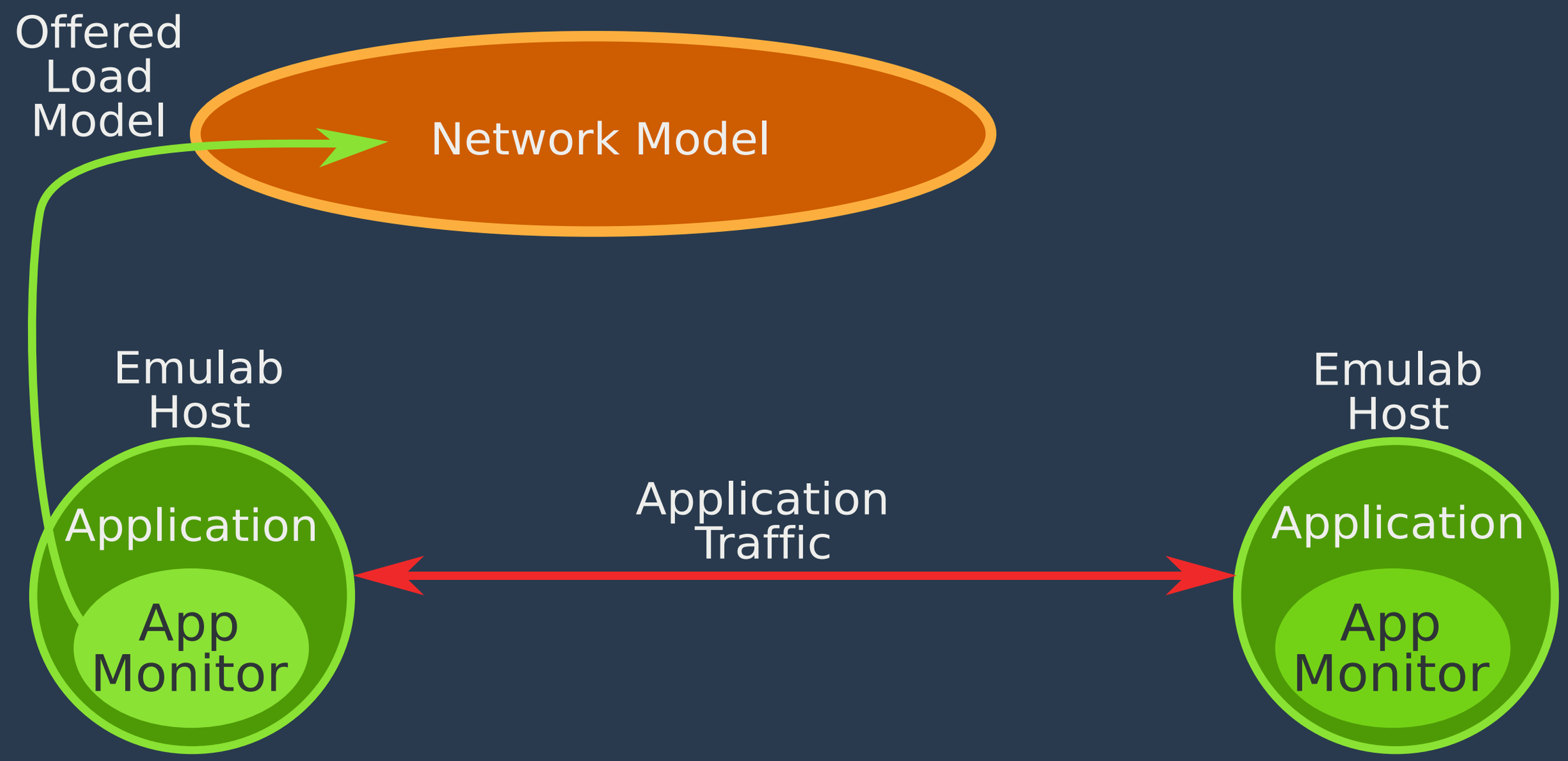
- Flexible network measurement system
- Network stationarity results
- Two straightforward network models
- Shared bottleneck analysis
- PlanetLab scheduling delay measurements

Flexlab Architecture

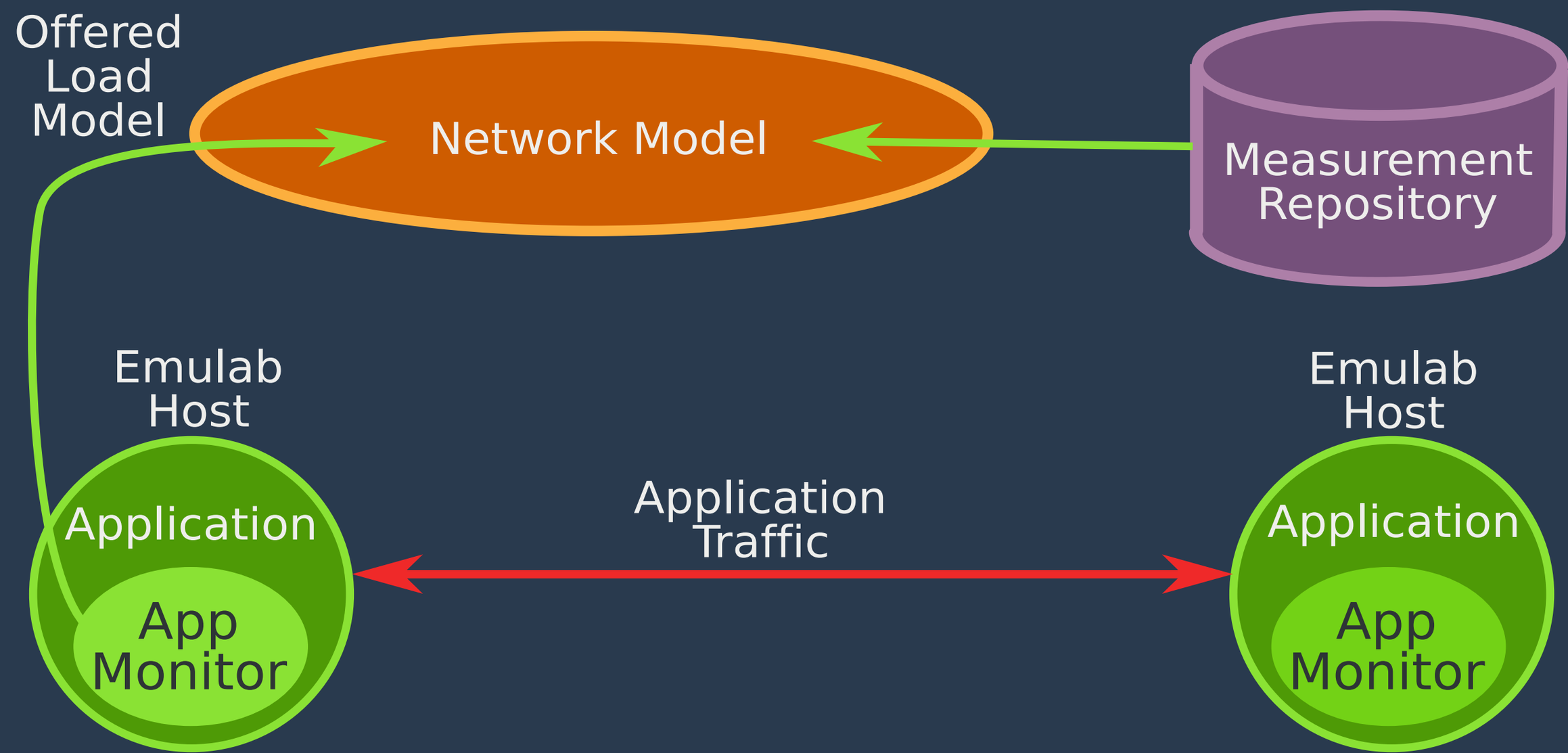
Flexlab: Application

Flexlab: Application Monitor

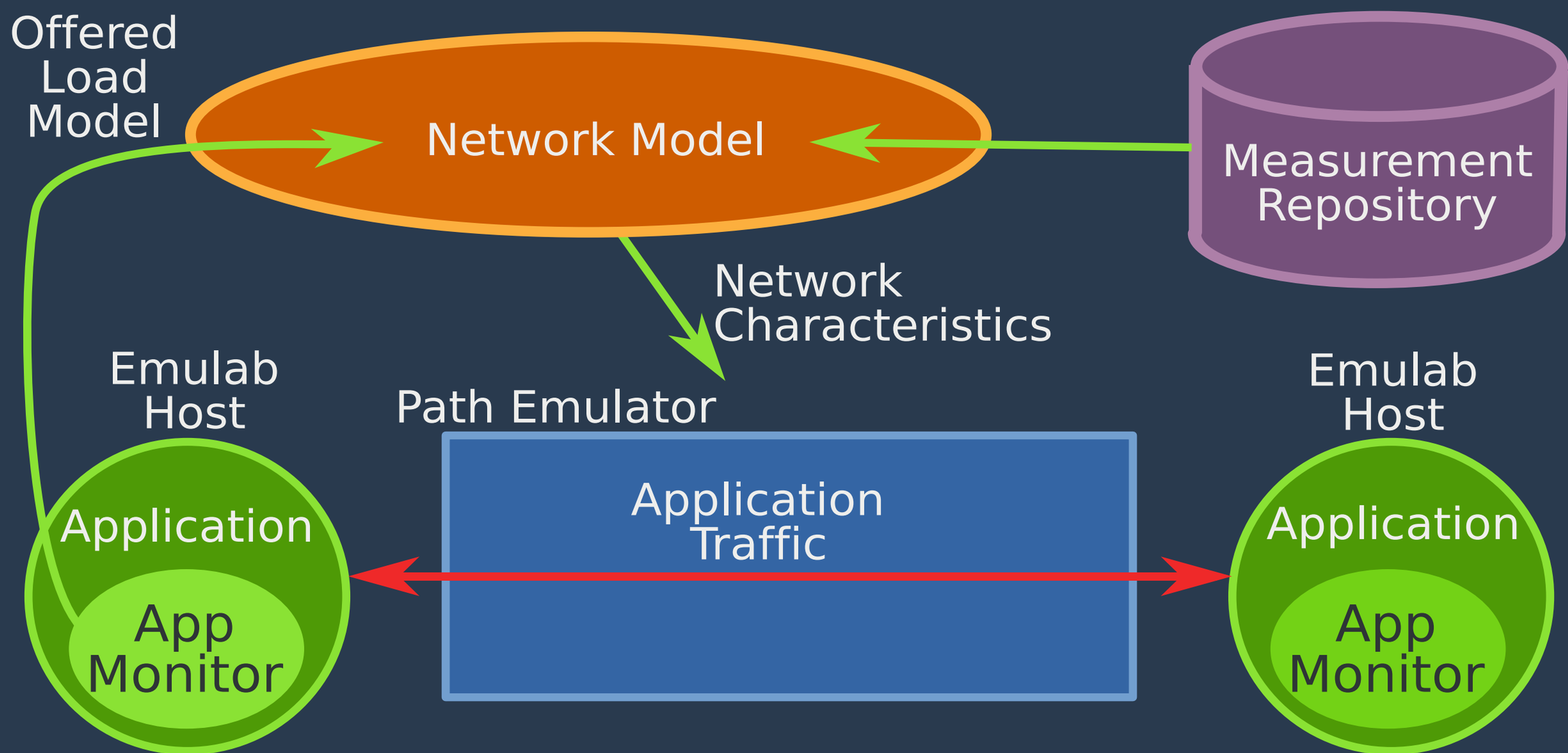
Flexlab: Network Model



Flexlab: Measurement Repo.

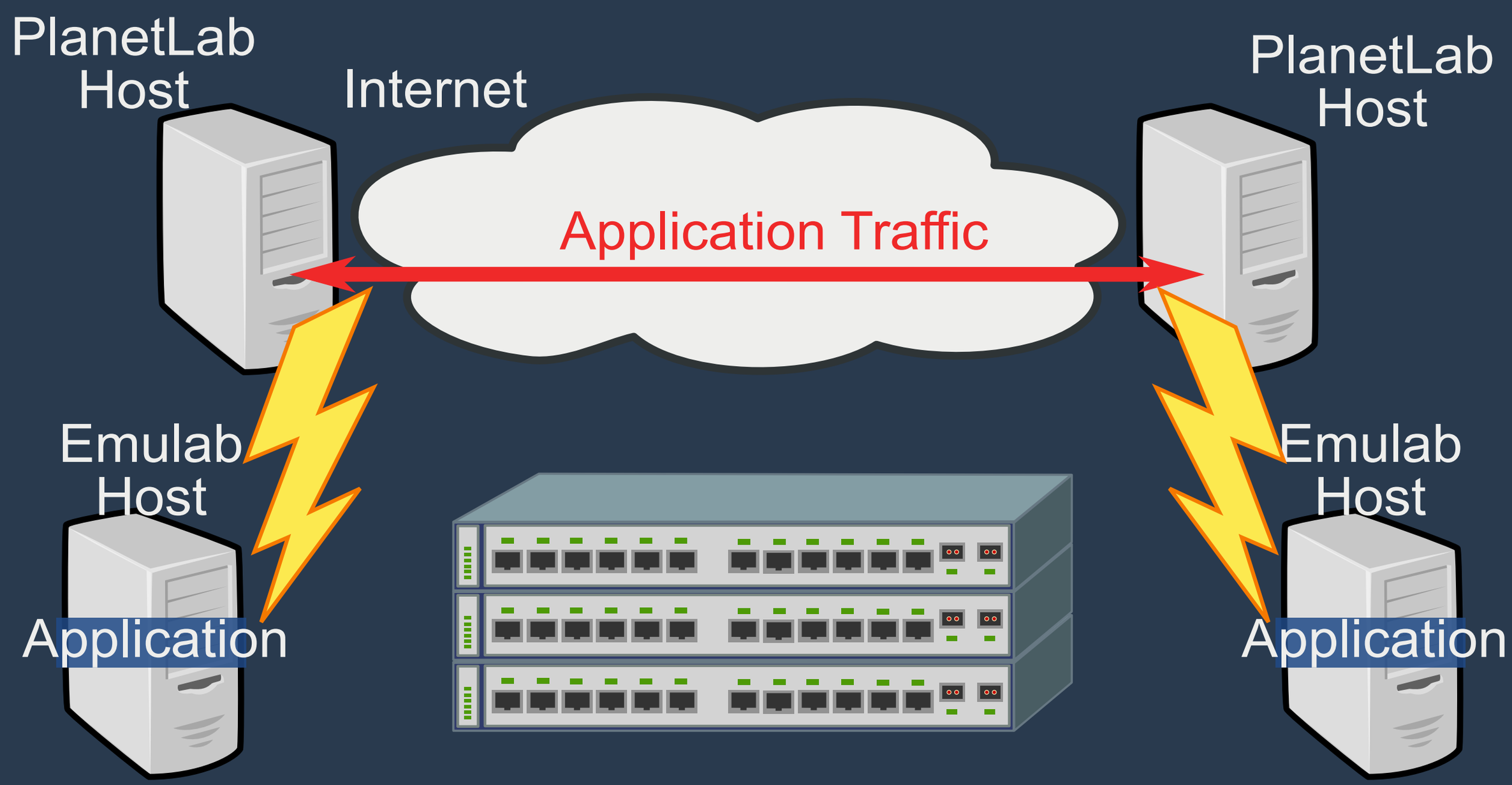


Flexlab: Path Emulator

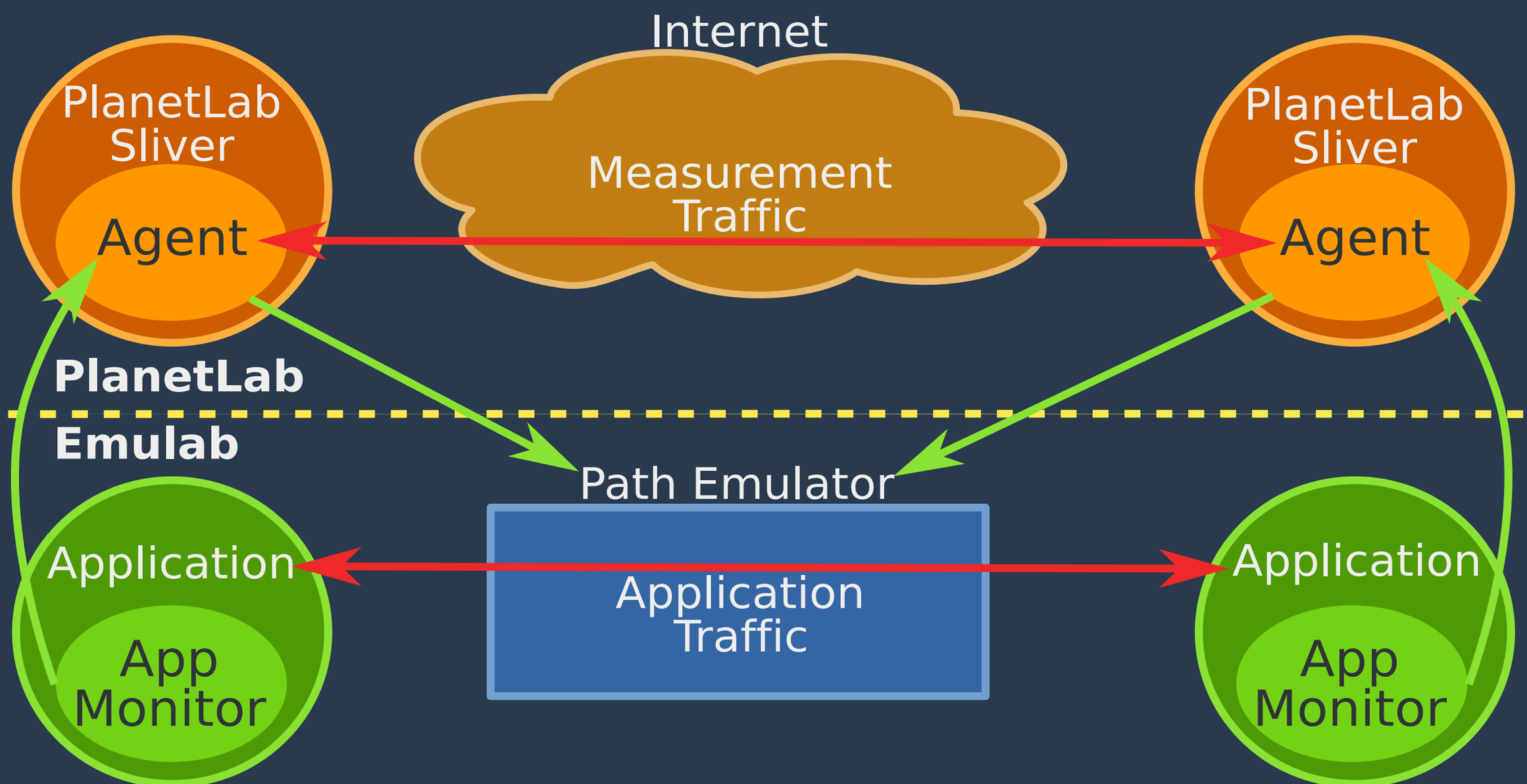


ACIM:
Application-Centric Internet Modeling

Imagine Ideal Fidelity



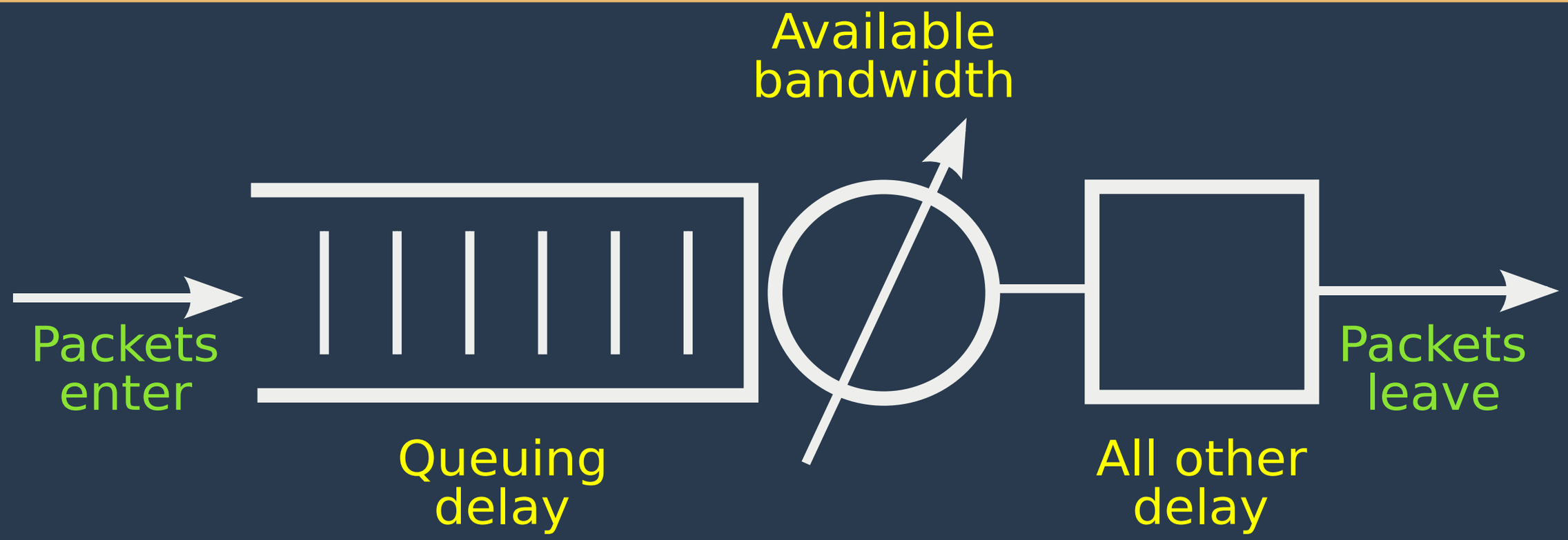
ACIM Architecture



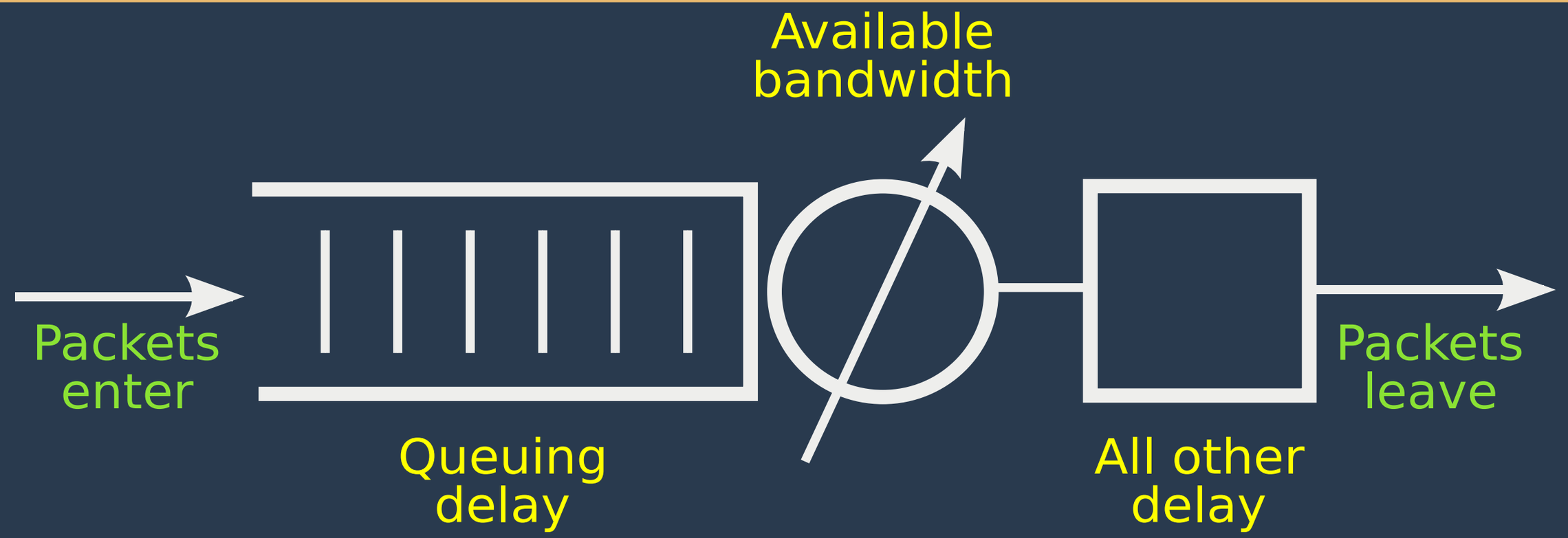
ACIM Design Challenges

- Determining when to drop packets
- Finding relationship between throughput and ABW
- Extension to UDP
- CPU starvation on PlanetLab
  - Host artifacts in throughput
  - Packet loss in libpcap

ACIM Path Emulator Parameters

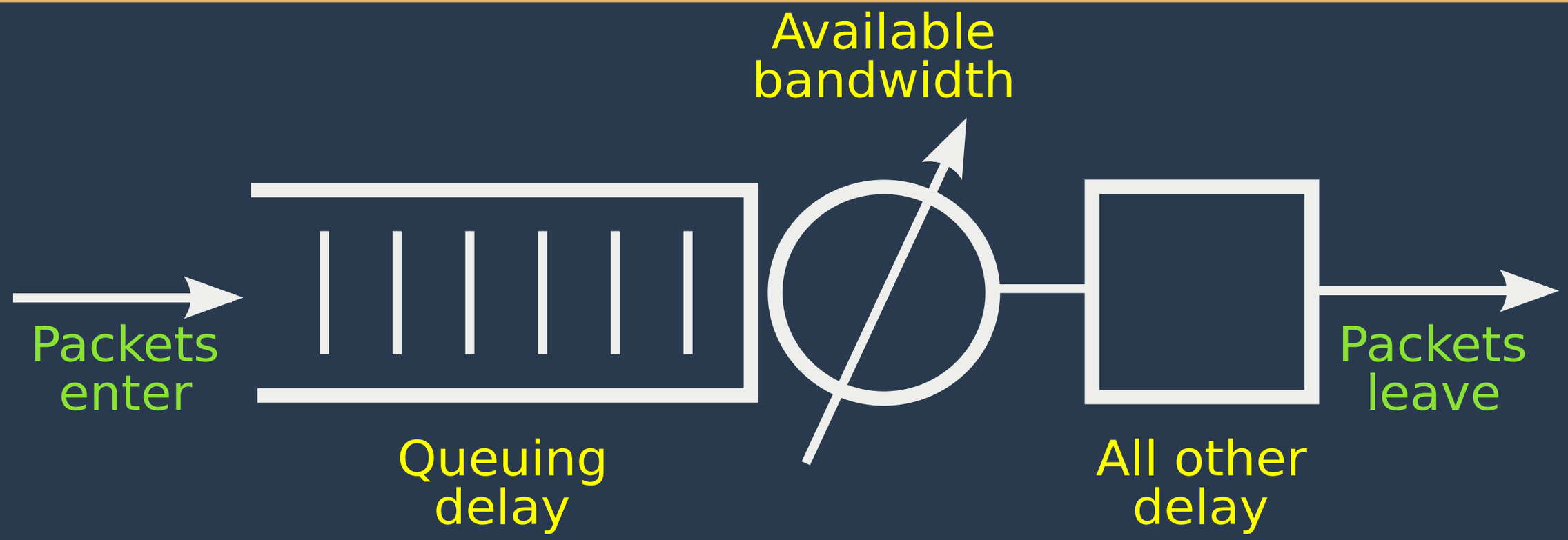


All Other Delay



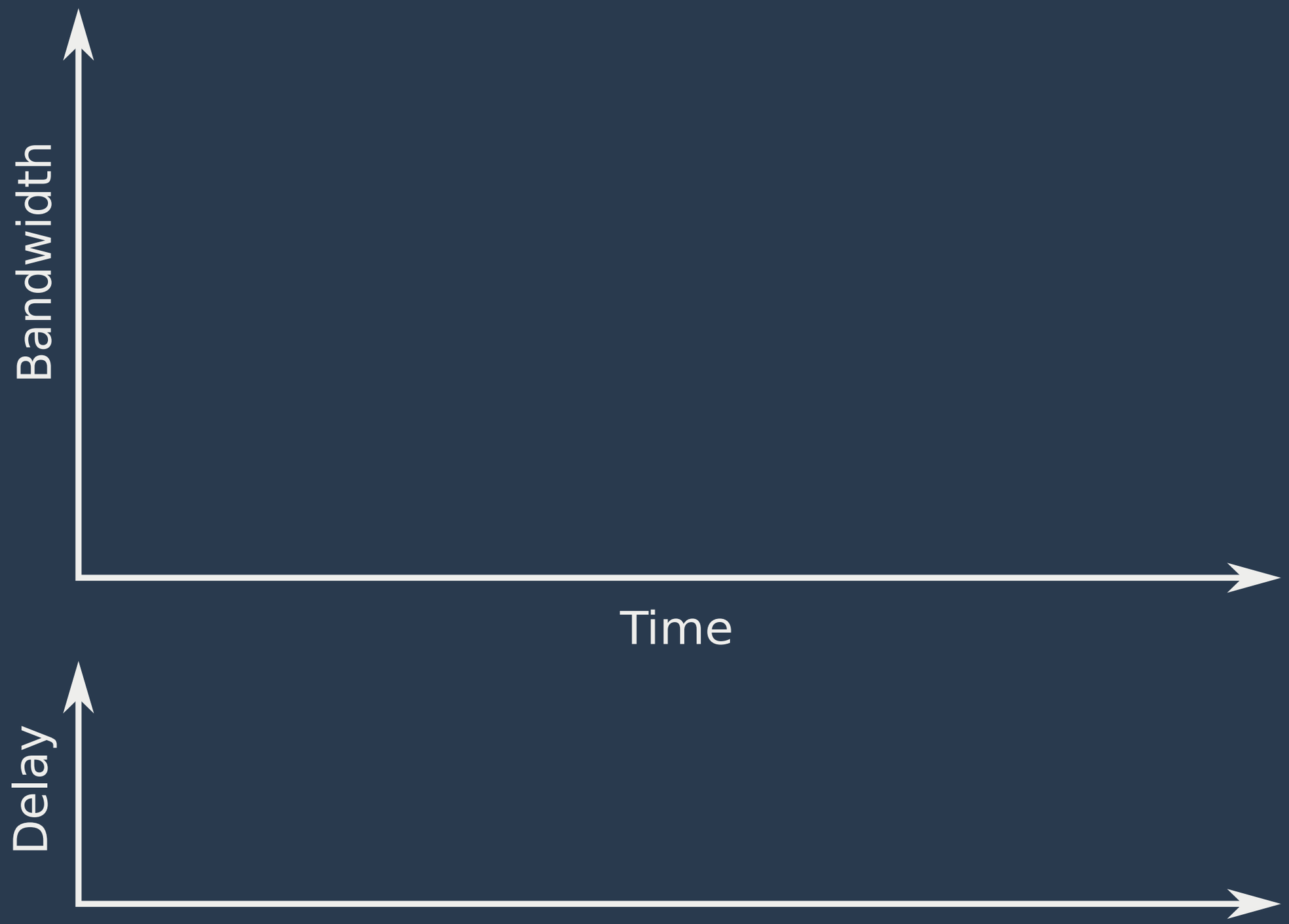
- Base RTT: Smallest RTT seen recently [Vegas 95]
- Packets saw little or no queueing delay

Packet Loss



- Caused by full queue at bottleneck link
  - Difficult to measure directly
- So measure queue length in time: Max recent RTT - Base RTT

Throughput and ABW



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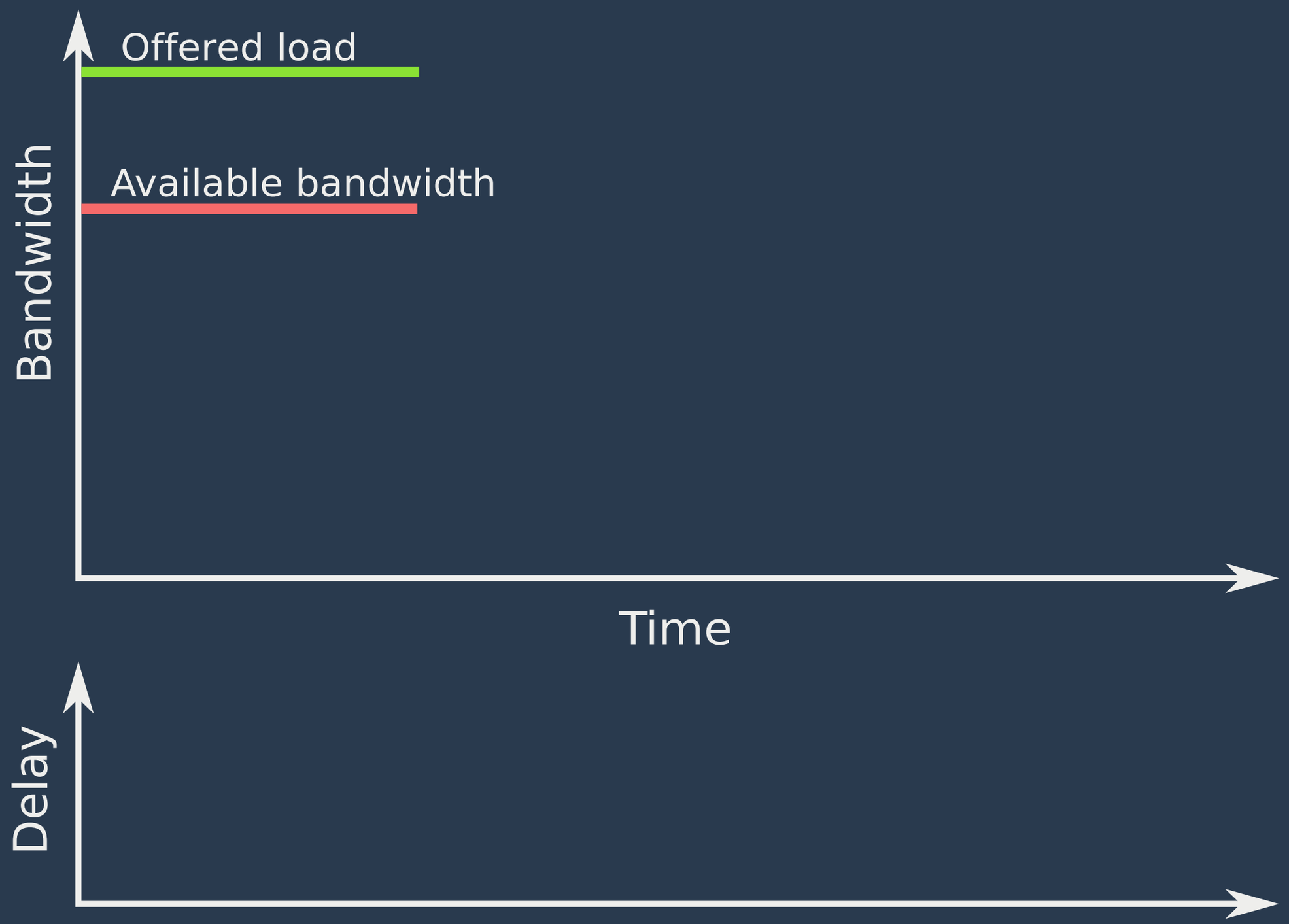
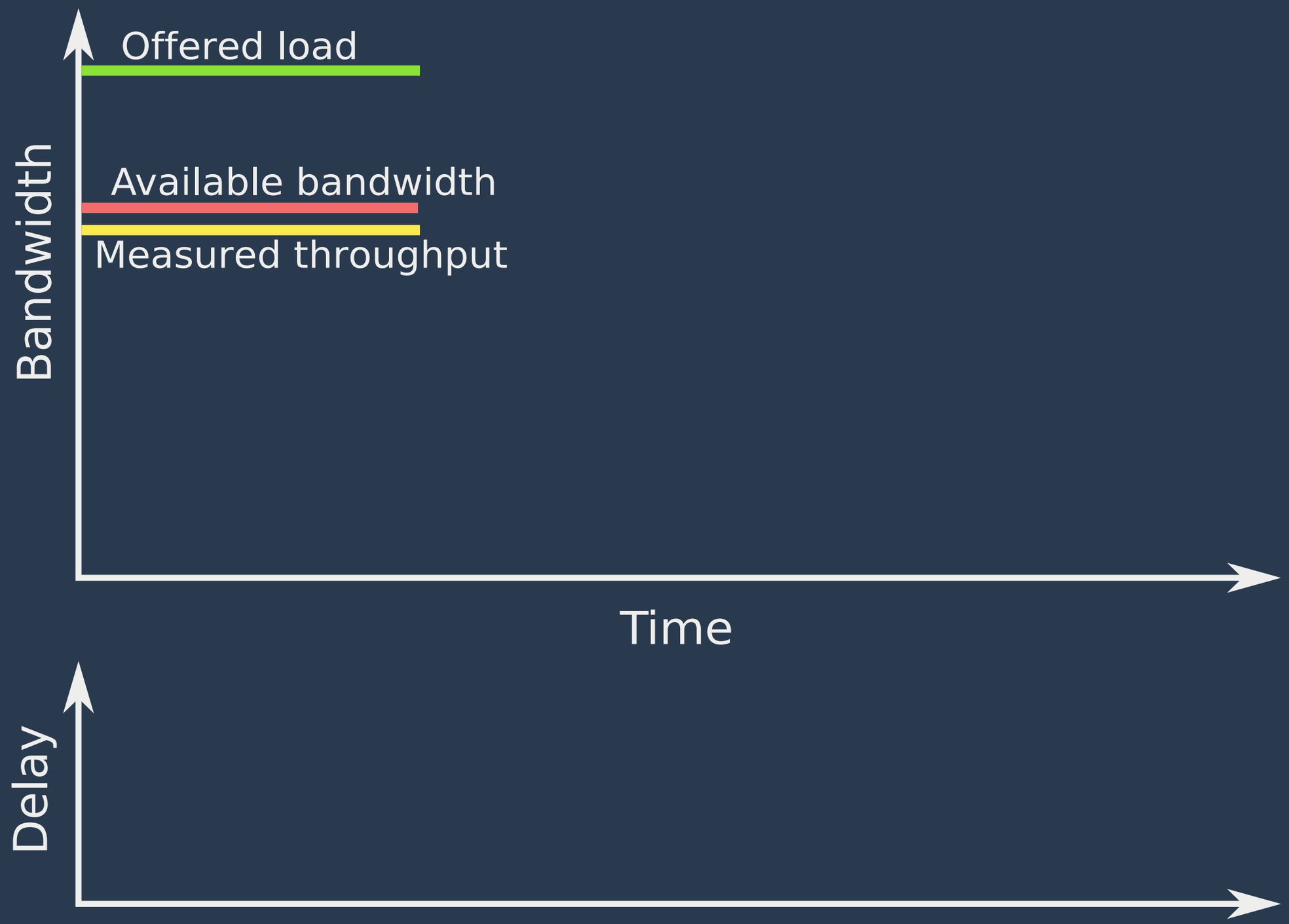


Throughput and ABW



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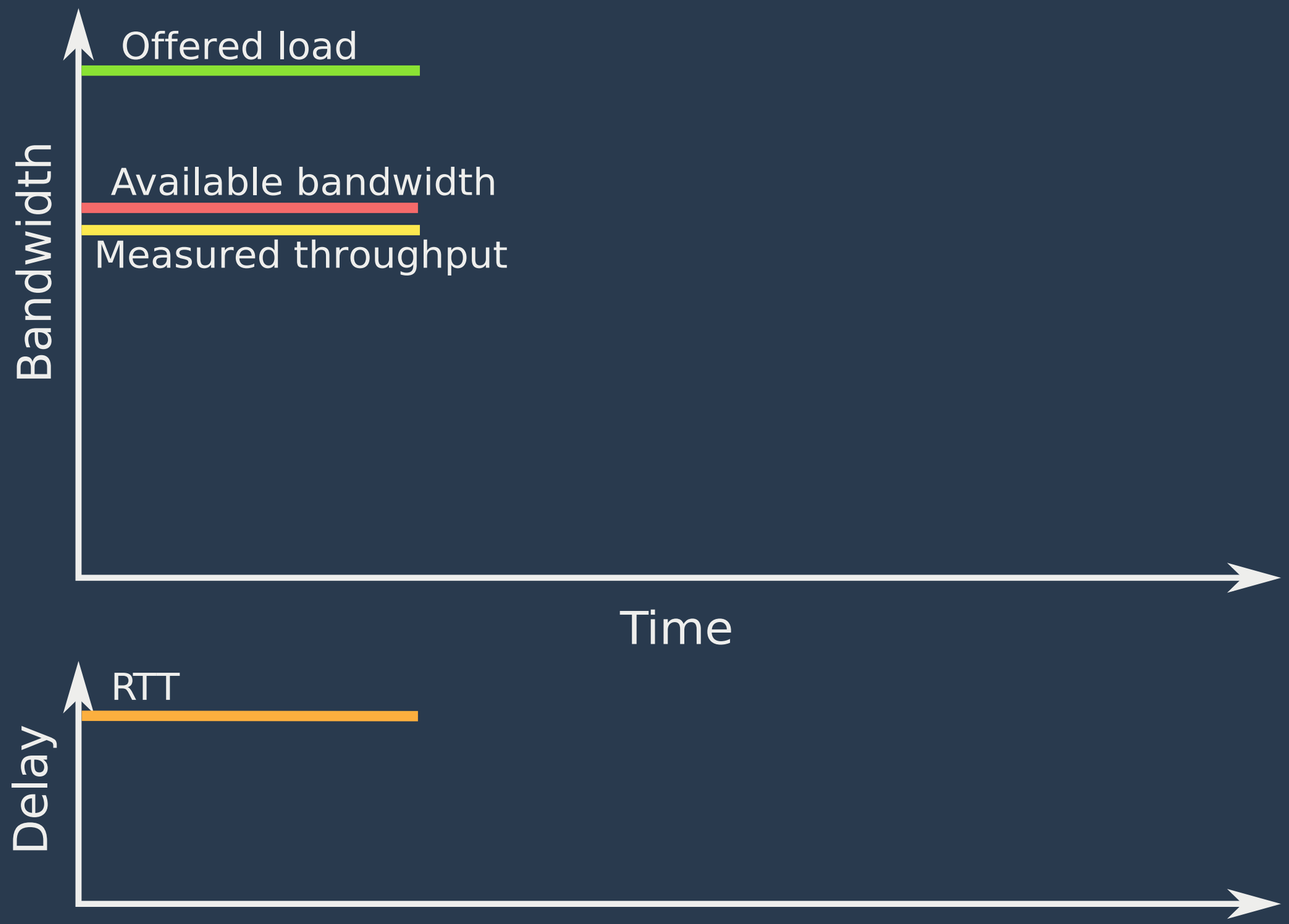

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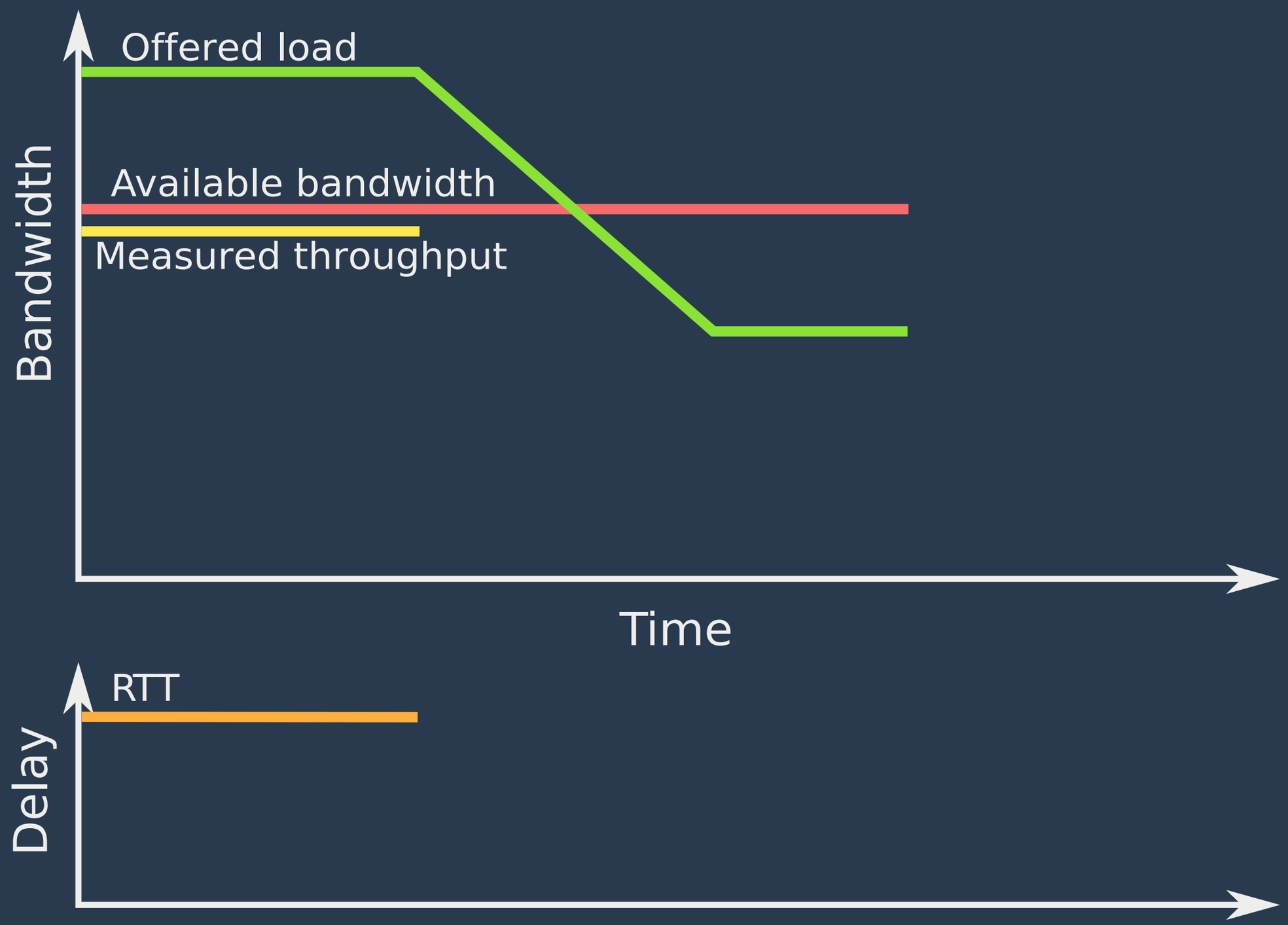
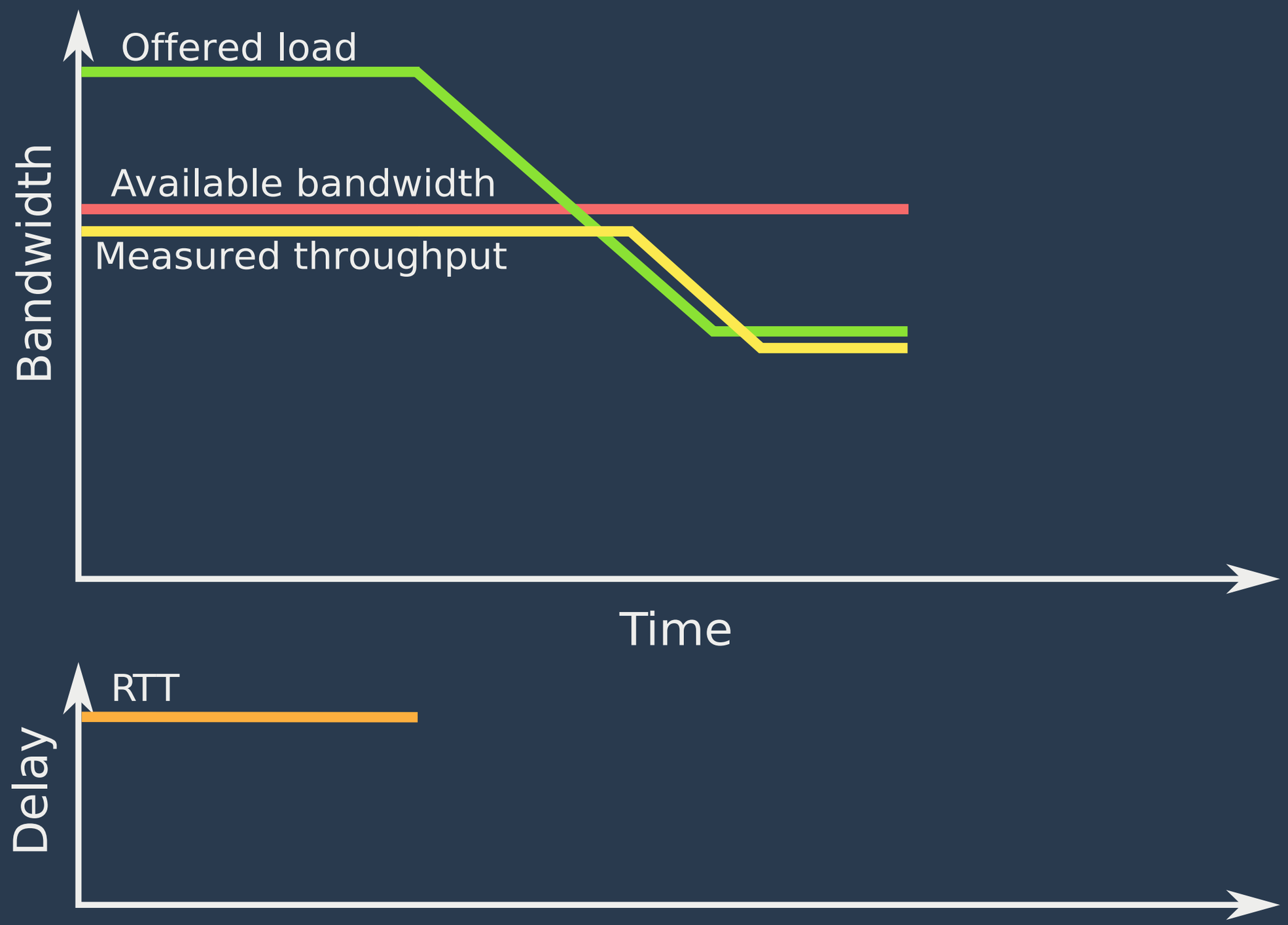


Throughput and ABW



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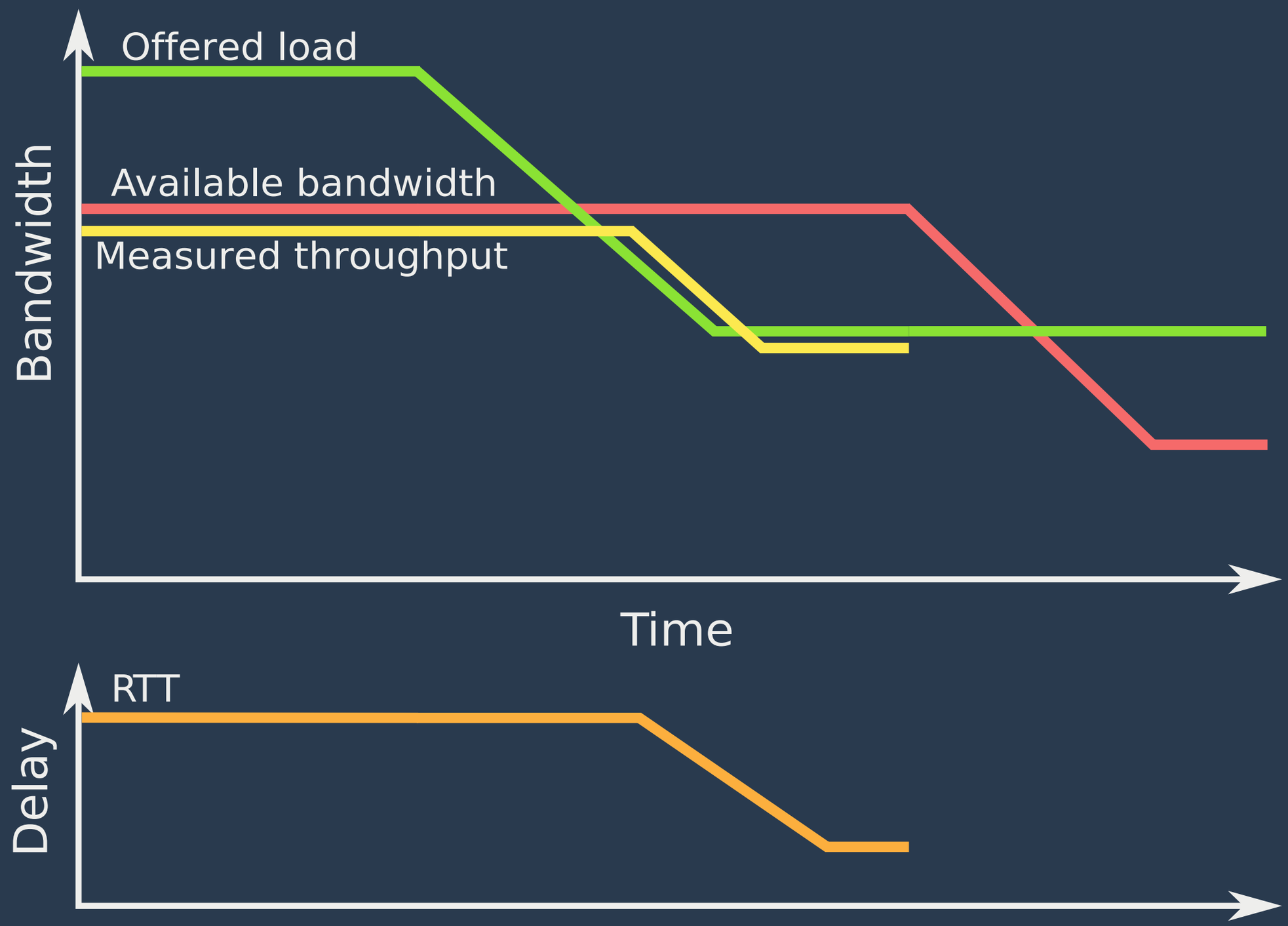

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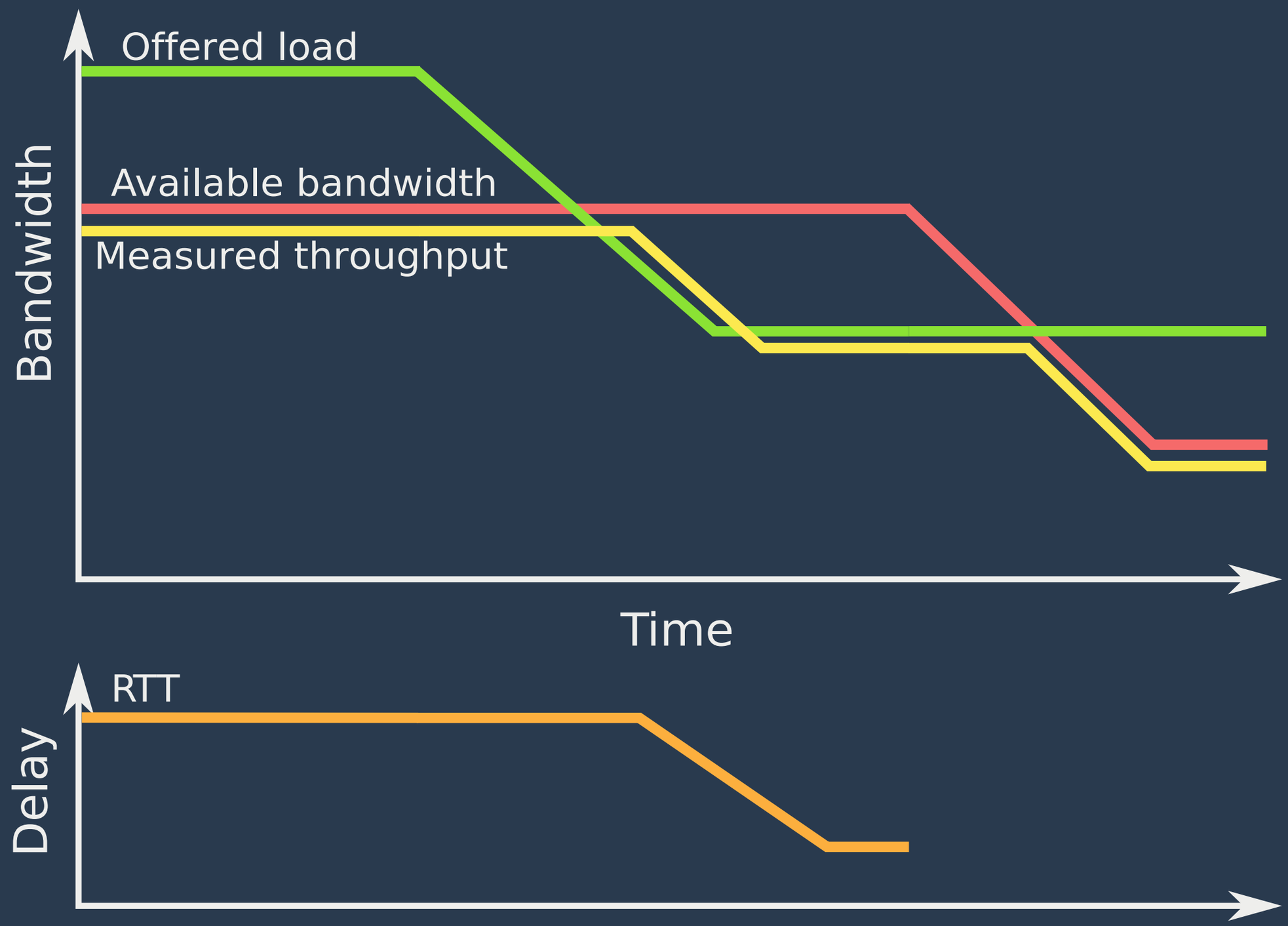

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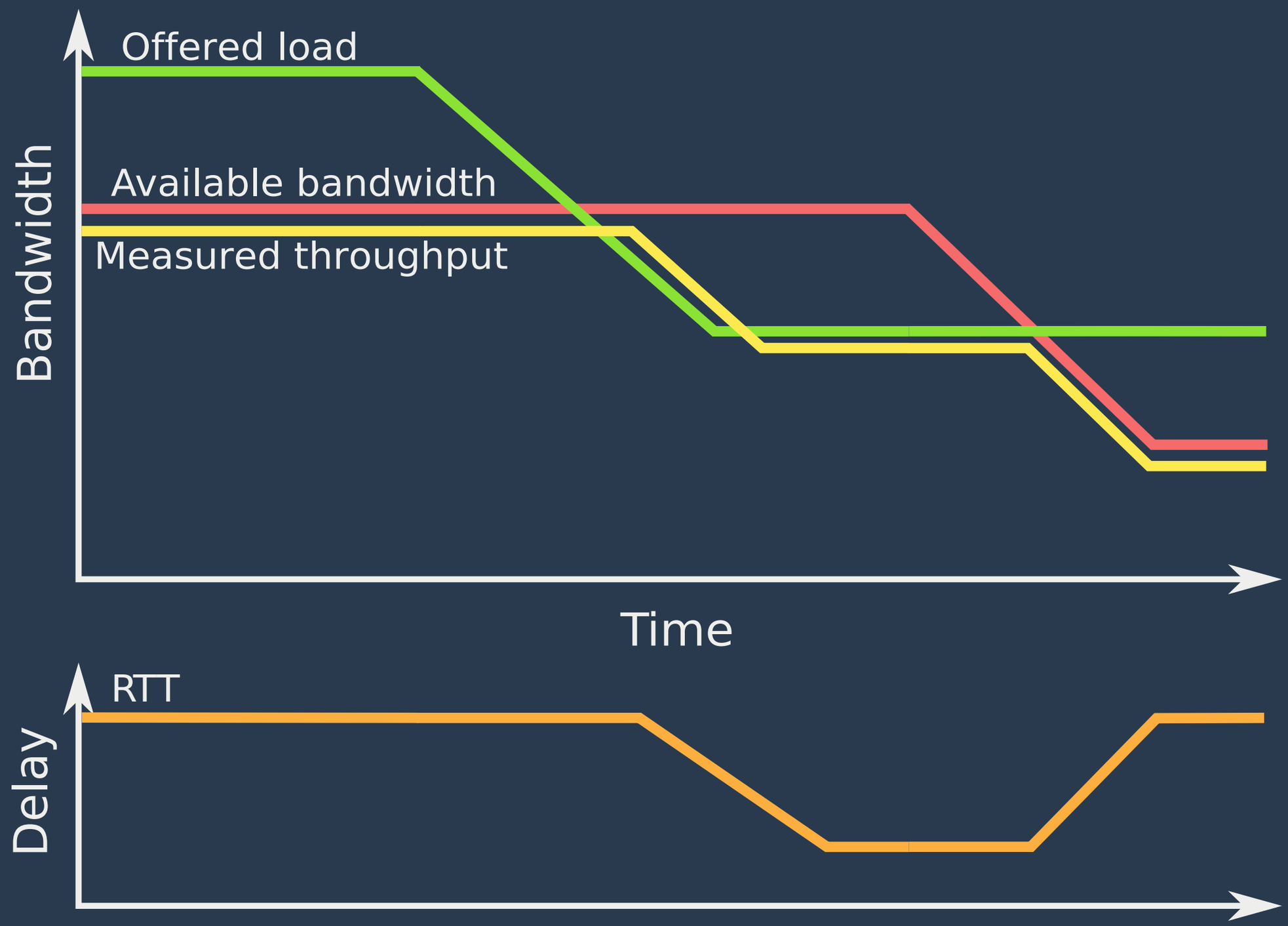

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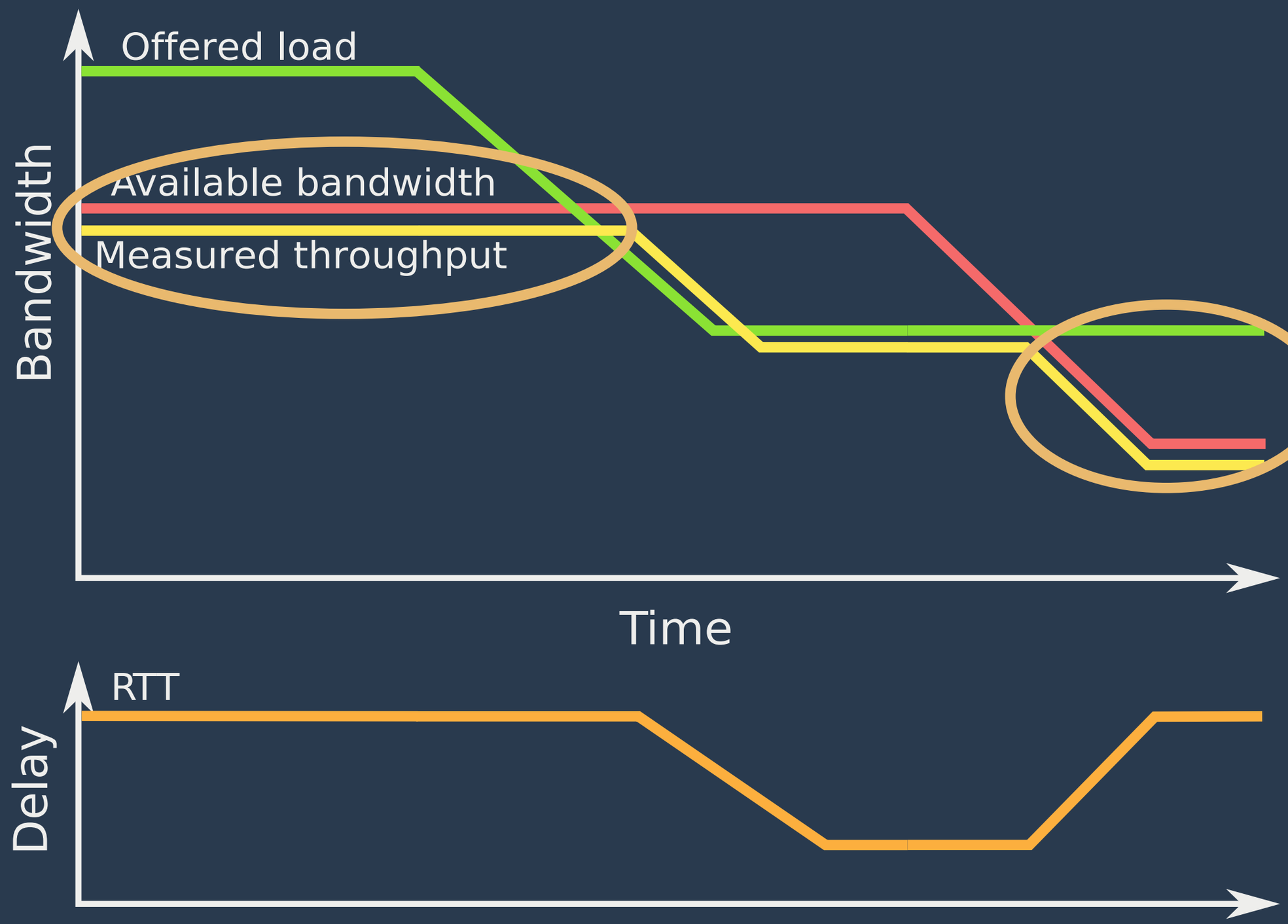


Throughput and ABW

- If (throughput > last ABW measurement), use new value
- Else, look for indications that throughput has reached ABW
  - Socket buffer is filling up AND
  - Recent RTTs have been increasing
    - Using linear regression

ACIM Features

- Precise: assesses only relevant parts of the network
  - Scales in nodes and paths
- Complete: automatically captures all relevant network behavior
  - Simpler to measure e2e effects than find causes
  - Detects rare and transient effects
  - Evokes all reactive network behaviors (except content-based)
  - Rapidly tracks conditions

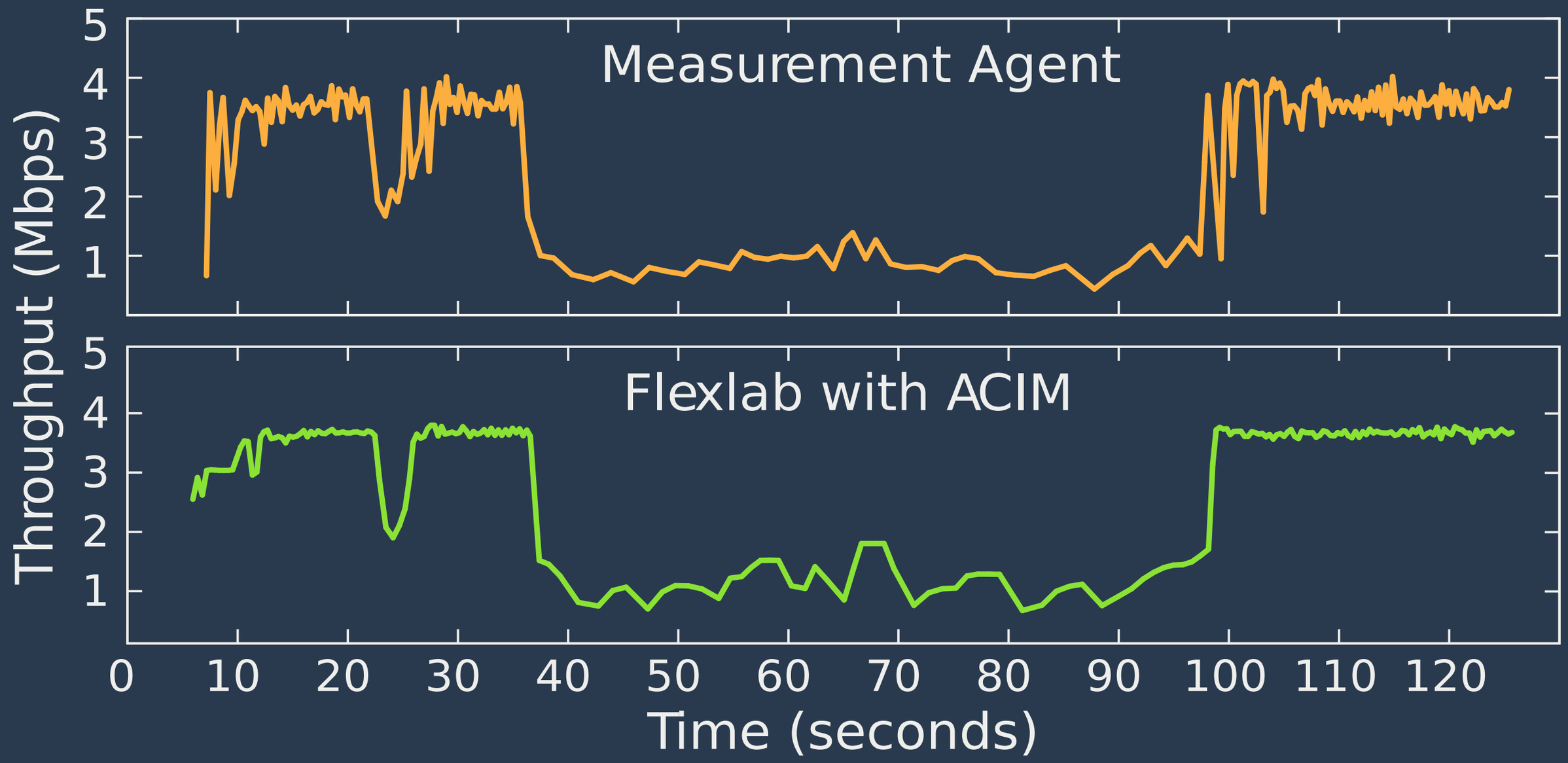
ACIM Accuracy

- Is ACIM path emulation accurate?
- Is it accurate at fine granularity?

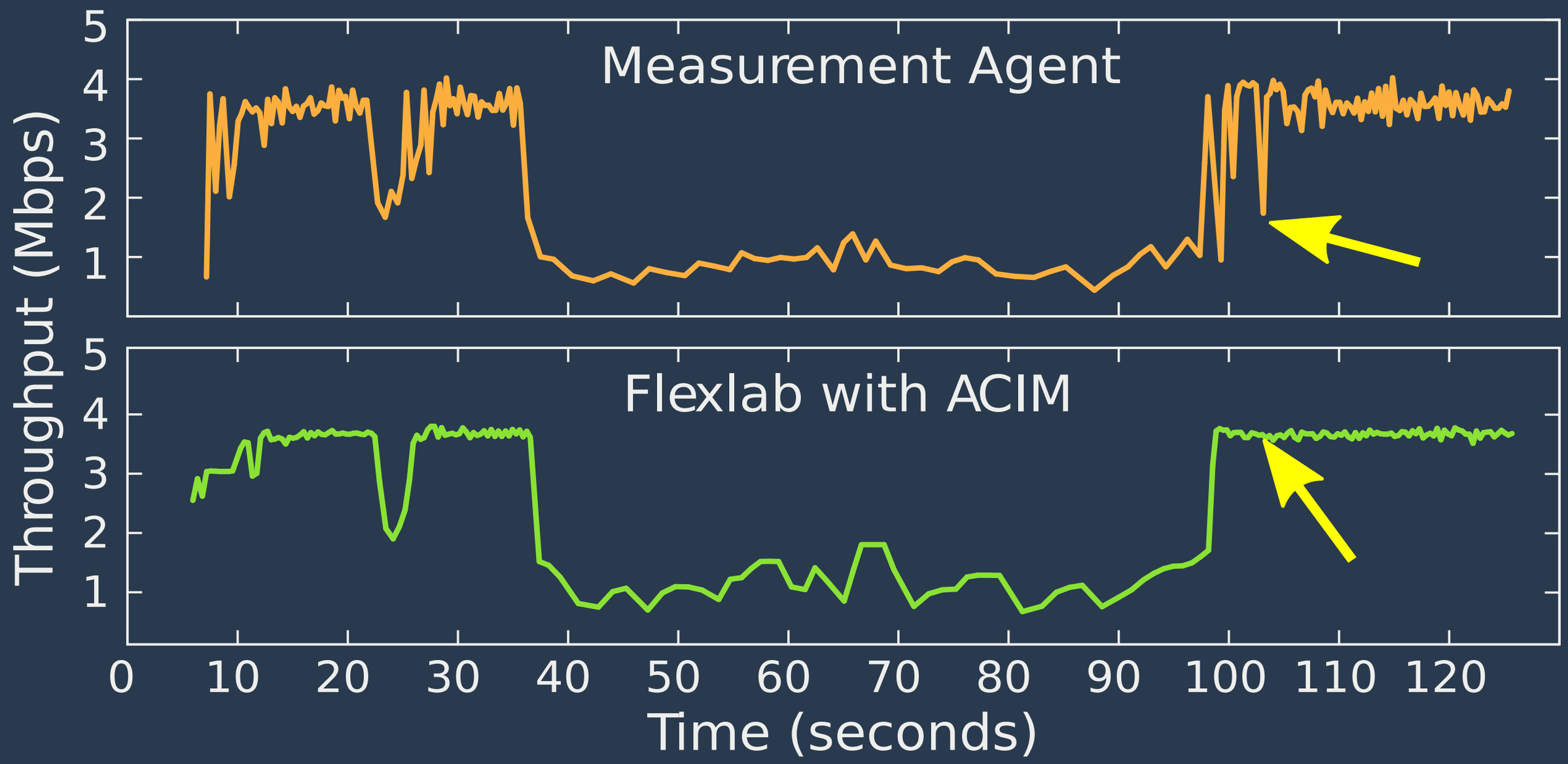
Methodology

- iperf runs in Emulab
- Measurement Agent runs on PlanetLab at UT Austin and AT&T Research
- We added transient TCP cross traffic between these sites

TCP iperf Throughput



TCP iperf Throughput



A Real Application

- Does ACIM give accurate results for a real,complicated application?

A Real Application

- Does ACIM give accurate results for a real,complicated application?
- ... does PlanetLab?

A Real Application

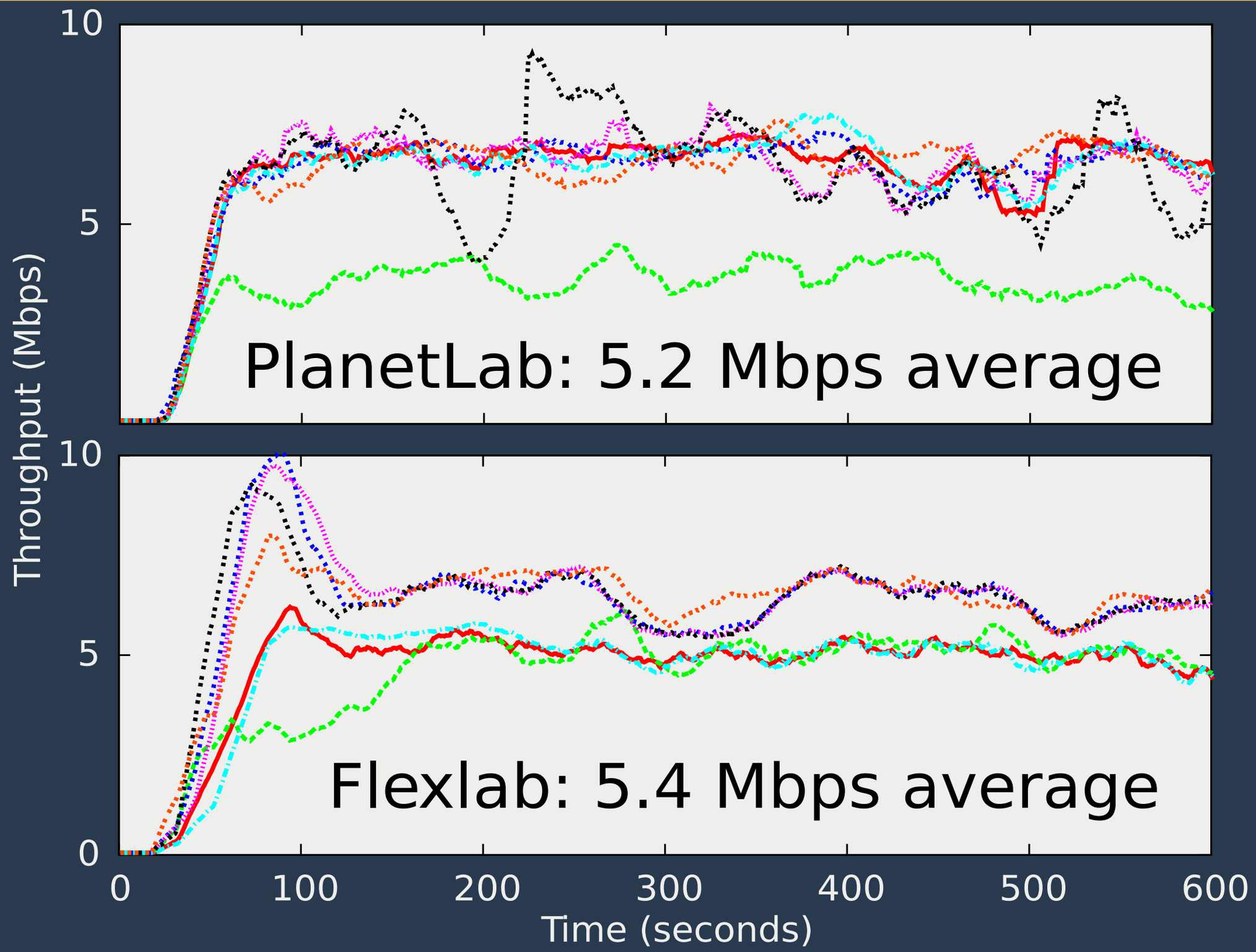
- Does ACIM give accurate results for a real,complicated application?
- ... does PlanetLab?
- Can we discover ground truth?

Methodology: BitTorrent

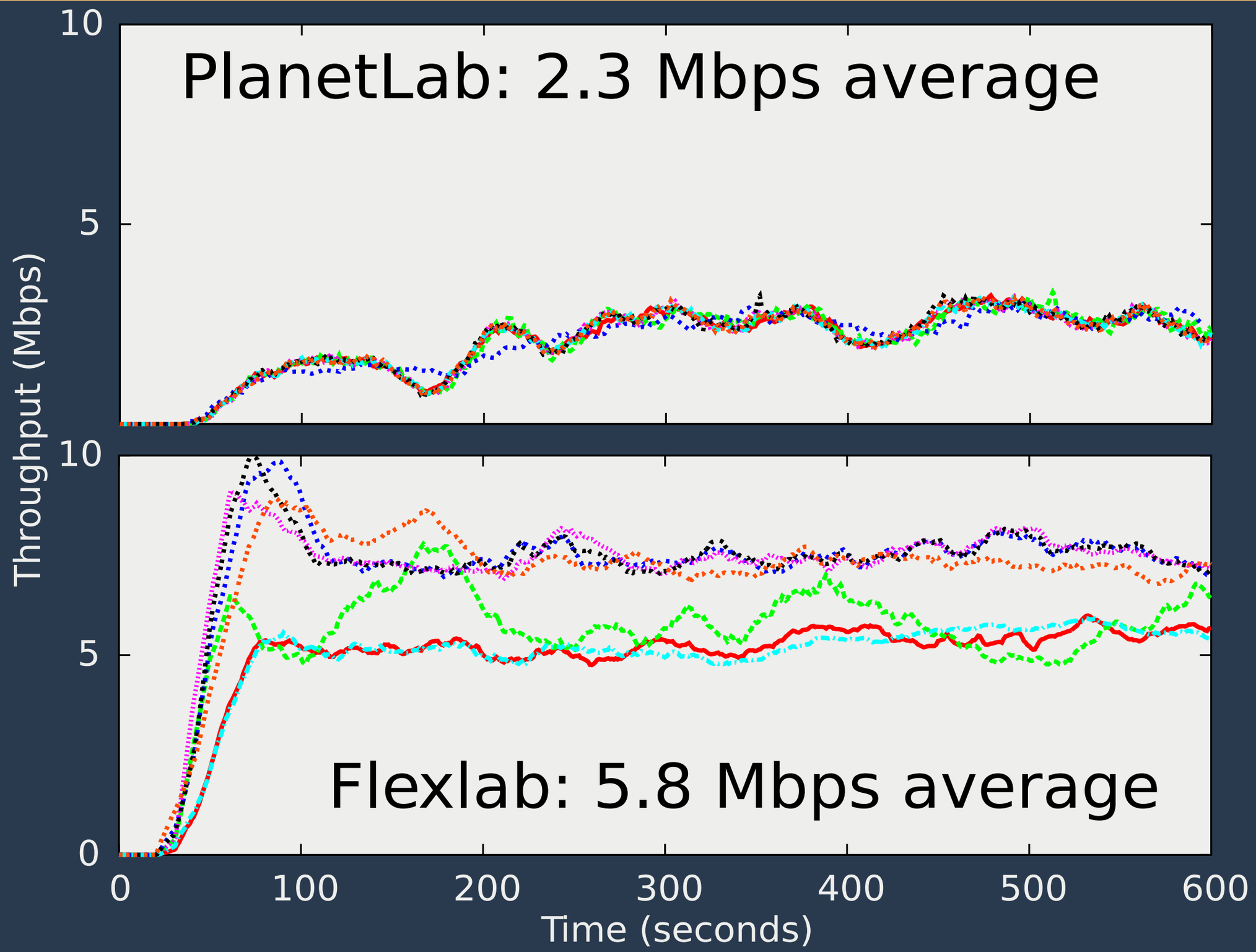
- Two simultaneous instances of reference BitTorrent:
  - One on PlanetLab
  - One in Flexlab
- Eight nodes in US and Europe: One seed, seven clients
- We reduced randomness in BT … but some still remains

BitTorrent w/ CPU Reservation

BitTorrent w/ CPU Reservation



BitTorrent w/o CPU Reservation



BitTorrent Bottom Line

- Conclusion: For this experiment, both Flexlab and PlanetLab with CPU reservations give accurate results
  - PlanetLab alone does not
- CPU availability on PlanetLab hurts BitTorrent
- ACIM reduces host resource needs on PlanetLab for this experiment
  - BitTorrent: 36-76% CPU
  - ACIM Agent: 2.6% CPU
  - Factor of 15 - 30 CPU
  - Factor of 4 memory

The Future?

- No need to perfect in PlanetLab:
  - Full resource isolation
  - Total control over hosts
  - Orthogonal control network
- ... use in the emulators that already have them
- Use PlanetLab nodes as NICs
- Conserve resources for deployed services with end users

Conclusion

- New approach to evaluating networked systems
- Separates the network model
- Designed to leverage vibrant measurement and modeling community
- Couples an emulator to an overlay testbed
- ACIM high fidelity emulation technique
- Contact testbed-ops@emulab.net to use

Backup Slides

Why not just add more nodes to every PlanetLab site?

- Remaining problems:
  - Poor repeatability
  - Hard to develop/debug
  - No privileged operations
- Some malicious traffic cannot be tested
- Some Flexlab network models reduce network load
- Emulab node pool stat muxed and shared more efficiently than per-site pools
- Overload can (will?) still happen with PL's pure shared-host model
- Major practical barriers: admin, cost

Flexlab and VINI

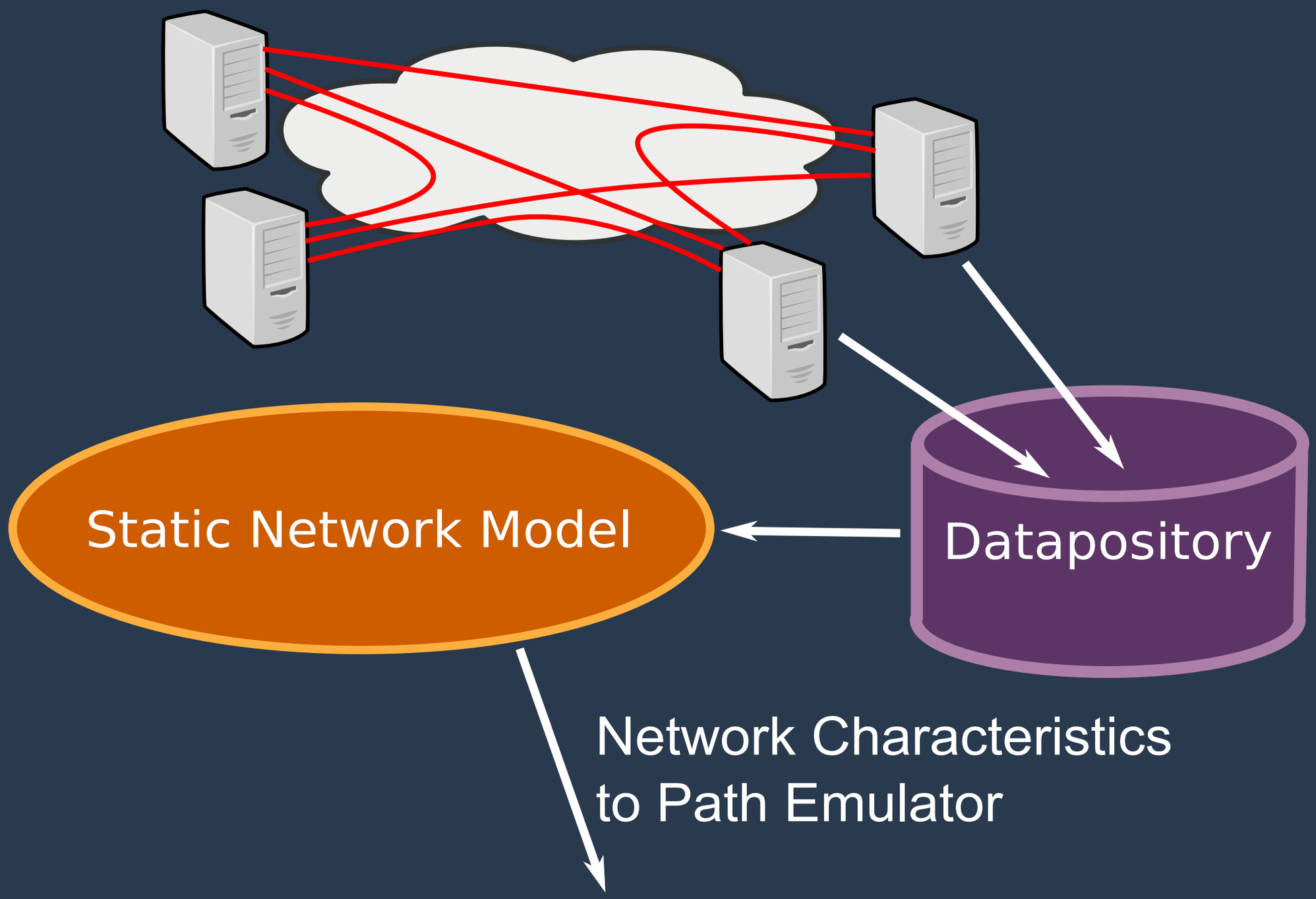
- Entirely different kinds of realism and control
- Flexlab: passes "experiment" traffic over shared path
  - Real Internet conditions from other traffic on same path, but app. traffic is not from real users
  - Control: of all software
  - Environment: friendly local dev. environ, dedicated hosts
- VINI: can pass "real traffic" over dedicated link
  - Real routing, real neighbor ISPs, potentially traffic from real users, but network resources are not realistic/representative
  - Dedicated pipes with dedicated bandwidth, that insulate experiment from normal Internet conditions
  - Control: restricted to VINI's APIs (Click, XORP, etc.)
  - Environment: distributed environ; shared host resources

Change Point Analysis

Path	High	Low	Change
Asia to Asia	2	1	0.13%
Asia to Commercial	2	0	2.9%
Asia to Europe	4	0	0.5%
Asia to I2	6	0	0.59%
Commercial to Commercial	20	2	39%
Commercial to Europe	4	0	3.4%
Commercial to I2	13	1	15%
I2 to I2	4	0	0.02%
I2 to Europe	0	0	-
Europe to Europe	9	1	12%

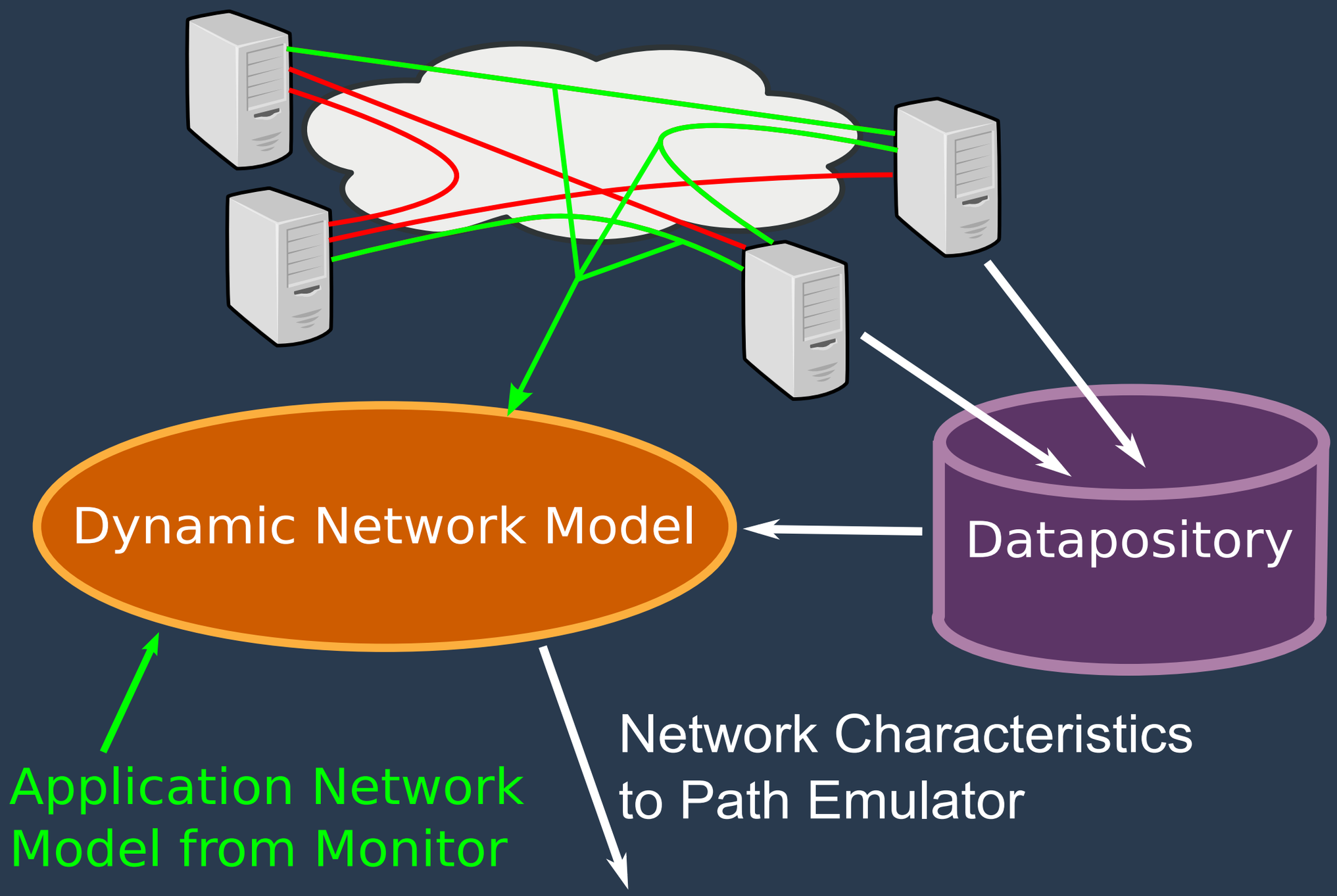
Simple Static Model

Flexmon All-Sites PlanetLab Measurements

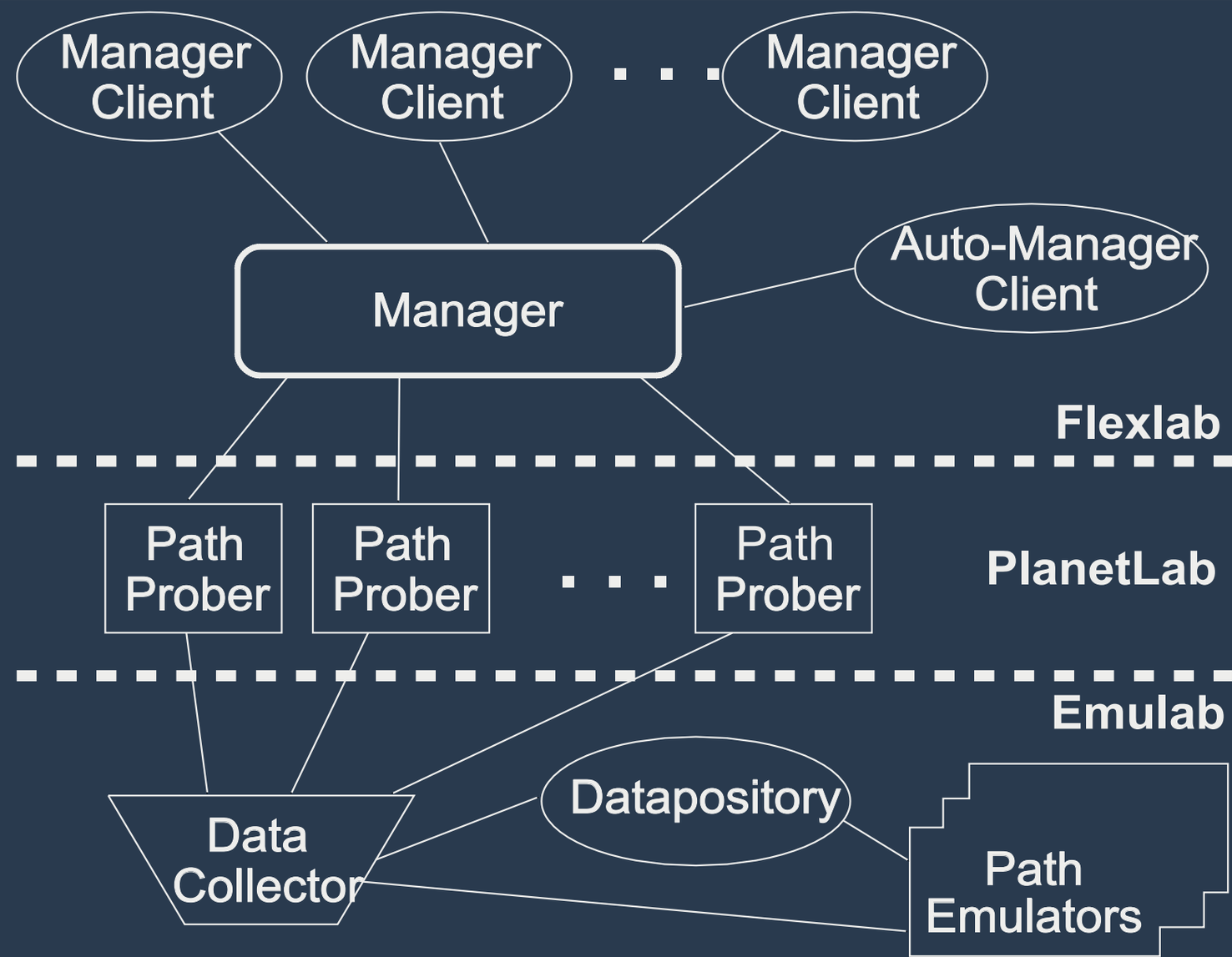


Simple Dynamic Model

Flexmon All-Sites PlanetLab Measurements



Flexmon Architecture



- Shared
- Reliable
- Safe

- Adaptive
- Controllable
- Accommodates high-performance data retrieval

CPU Starvation on PlanetLab

- Host Artifacts
  - Long period when agent can't read or write
  - Empty socket buffer or full receive window
  - Solution: Detect and ignore
- Packet loss from libpcap
  - Long period without reading libpcap buffer
  - Many packets are dropped at once
  - Solution: Detect and ignore

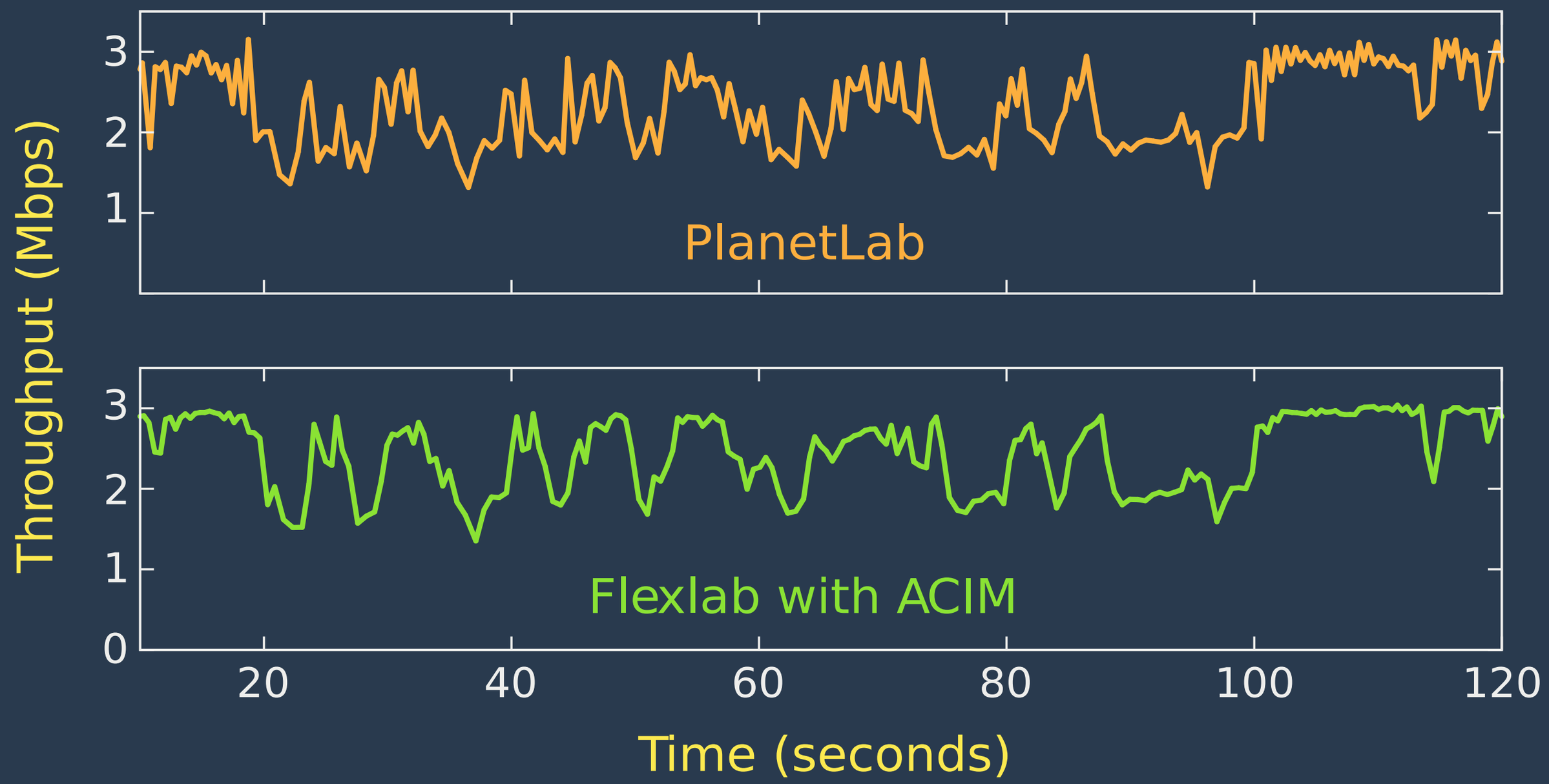
Reverse Path Congestion

- Can cause ack compression
- Throughput Measurement
  - Throughput numbers become much noisier
  - We abuse the TCP timestamp option
  - PlanetLab: homogeneous OS environment
  - Extending it would require hacking client
- RTT Measurement
  - Future work

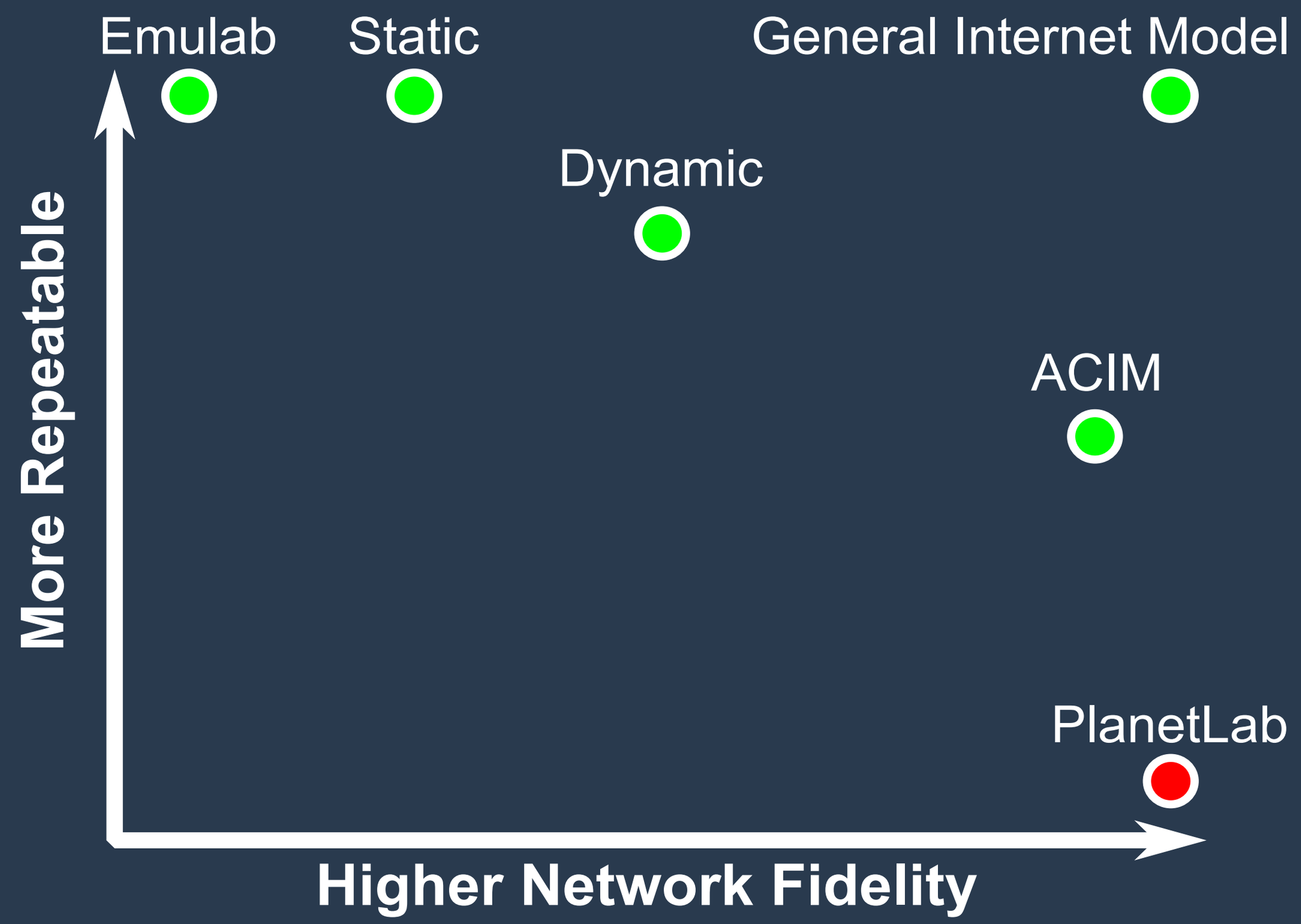
Initial Conditions

- Needed to bootstrap ACIM
  - ACIM uses traffic to generate conditions
  - But conditions must exist for first traffic
- We created a measurement framework
  - All pairs of sites are measured
  - Put data into measurement repository
  - Set initial conditions to latest measurements

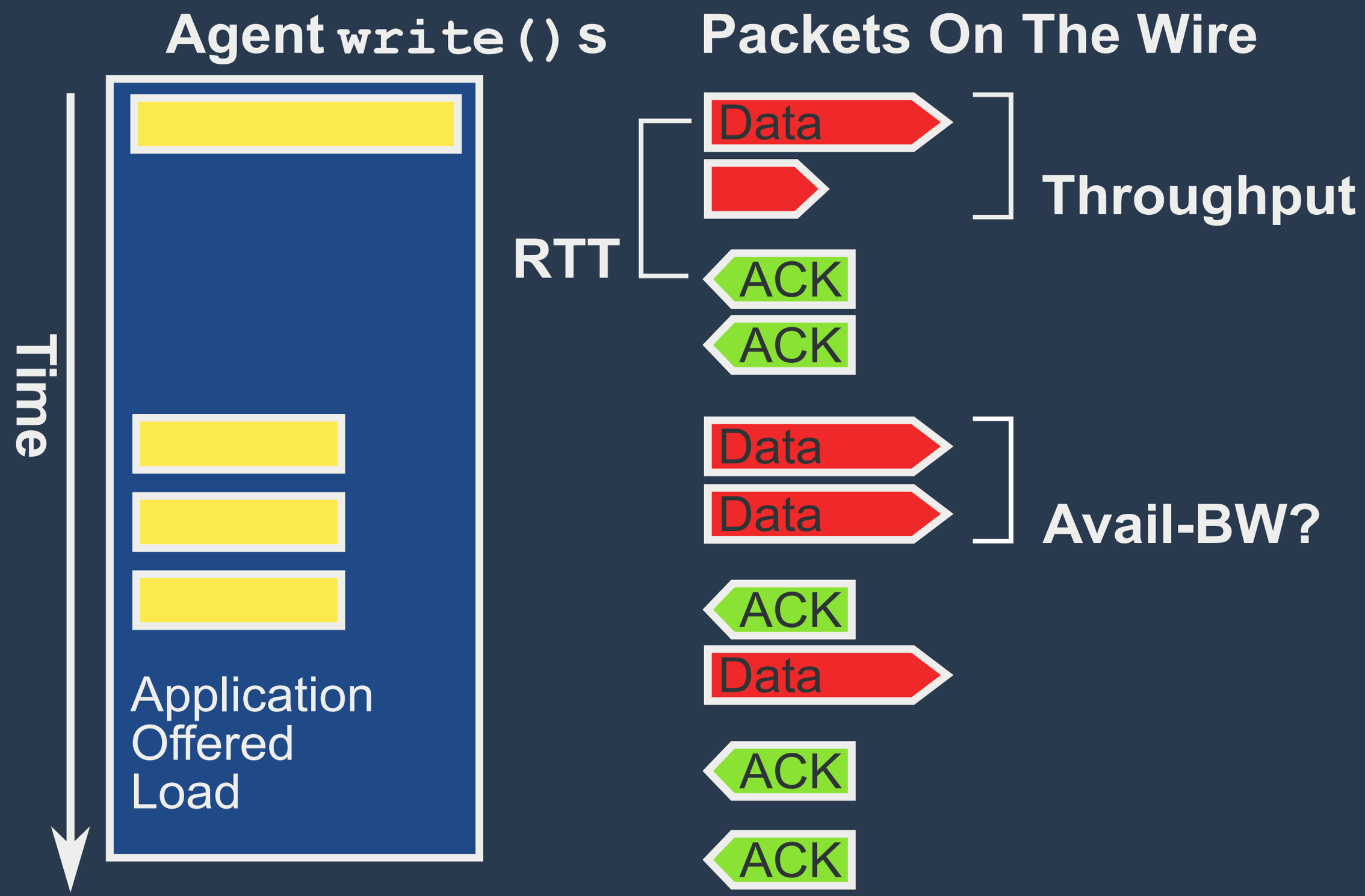
Simultaneous TCP iperf



Repeatability vs. Fidelity



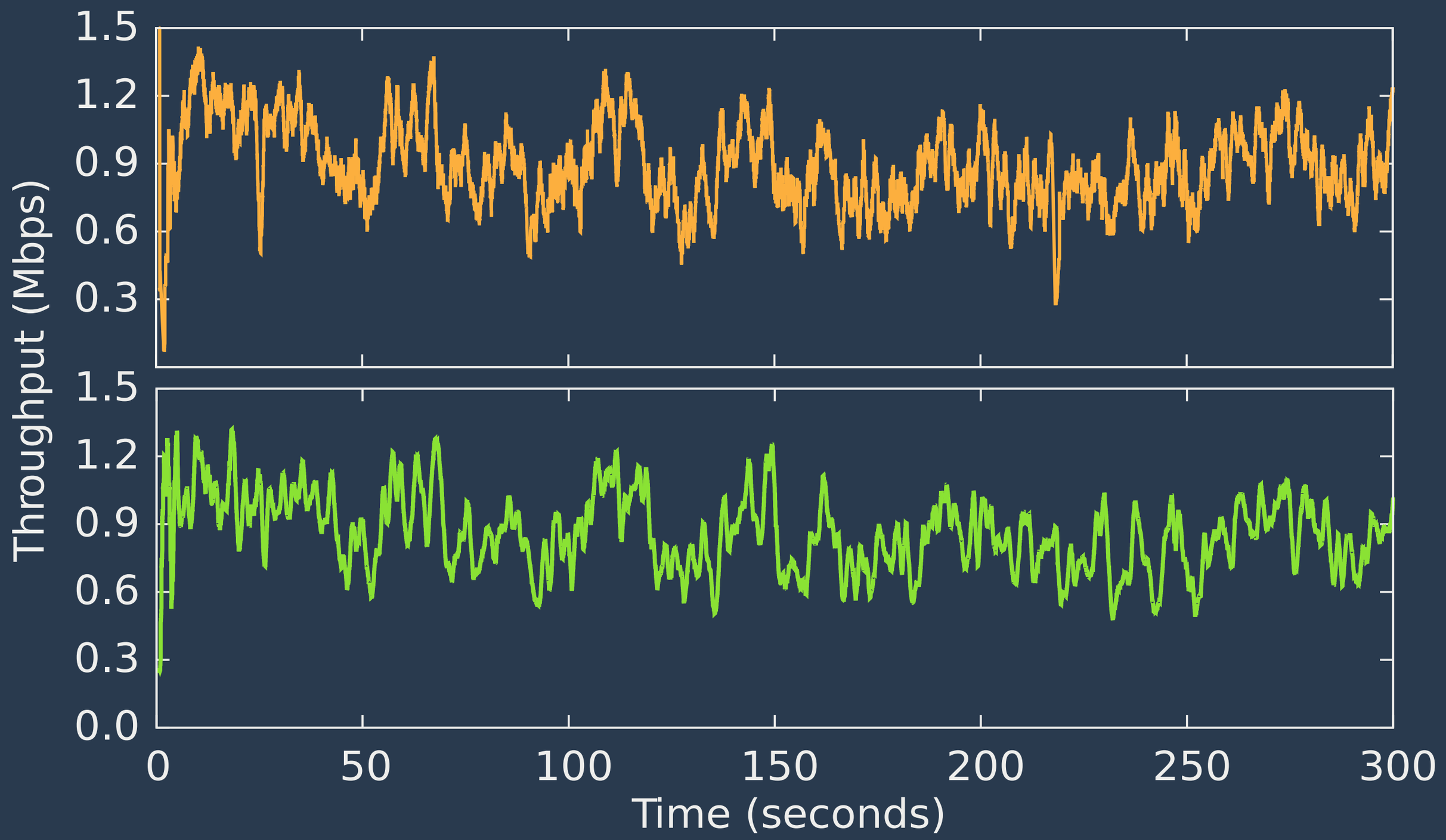
Throughput and ABW



Currently available for Beta Testing

http://www.flux.utah.edu/flexlab

UDP Streaming Video



Opens Up New Questions

- Further validation
- Accuracy tests at runtime
  - Similar in spirit to Emulab's linktest
- Use to compare models
  - Find which models most appropriate for different classes of applications
- Replay for ACIM
- Study fidelity of different software combinations
  - Different TCP implementation or OS in Emulab