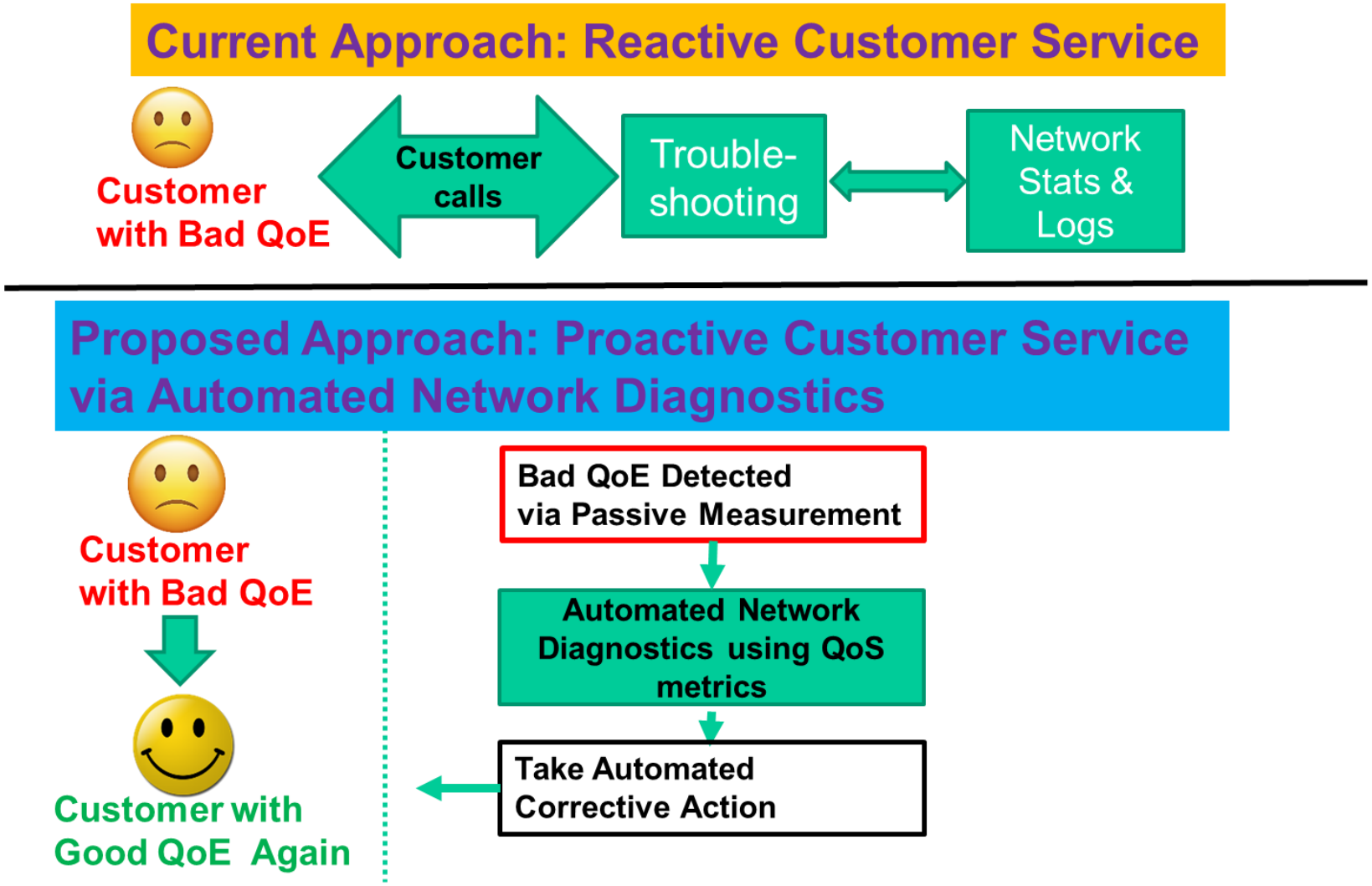
Application Layer QoS Metrics To Aid Network Performance Monitoring And Diagnostics For Encrypted Traffic

Chi-Jiun Su

Hughes Network Systems, LLC.

chi-jiun.su@hughes.com

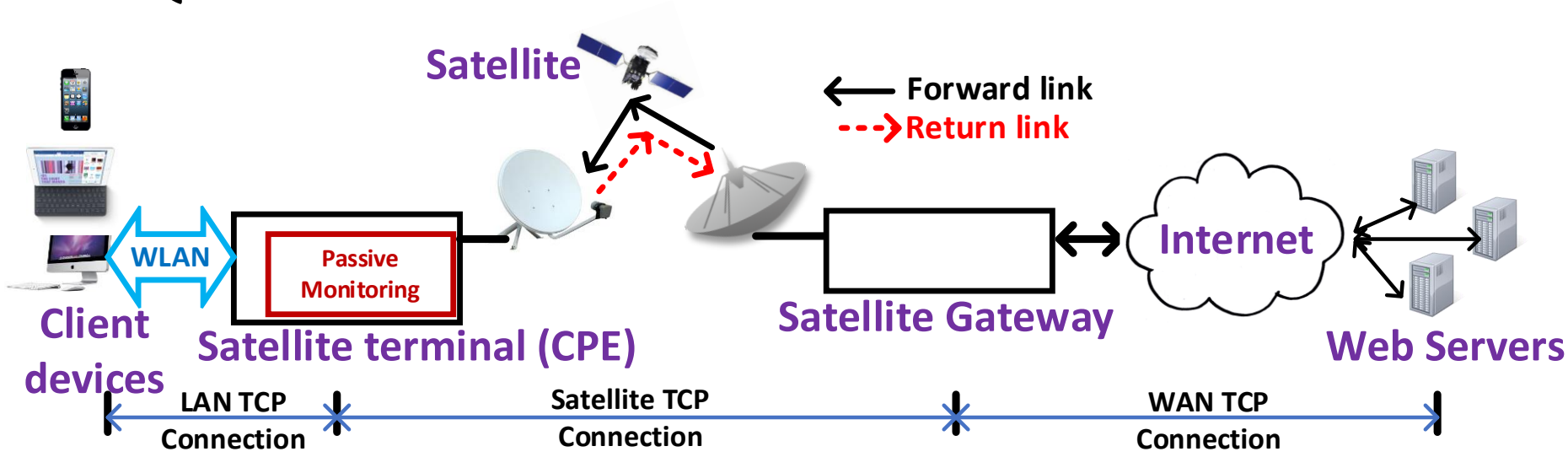
Motivation


Current Approach: Reactive Customer Service
Customer with Bad QoE
Customer calls
Trouble-shooting
Network Stats & Logs
Proposed Approach: Proactive Customer Service via Automated Network Diagnostics
Customer with Bad QoE
Customer with Good QoE Again
Bad QoE Detected via Passive Measurement
Automated Network Diagnostics using QoS metrics
Take Automated Corrective Action

Existing Approaches

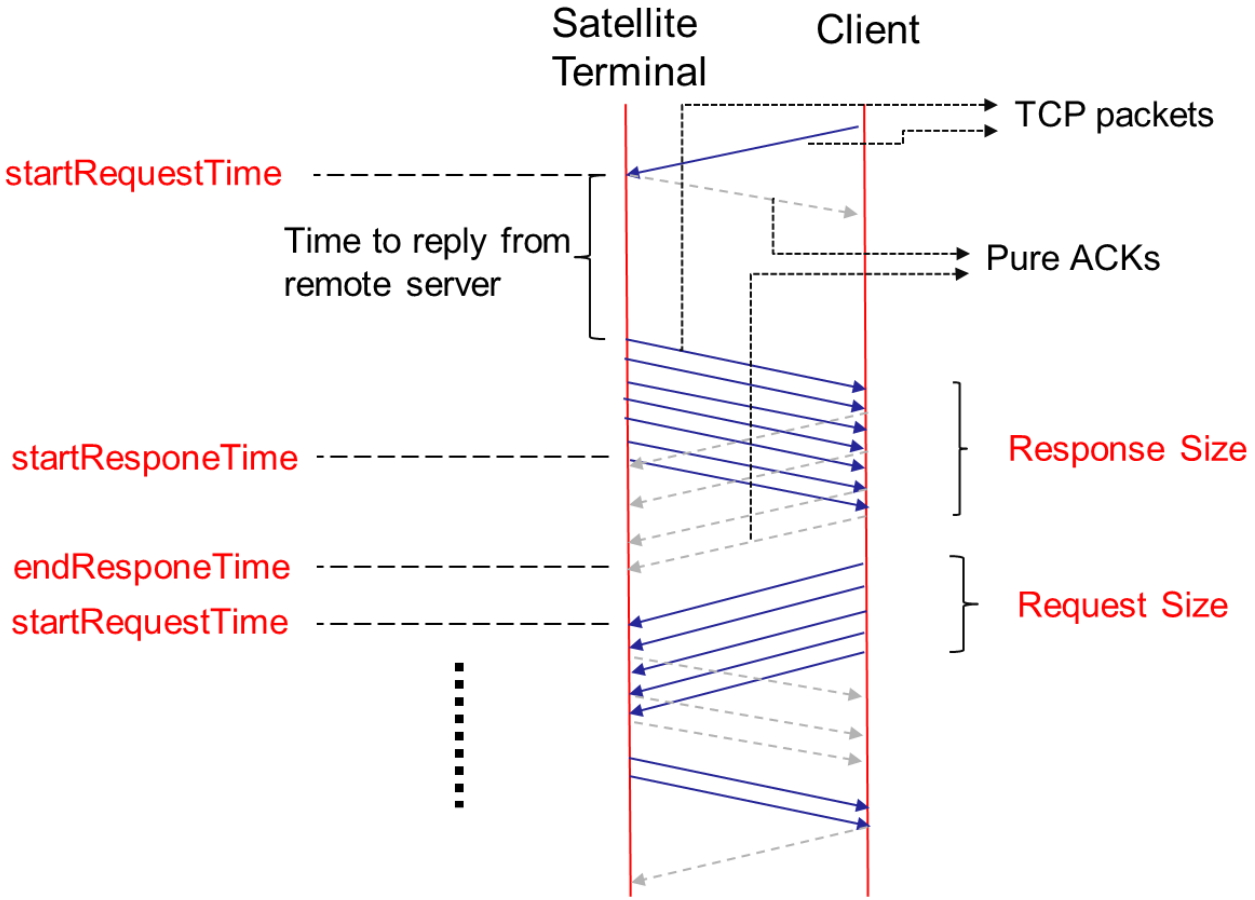
- ISPs monitor a huge list of metrics focusing on various aspects and different components of the networks.
  - Hardly any metrics that capture impact of network conditions on user applications and their quality of experience (QoE)
- Carry out active measurements on a subset of test terminals
  - Cannot be used for monitoring or detecting performance degradations.
  - Not feasible for a larger scale and for a continuous manner in a real operational network
  - May not detect network degradation experienced by customers at the time of measurement
- Follow a bottom-up manner, which starts with the metrics capturing the lower layer performance

Continuous Passive Monitoring of Application Layer QoS Metrics



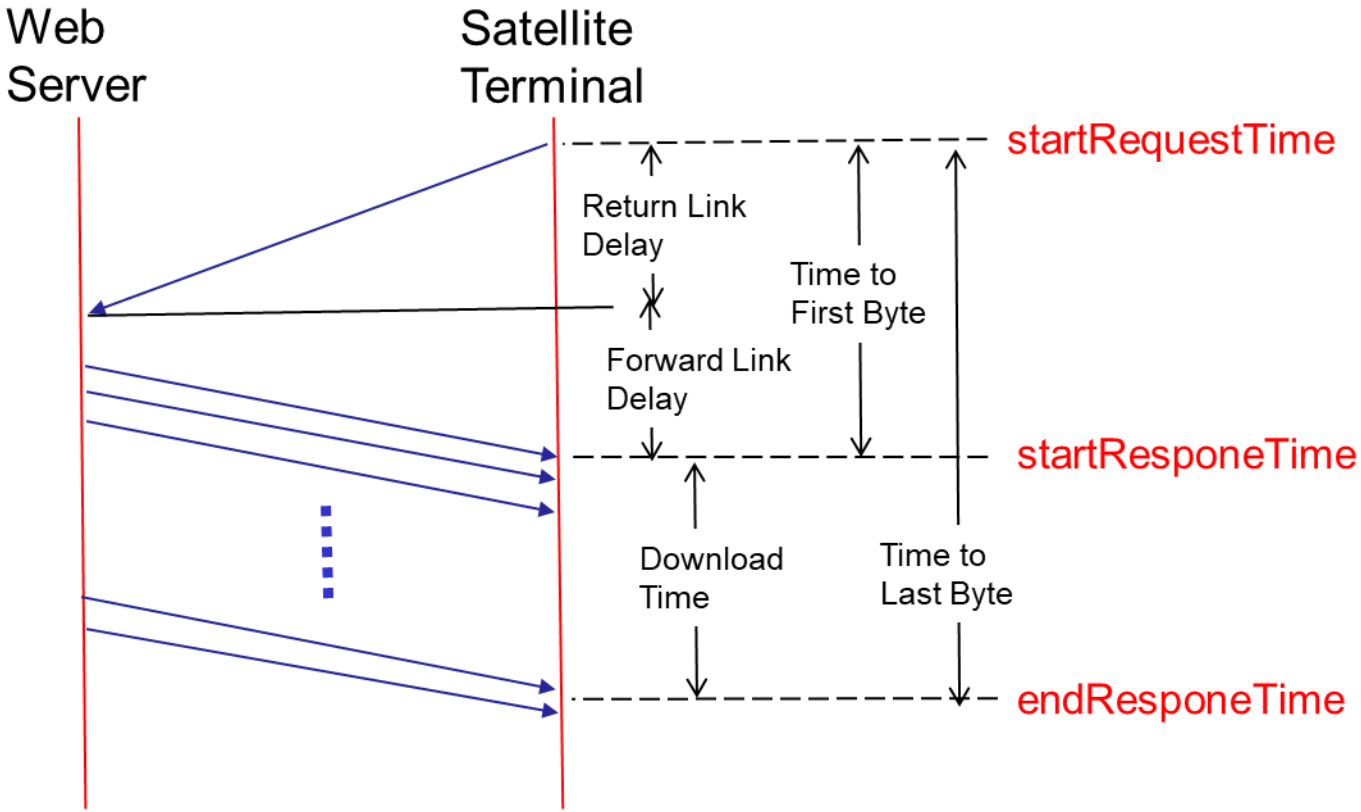
- Does not require cooperation from users, instrumentation of user devices, and measurements hooks from the server or client applications

Estimating Application Characteristics from TCP Layer Information for HTTPS



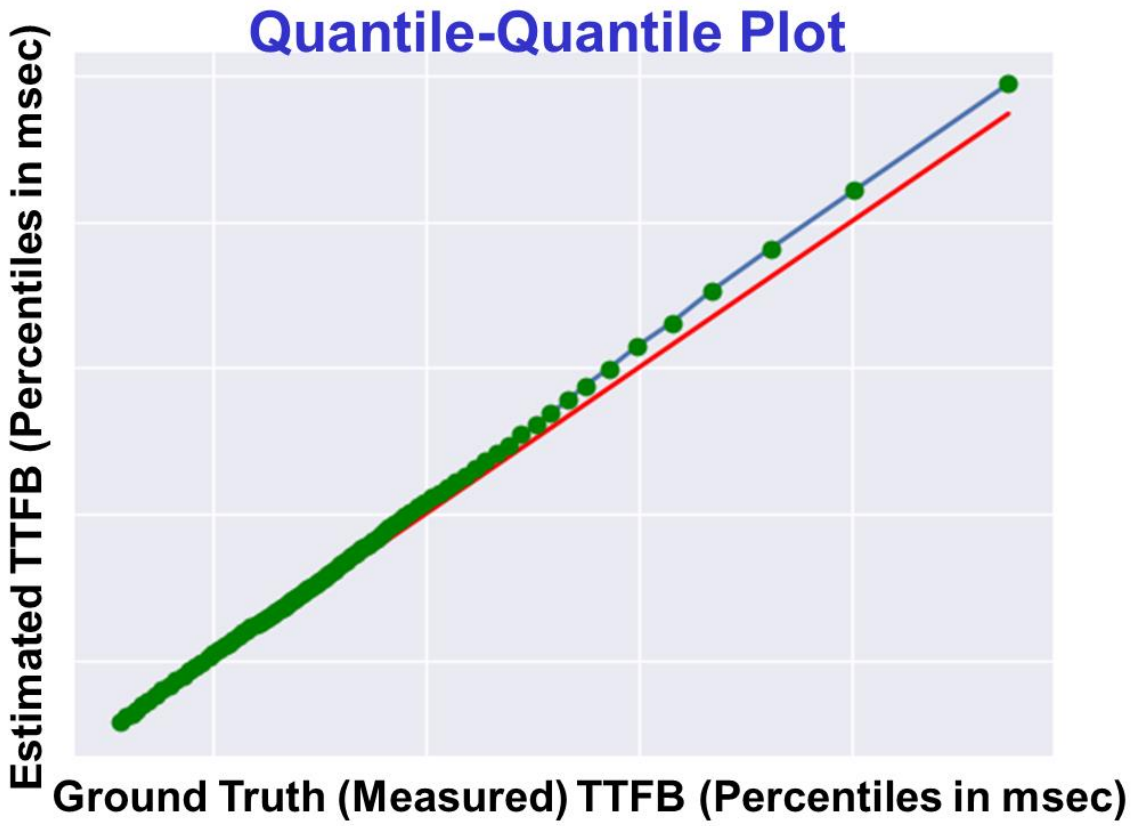
- Identify key events that are indicative of application layer behavior
- Use TCP state machine statistics for a TCP connection, or TCP header fields of packet exchanges in both directions
- Estimate start and end times and sizes of HTTP request and HTTP responses.

Application Layer QoS metrics



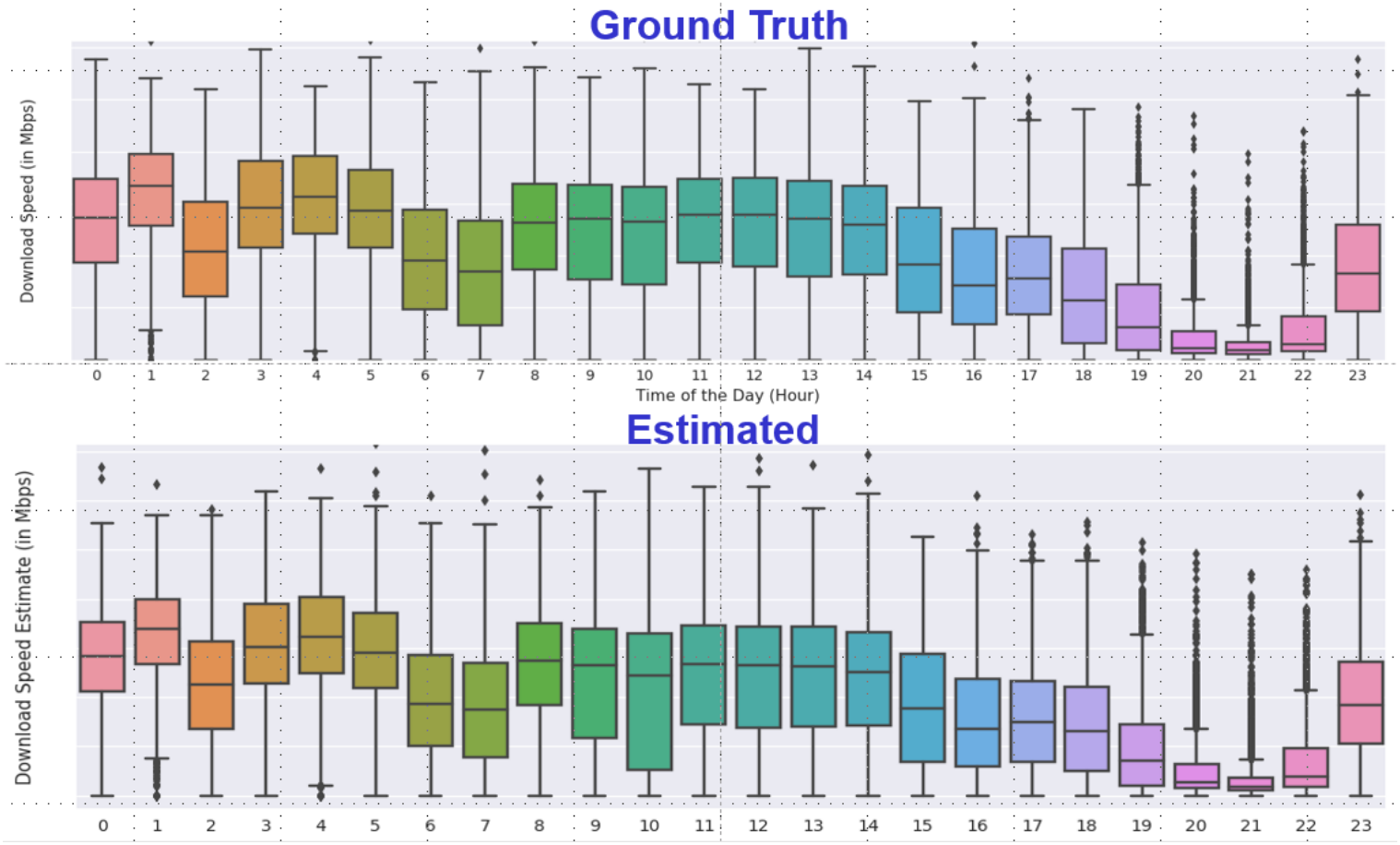
- Time to first byte (TTFB)
  - Time difference between the start of a HTTP request and the start of a HTTP response corresponding to the request, received at the satellite terminal
  - Impact interactive web browsing QoE
- Time to last byte (TTLB)
  - Time difference between the start of a HTTP request and the end of a HTTP response corresponding to the request, received at the terminal
  - Impact video streaming QoE
- Application layer download speed (DS)
  - Size of a response in bits divided by Time To Download for the response in seconds.
  - Impact bulk download QoE

Validating Estimated Application Layer QoS Metrics: TTFB



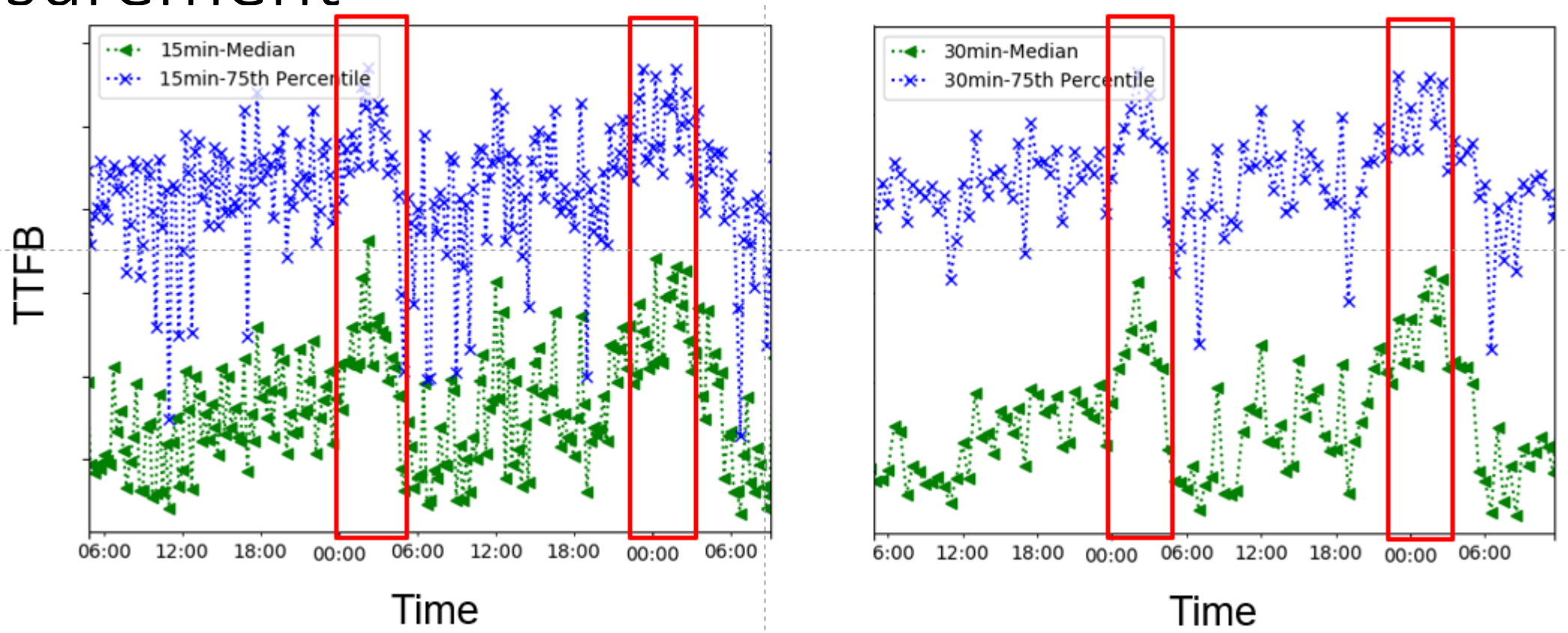
- Overall, the estimated TTFB values closely follow the distribution of the ground truth TTFB.
- Estimates more accurately for smaller TTFB values, but overestimates the ground truth for higher TTFB values

Validating Estimated Application Layer QoS Metrics: DS



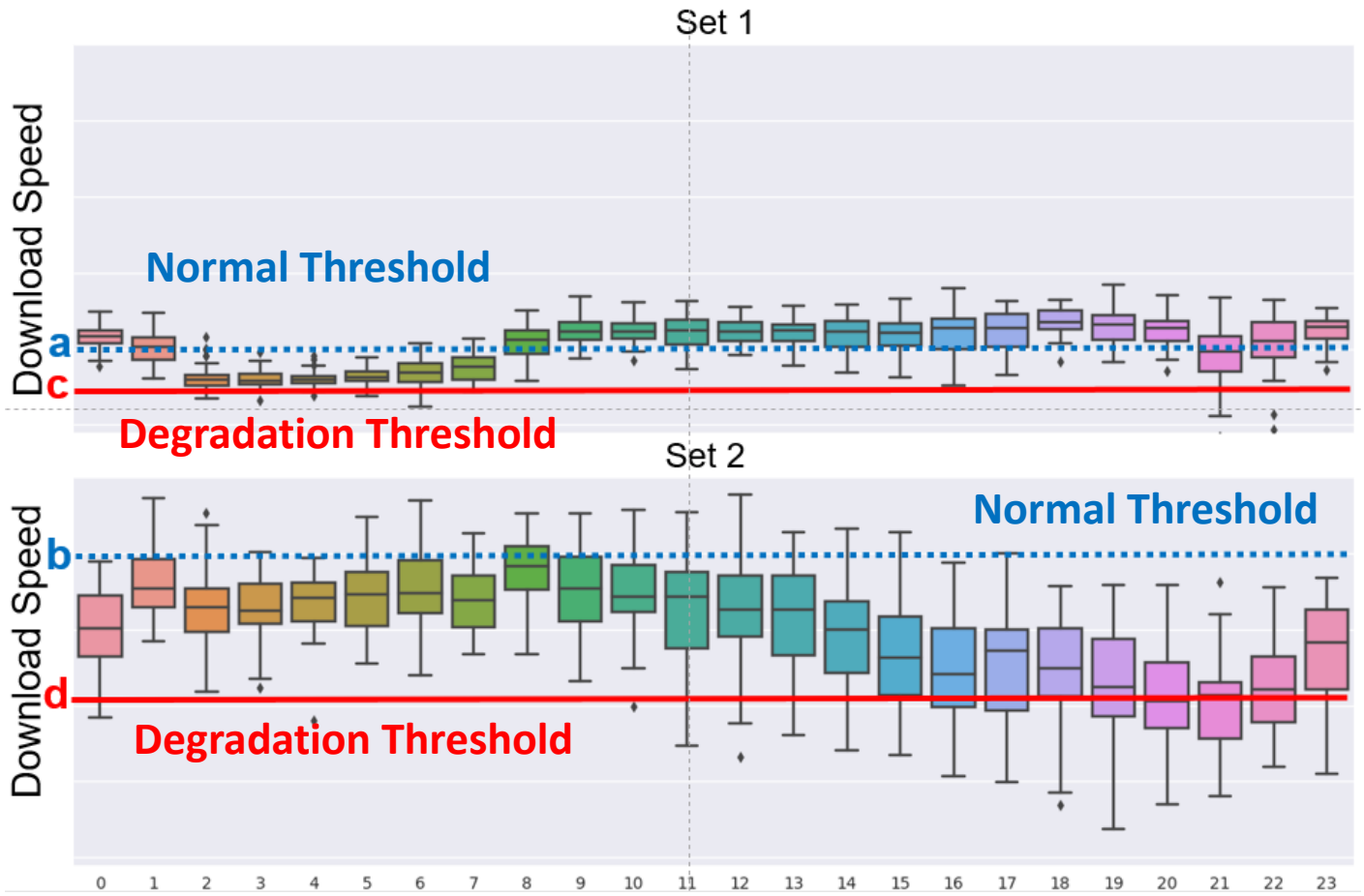
- Distribution of estimated DS is also close to that of ground truth DS

Short window for on-demand and active measurement



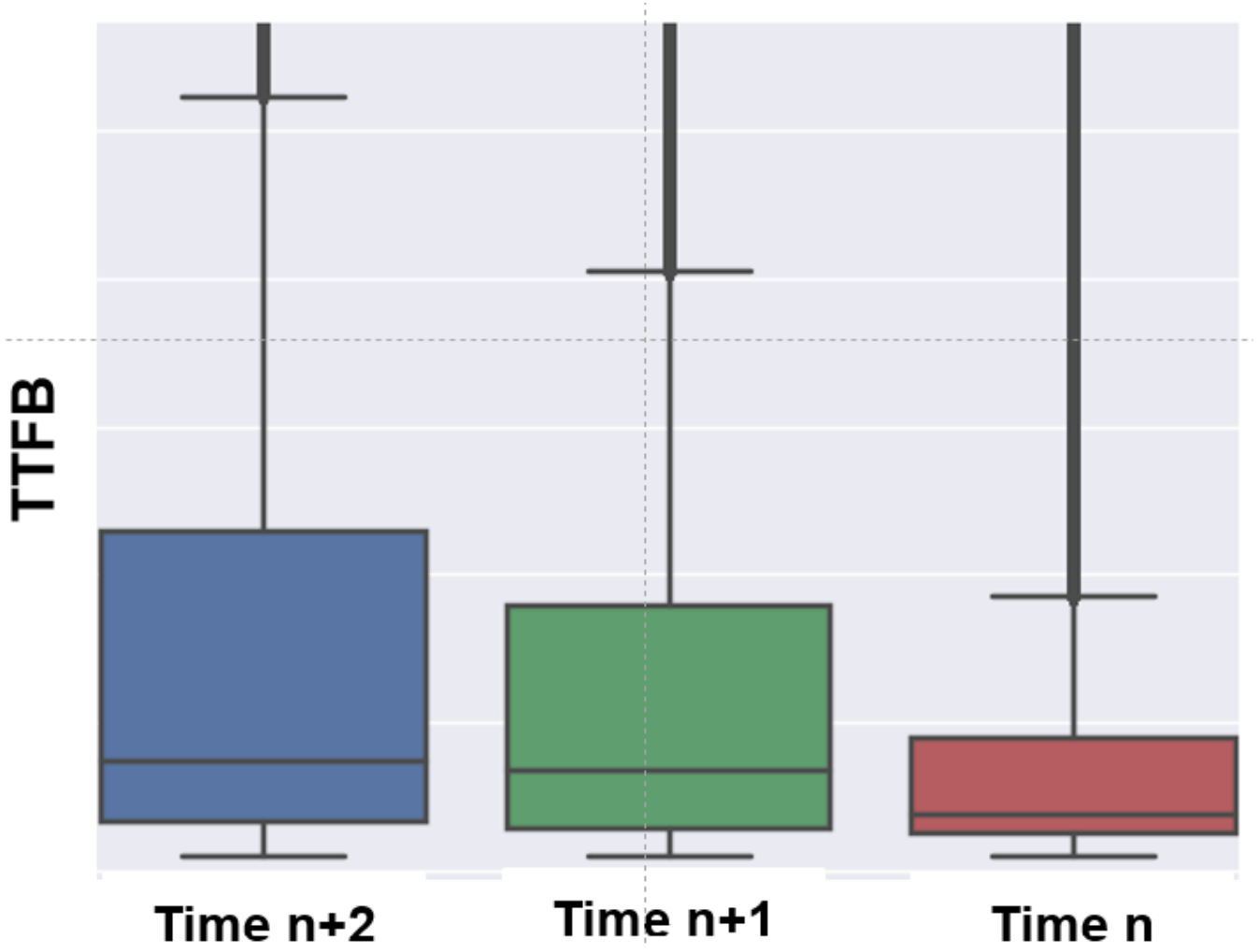
- Both median and 75th percentile of TTFB over the 15-minute window are sufficiently stable and similar to the values of the 30-minute window

Detecting network performance degradation



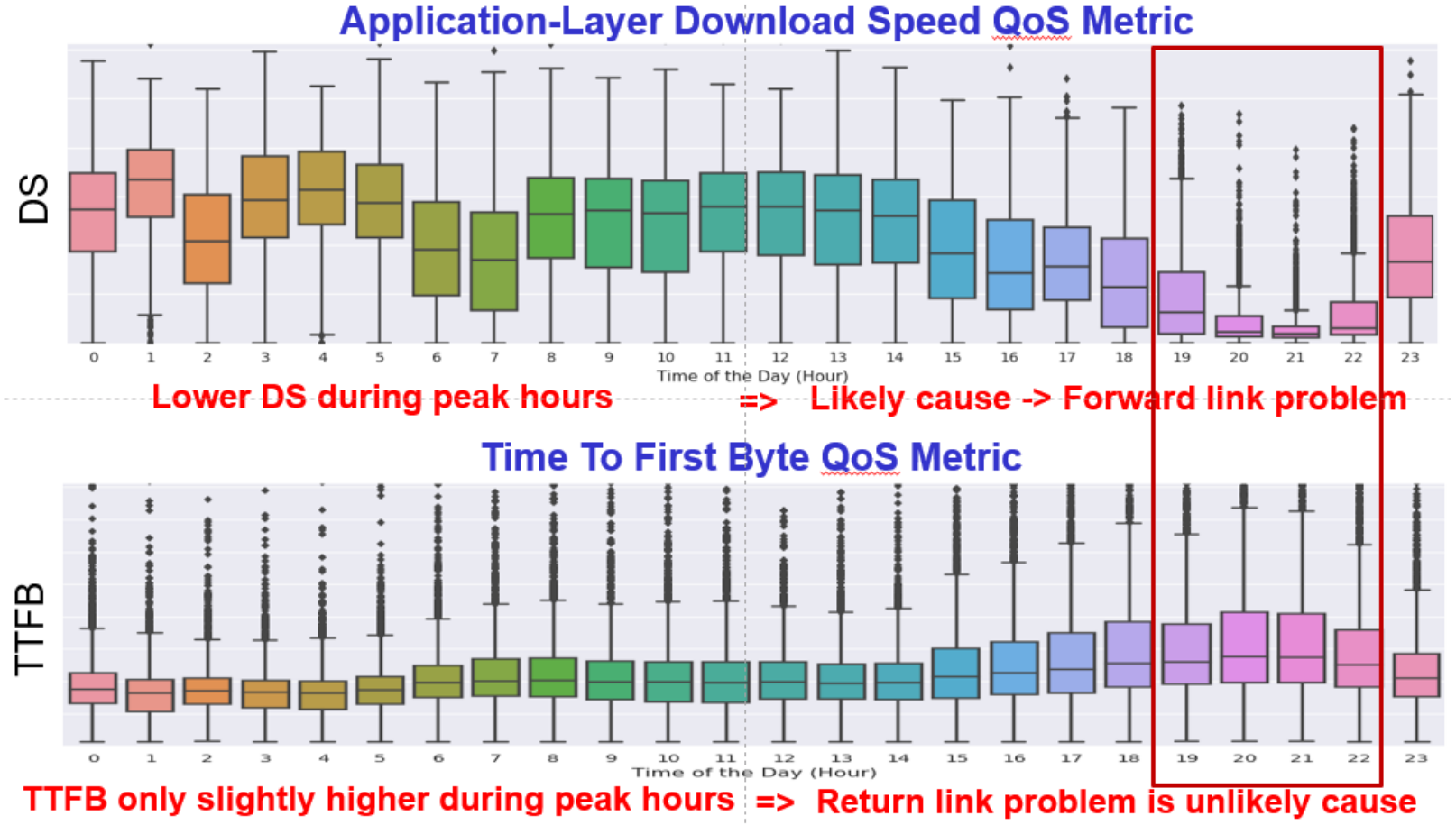
- Two different thresholds represent two subscription plans with different data rates: a<b and c<d
- Set 1 (Lower tier subscription)
  - Application layer DS meets or exceeds the target DS for most of the hours in the 24-hour period but comes close to degraded performance during 2-6 and 21-22 hours
- Set 2 (Higher tier subscription)
  - Target DS is rarely met but DS stay above degraded condition most of the time during the 24-hour period

Tracking trends in the network performance



- Evolution of TTFB values over three time periods from Time n, Time n+1 and Time n+2
- Increasing trend of the TTFB values indicates that the network performance is getting worse over time

Illustrative example of using DS and TTFB for network diagnostics



- Potential root cause of bad user's QoE can be degraded performance in forward link

Conclusion

- A low complexity non-intrusive method is proposed to estimate application-layer Quality of Service (QoS) metrics experienced by end-users.
- Passively and continuously monitors user's traffic from a vantage point within the ISP network.
- Accurately capture the network conditions experienced by end user’s devices or internet applications.
- Together with existing set of network statistics, provide more accurate network performance monitoring.
- Demonstrate that the metrics can be used for detecting degraded network performance and finding the root cause.
- Our top-down approach from user perspective complements the usual bottom-up technique using network component statistics and alerts.
- The concept can be extended to the new generation of encrypted traffic such as QUIC with more complex algorithms and with less accuracy.