Network traffic time series analysis

Traffic measurements: Pre-1990

- Early Telephony: Importance of measurements (e.g., Erlang, Palm, Wilkinson, ...)
- Modern Telephony: Measurements are a scarce commodity; supposedly „well-understood“ characteristics
- Early data networking: Importance of measurements (e.g., ARPANET measurements by Kleinrock, et al.)
- Modern data networking: No data or only a few small data sets are available

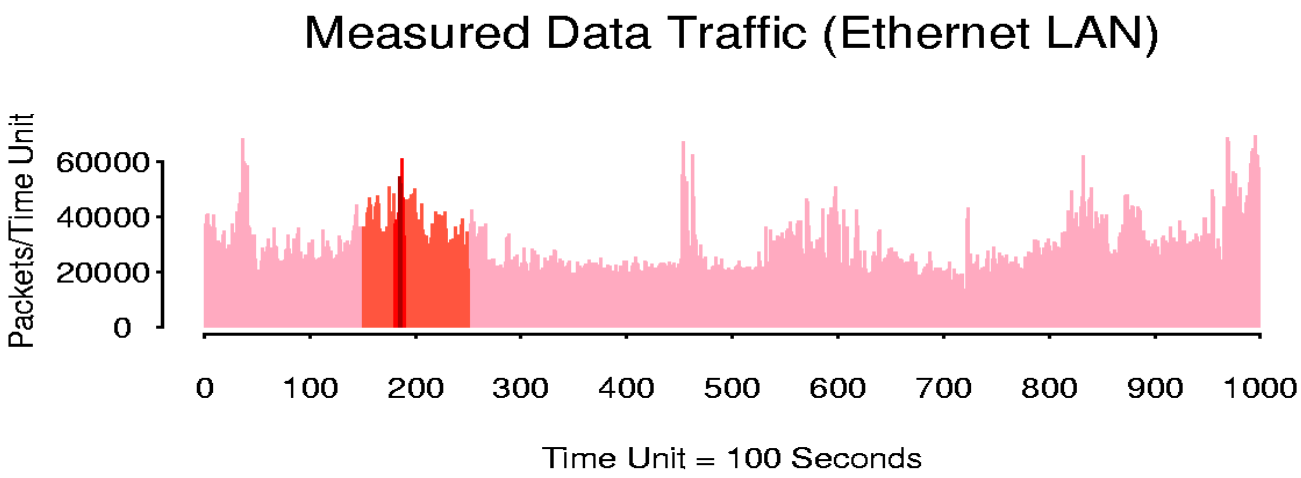
Traffic measurements: Pre-1990

- Traffic data analysis
  - Strictly traditional inference techniques
  - Focus on choosing best-fitting model
  - Obsession with „Squeezing a data set dry“
- Traffic and performance modeling
  - Black-box or operational models dominate
  - No real need to talk to subject-matter experts
  - Traffic is viewed as „just another time series ...“
  - Main objective: „What can be analyzed?“

Post-1990: What has changed?

- Traffic measurements
  - Abundance of traffic measurements; reproducibility
- Traffic data analysis
  - Data exhibits unusual features
  - From statistical inference to scientific inference
  - Networks are complex; need for subject-matter expertise
- Traffic and performance modeling
  - Need for physical-based or structural models
  - Main objective: „What matters for performance?“

Sample data trace

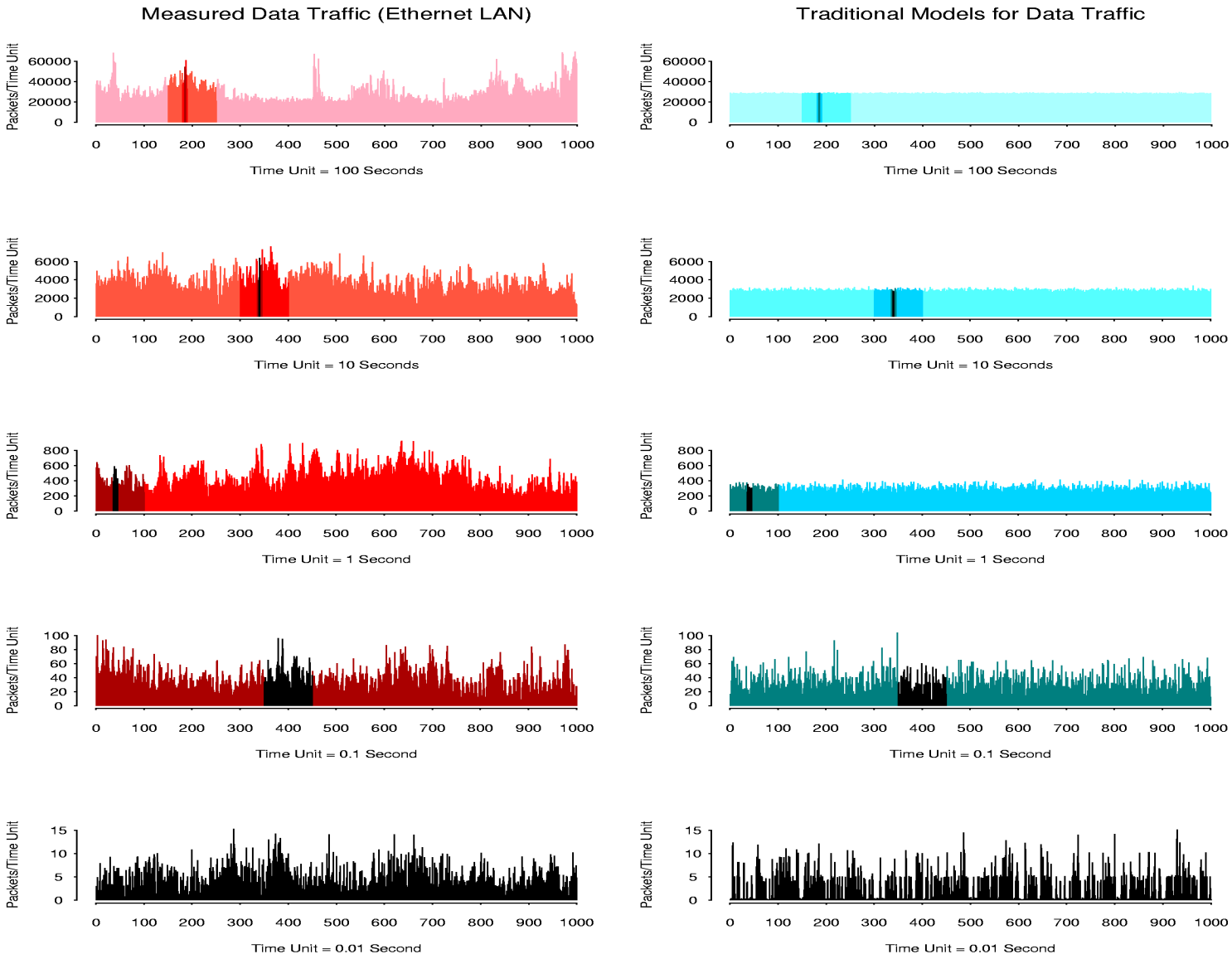


High-volume measurements

- 1 hour of ETHERNET LAN traffic (10 Mbits)
  - About 1 million packets
- 1 day of uninterrupted ETHERNET LAN
  - About 2 Gigabytes of data
- 1 hour of ATM traffic (155 Mbits)
  - About 100 million packets
- 1 day of uninterrupted ATM measurements
  - About 1 Terabyte of data
- 1 day of uninterrupted 1 Gigabit measurements
  - About 10 Terabyte of data

High-quality measurements

- Timestamp accuracy
  - From millisecond to microsecond accuracy
- More than just another time series
  - Information about all layers in network hierarchy
    - TCP/IP header information
    - Payload
    - Higher level protocol information


Measured Data Traffic (Ethernet LAN)
Traditional Models for Data Traffic
Packets/Time Unit
Time Unit = 100 Seconds
Time Unit = 10 Seconds
Time Unit = 1 Second
Time Unit = 0.1 Second
Time Unit = 0.01 Second

Time Series

Example

- # of packets (bytes) per 10 mseconds
- # of TCP connections arriving per second
- # of modem sessions arriving per second

Definitions

- Time series: $X_1, X_2, \ldots, X_n$
- Aggregated process: $X^{(m)}$

$$X^{(m)}(k) = \frac{1}{m}(X_{(k-1)m+1} + \ldots + X_{km}), \quad k \geq 1$$

- Stationary time series:

  distribution of X independent of time