Applying Statistical Process Control to the Adaptive Rate Control Problem

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Introduction and Motivation

- **Goal**
  - integration of meaningful feedback about the requirements and performance of multimedia applications into adaptive multimedia networking.
- **We would like to explore**
  - mechanisms for long-term characterization of network variability (e.g., delay, bandwidth, buffer size).
  - mechanisms for inducing application requirements into adaptive multimedia networking.
- **We would these mechanisms**
  - to be robust and easy to implement.

Outline of the Talk

- **Statistical Process Control & Multimedia Networking**
  - Long-Term vs. Short-Term Variability
  - Statistical Quality Control
  - Long-Term Stability Monitor

- **Applications of SPC to Adaptive Rate Control**
  - Adaptive Media Coding
  - Adaptive Media Synchronization
- **Conclusions**

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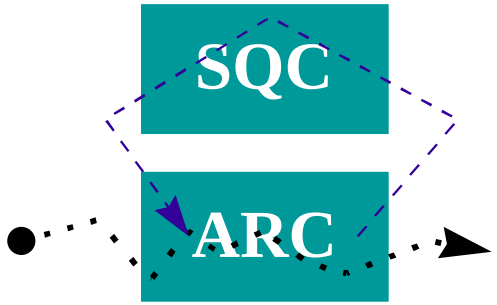
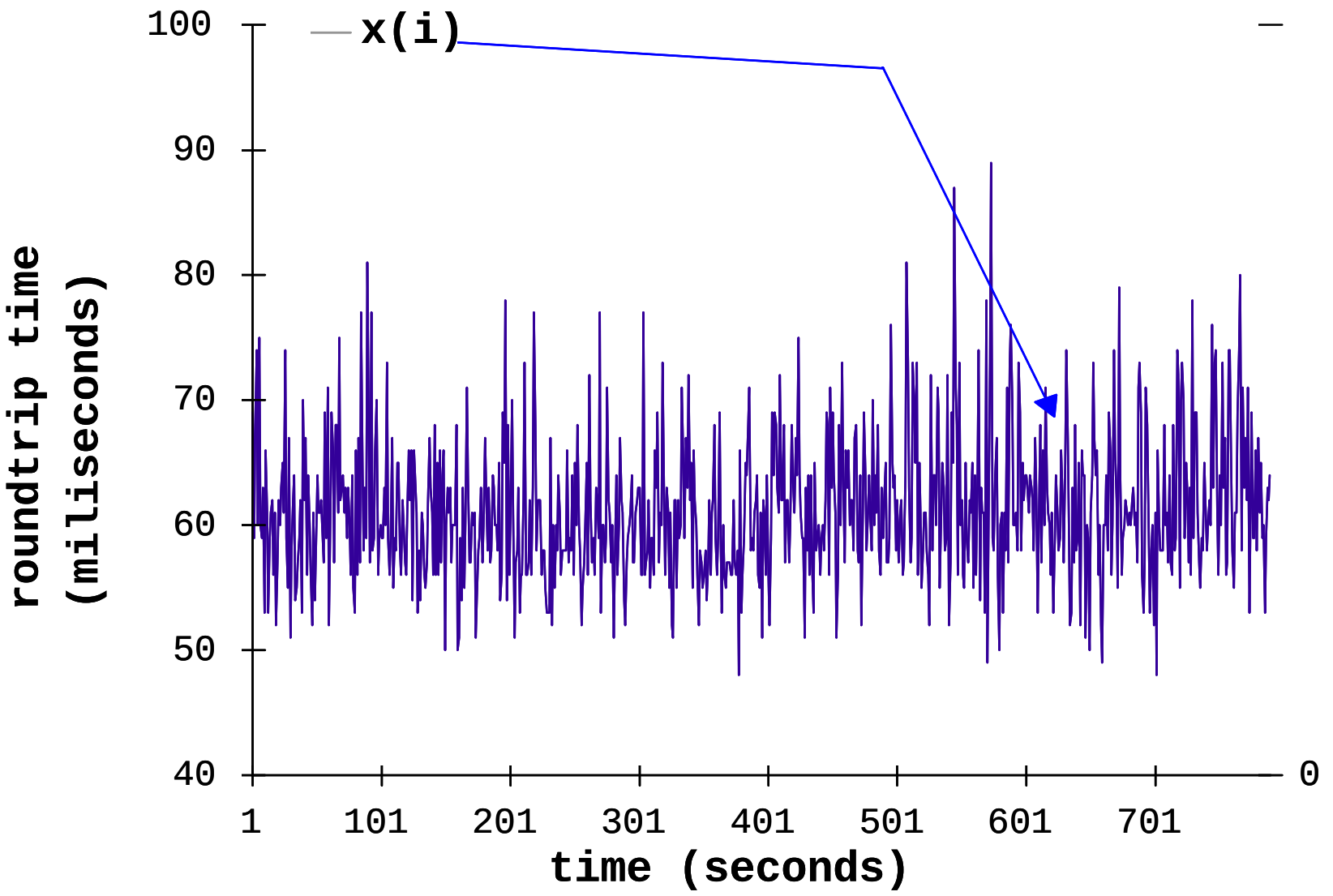


Long-Term vs. Short-Term Variability



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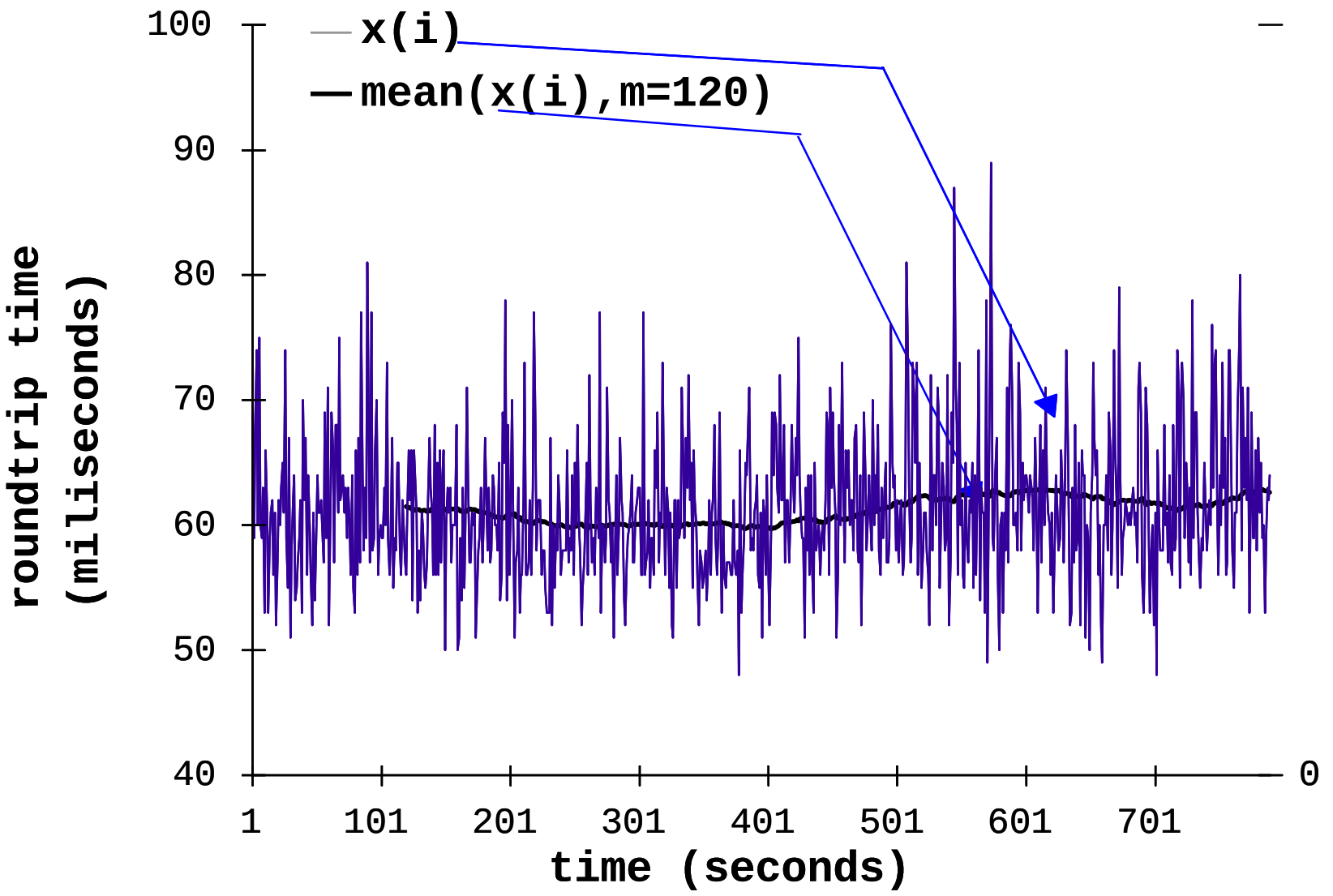

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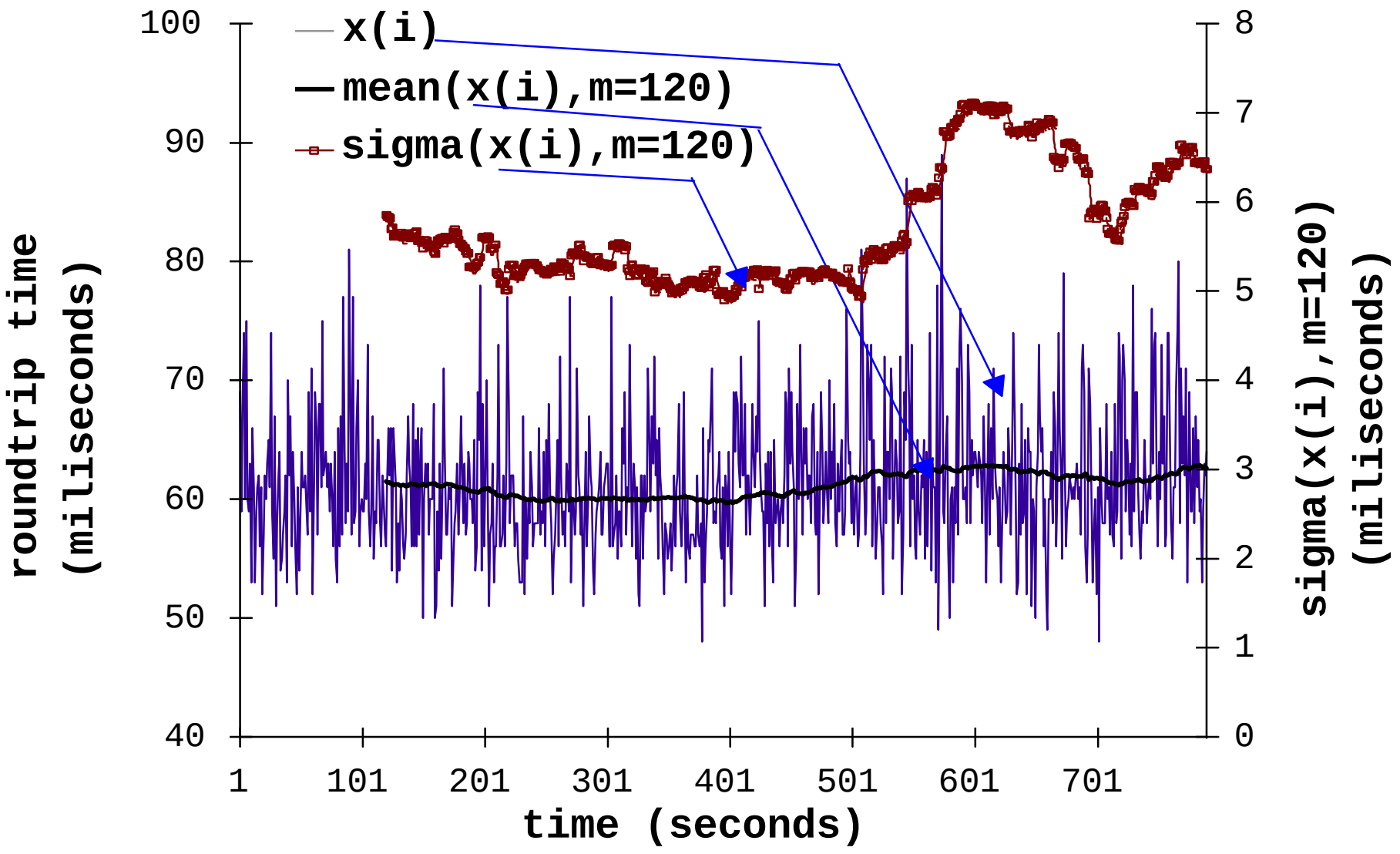
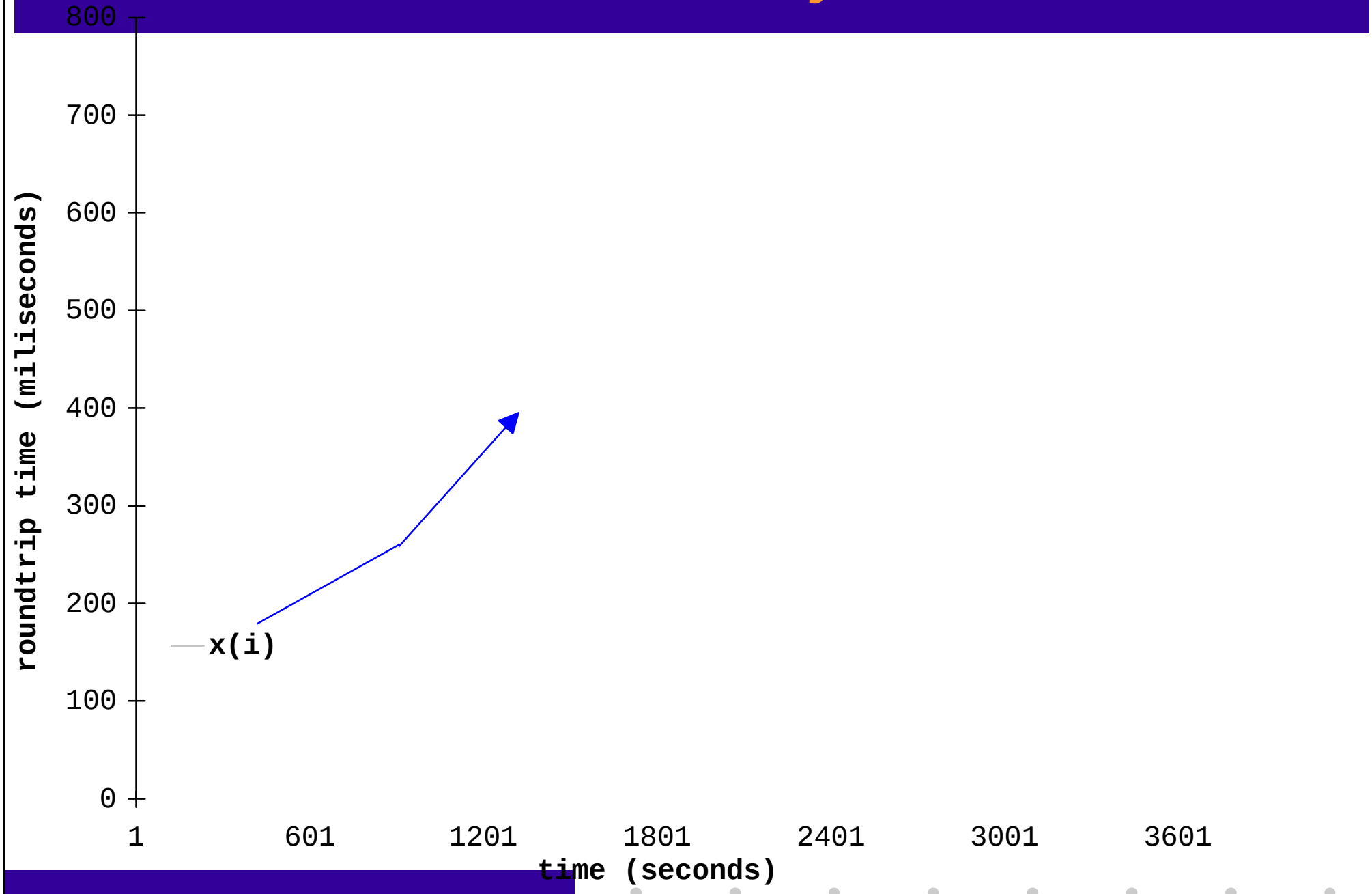


Statistical Quality Control



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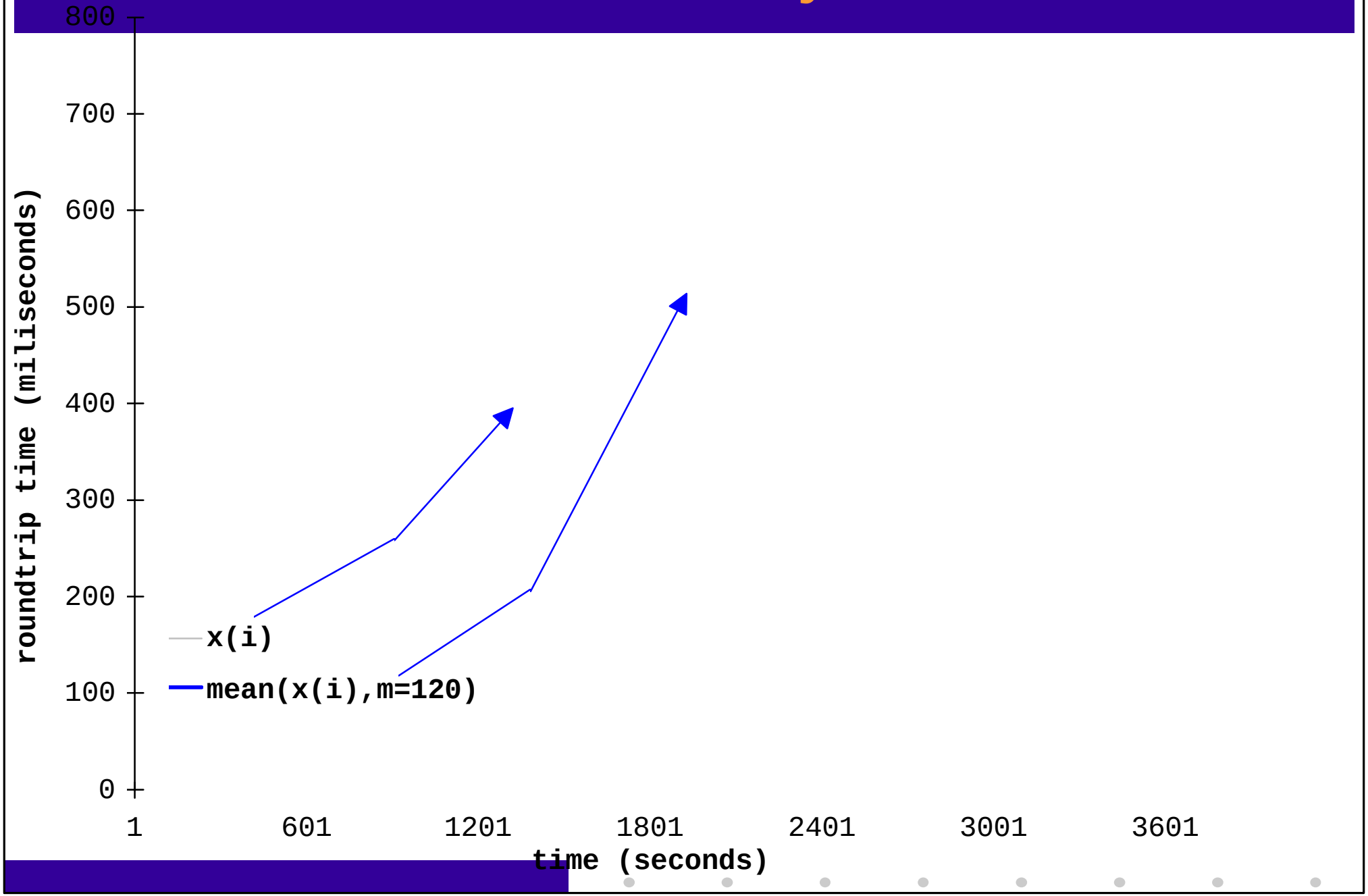

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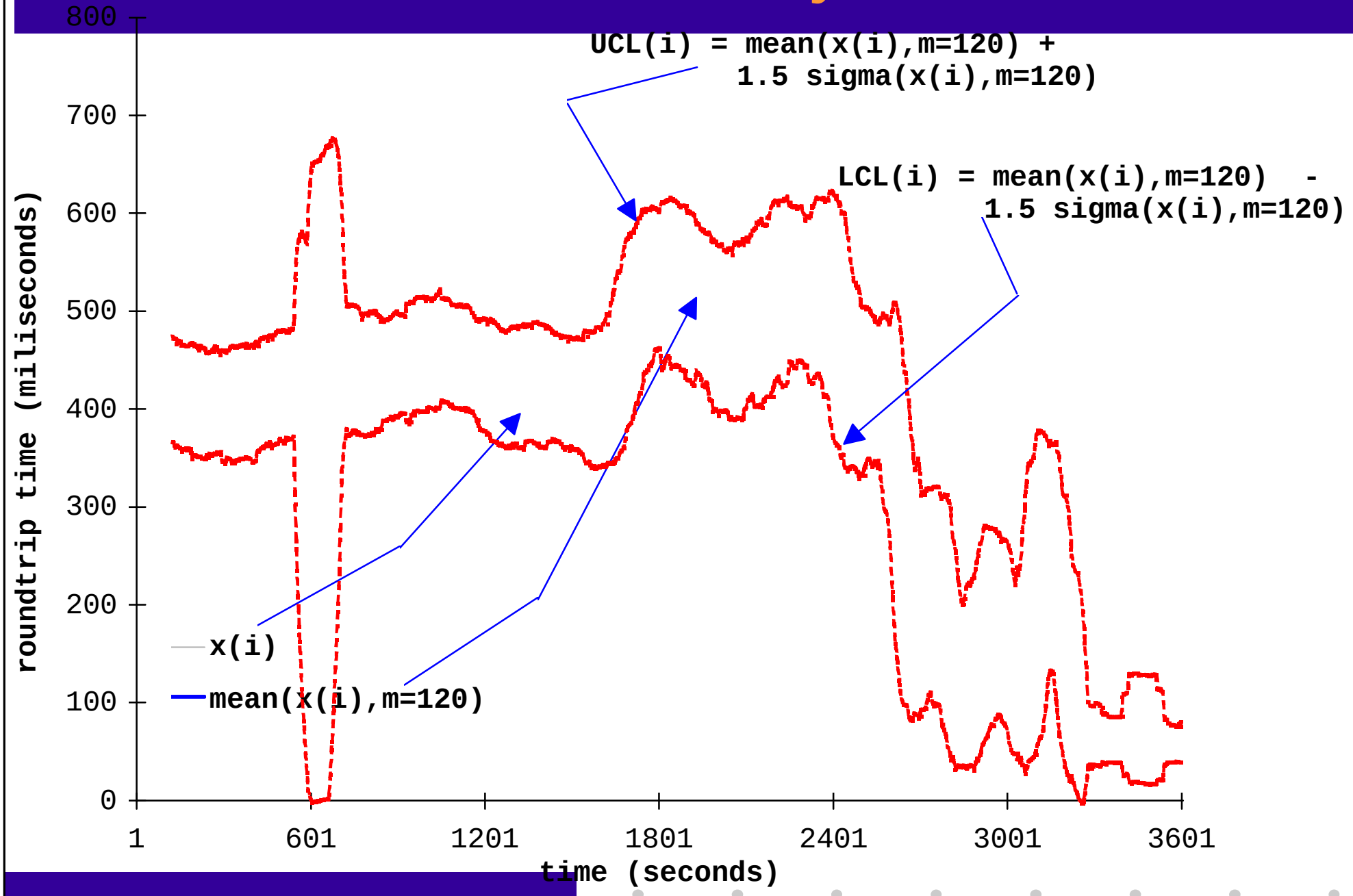

Statistical Process Performance (Specification of a Long-Term Monitor)

- smoothed process indicators (time scale, sampling, weights)
  - BMW(x_i,m) = UWMA smoothing

    $\mu(i,m) = \mu(x_i .. x_{m-i})$

    $\sigma(i,m) = \mu(x_i .. x_{m-i})$

    $\mu(i,m') = \mu(x_i .. x_{m'-i})$

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  - H0 : $\mu(i,m') = \mu(i,m)$
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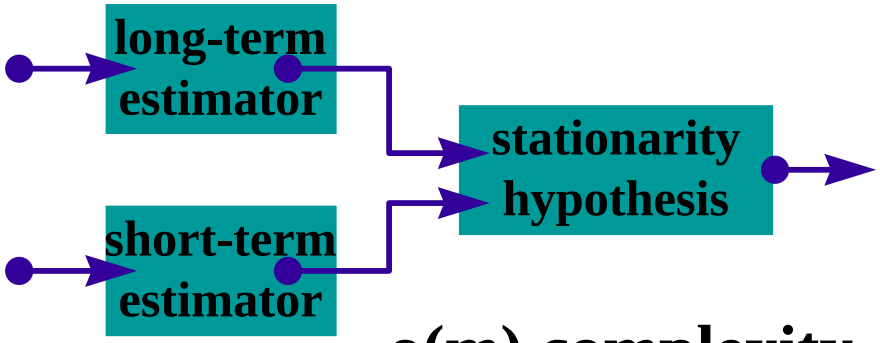
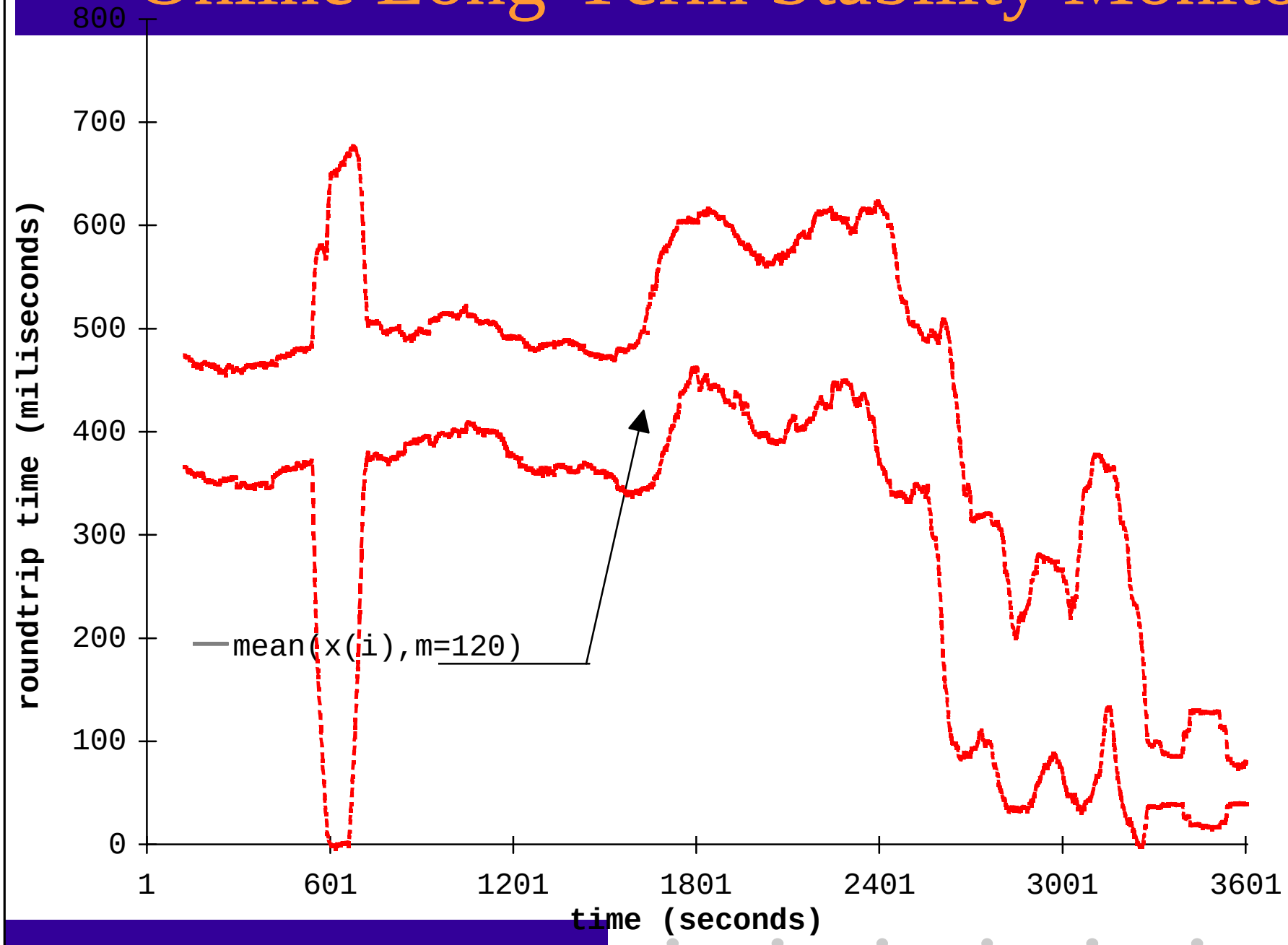
  - $Z0 = \mu(i,m') - \mu(i - {}^{m}/_{2}, m)$
- confidence interval & forecast estimation
  - if $|Z0| < k * \sigma(i,m)$ then $mon_i = mon_{i-1}$
  - else $mon_i = \mu(i,m)$
  - $mon^{*}_{i+1} = mon_i$



Online Long-Term Stability Monitor



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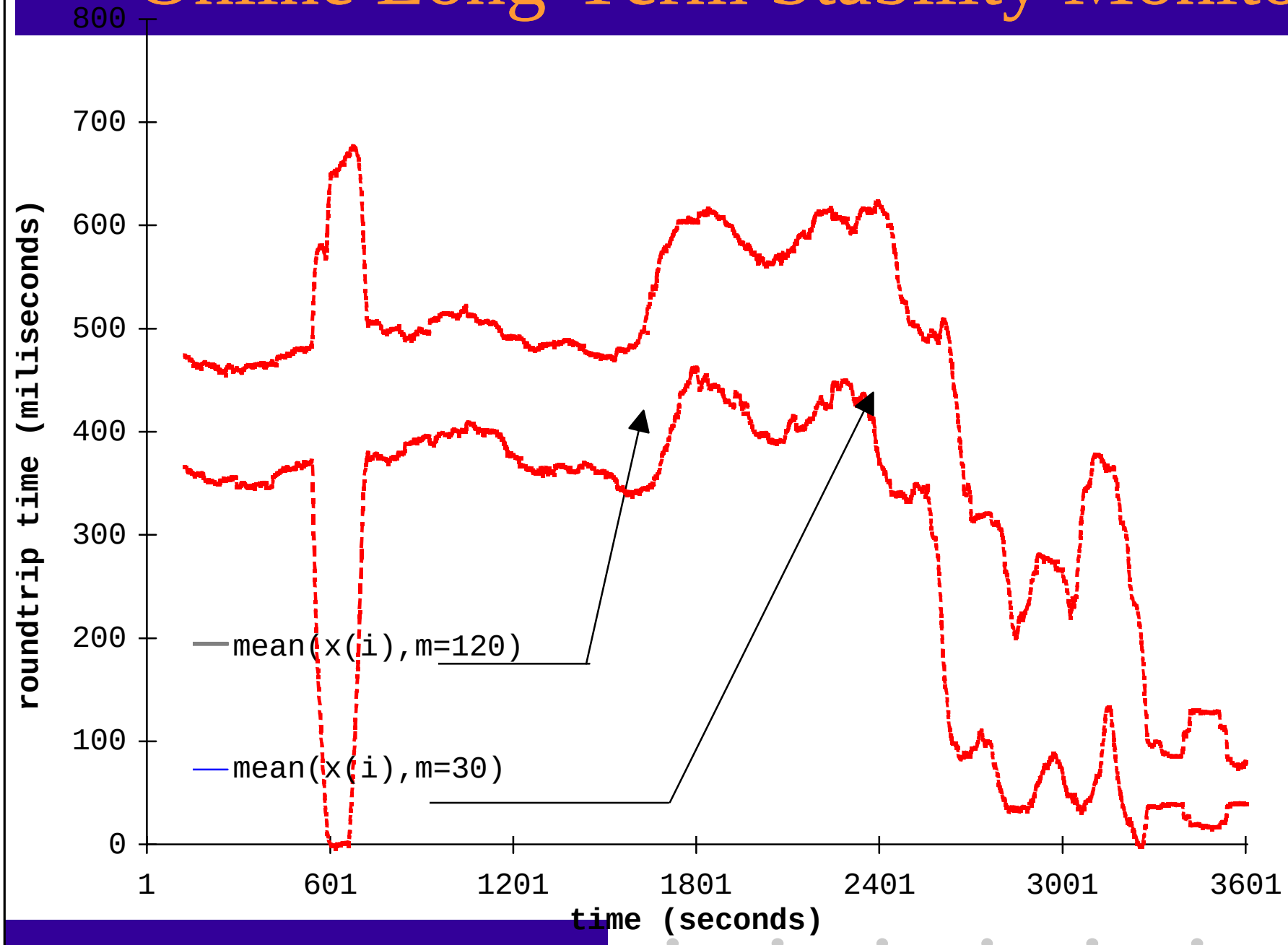

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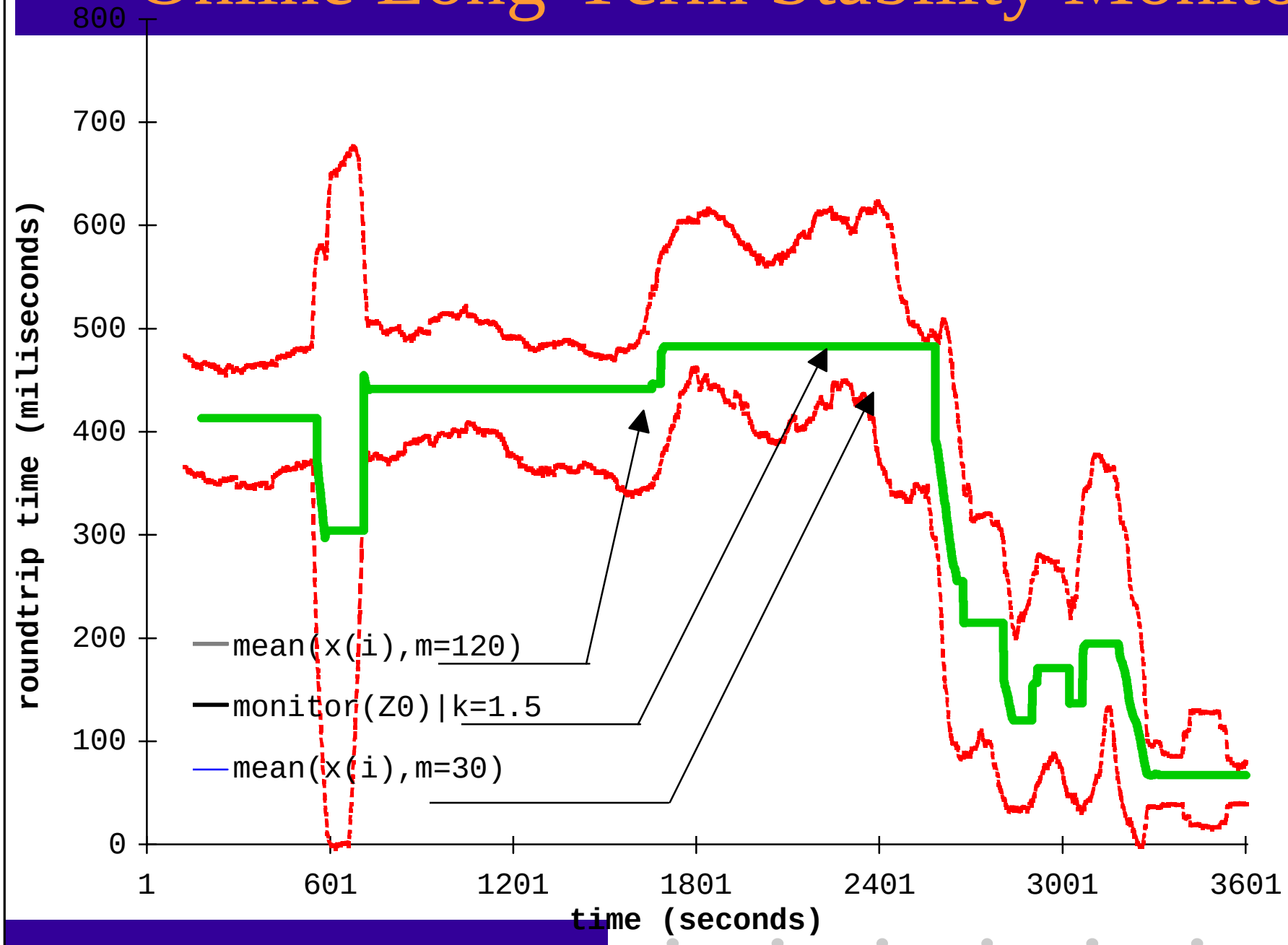
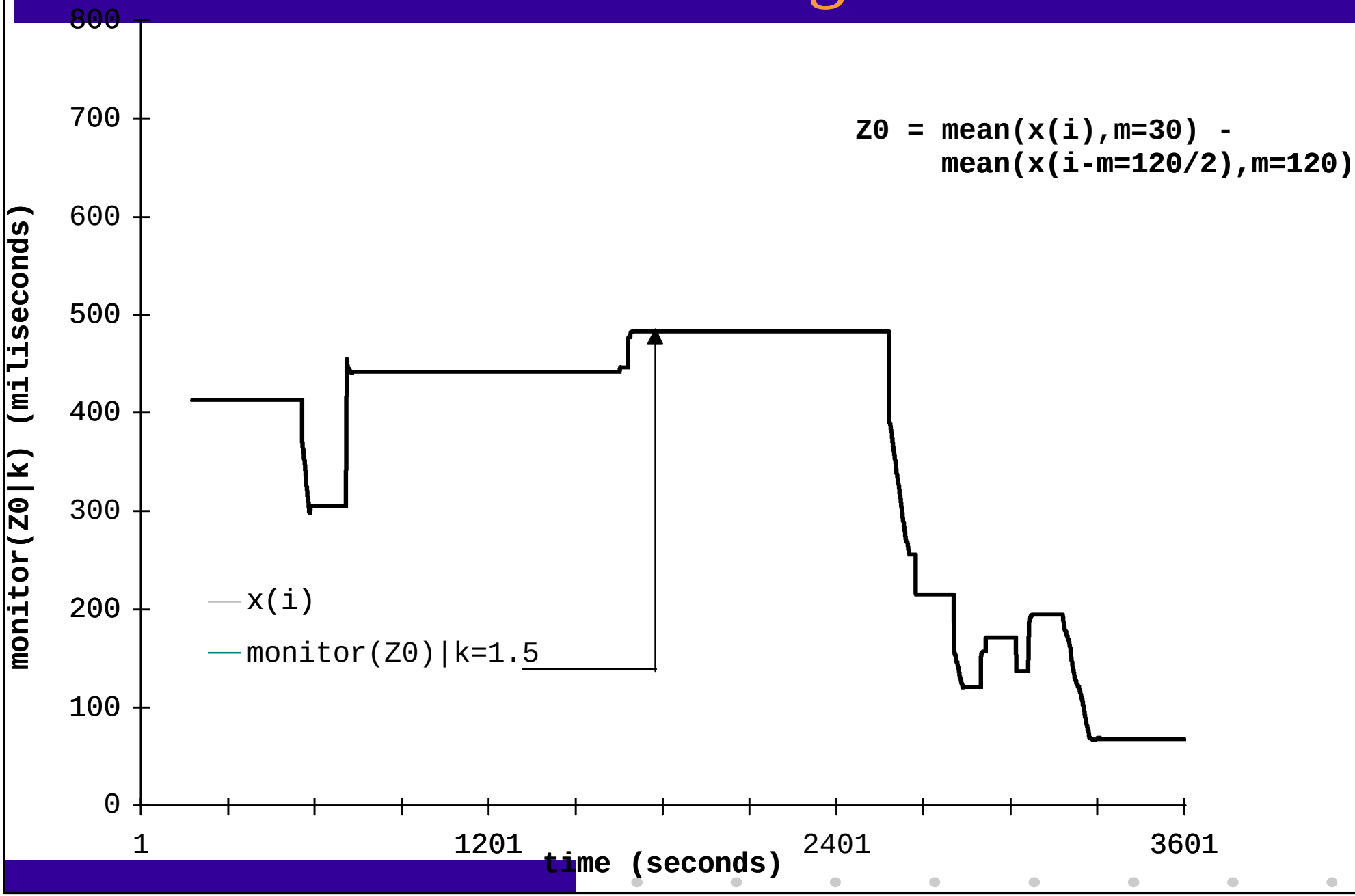


Performance of the Long-Term Monitor



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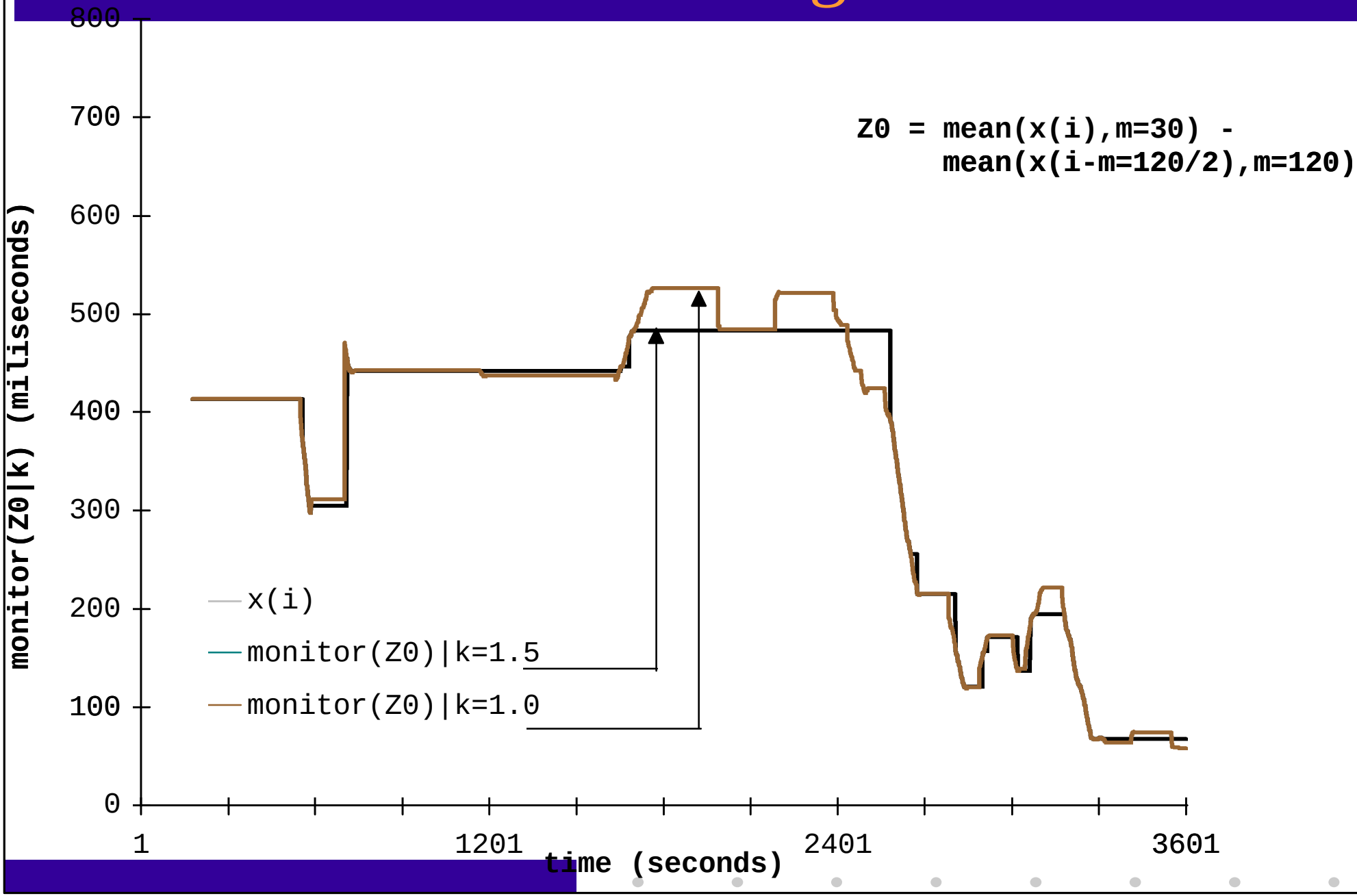

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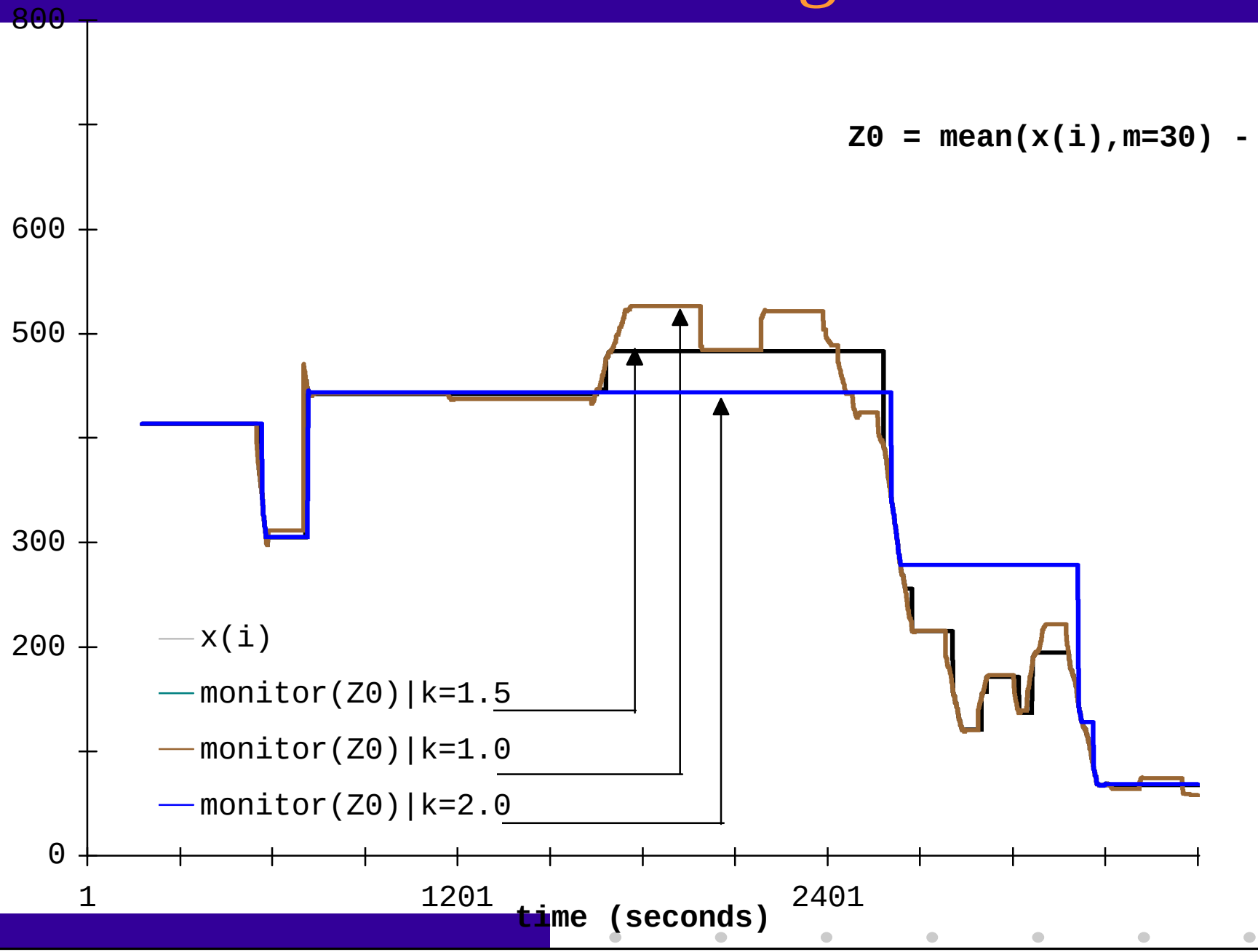

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  - Adaptive Media Synchronization
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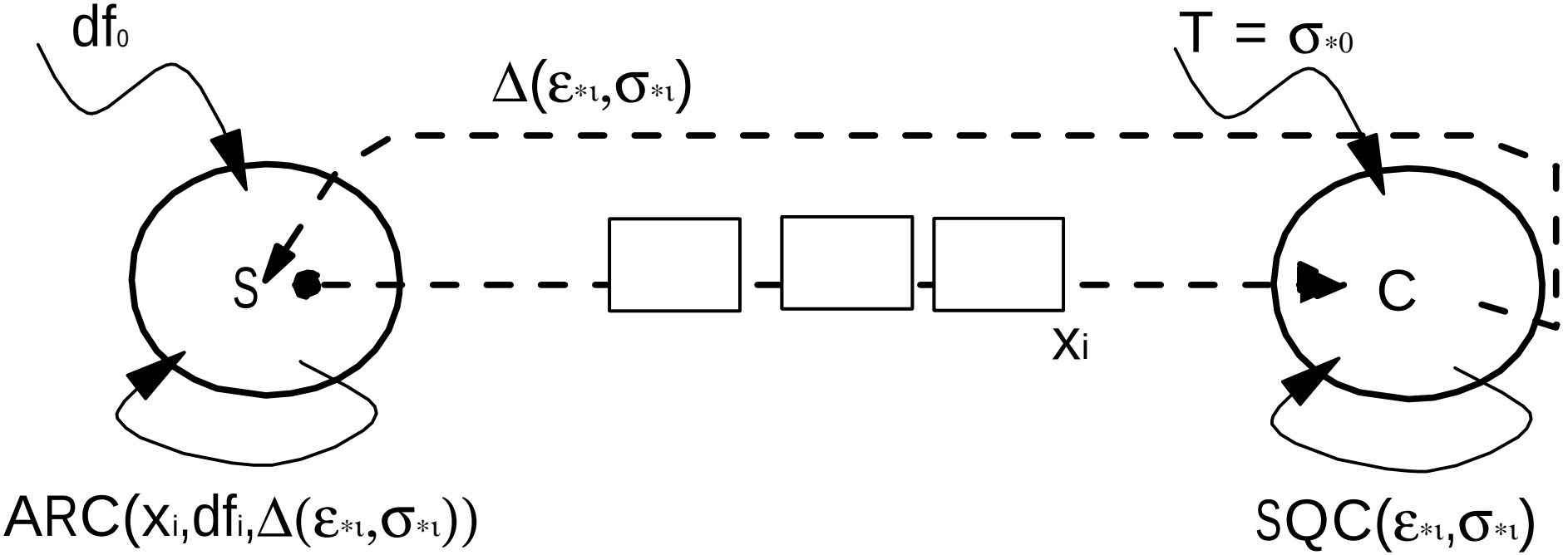
Long-Term Media Adaptation



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  - ARC(media, degree of freedom, feedback)
- **statistical quality control**
  - SQC(process indicator, process variability)

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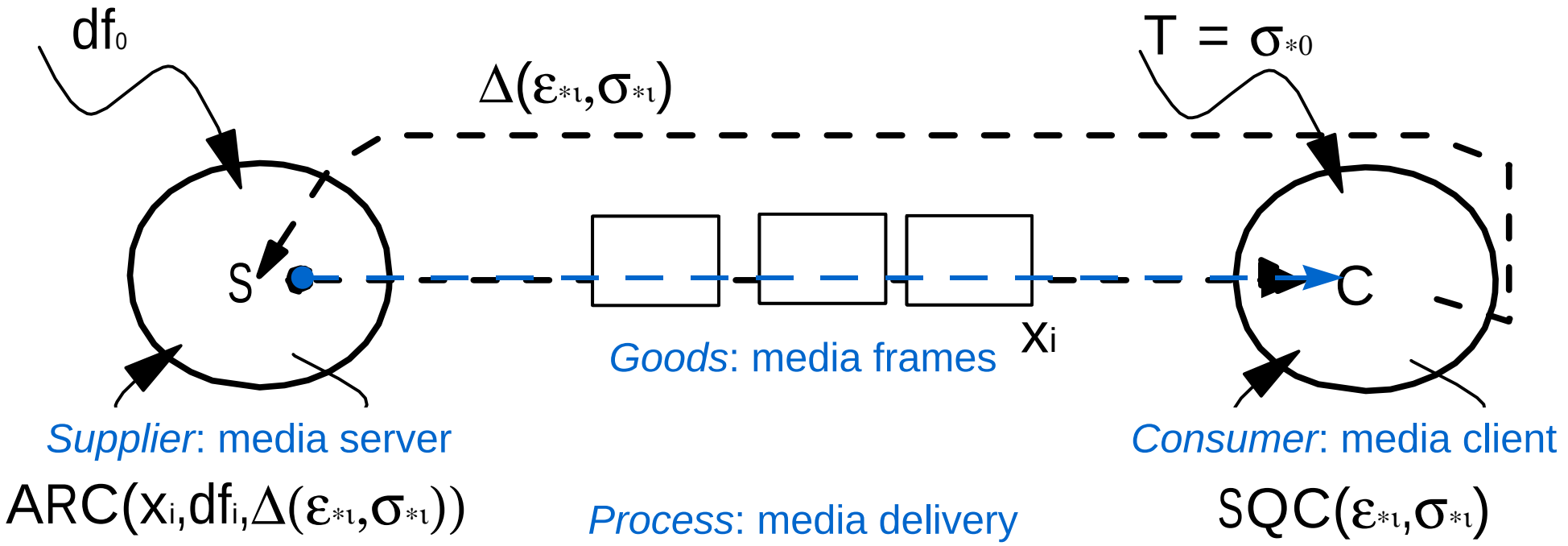

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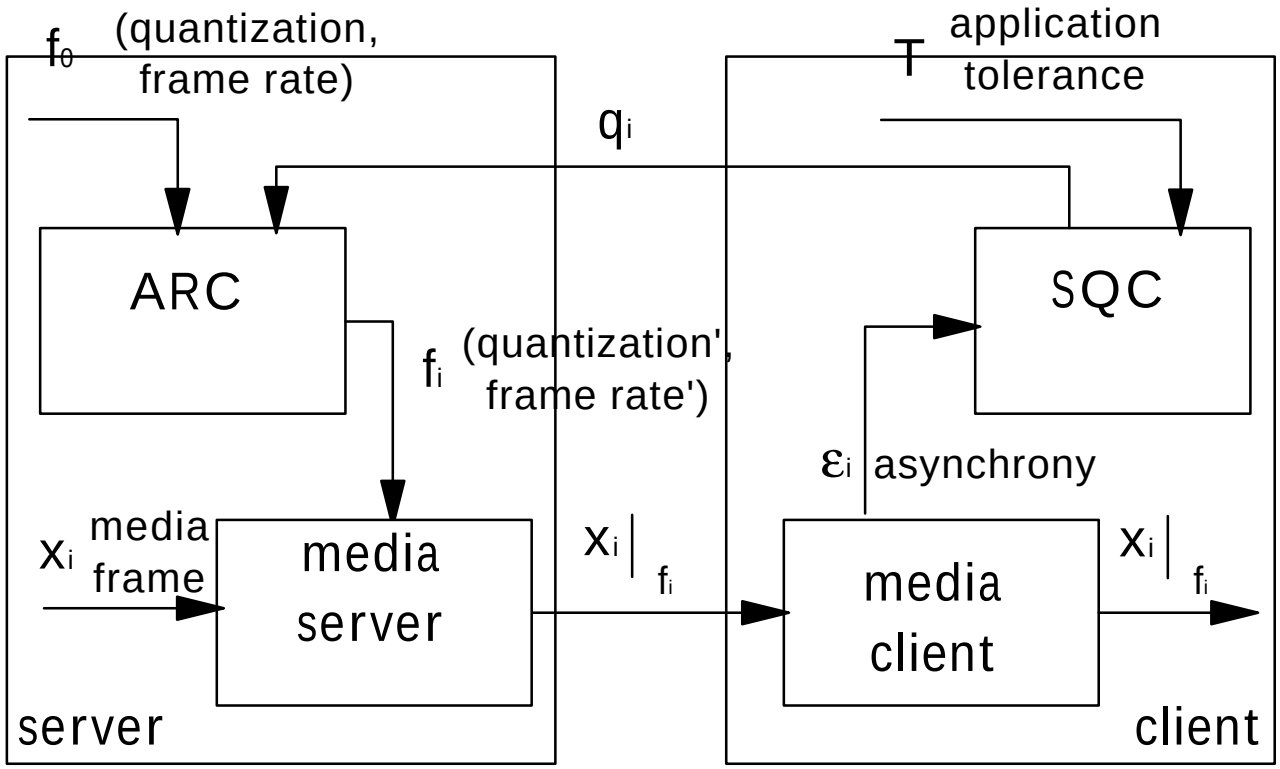
End-to-End Adaptive Media Coding

- **application-oriented**
- **media-independent feedback**
- **reactive to long-term (persistent) trends**



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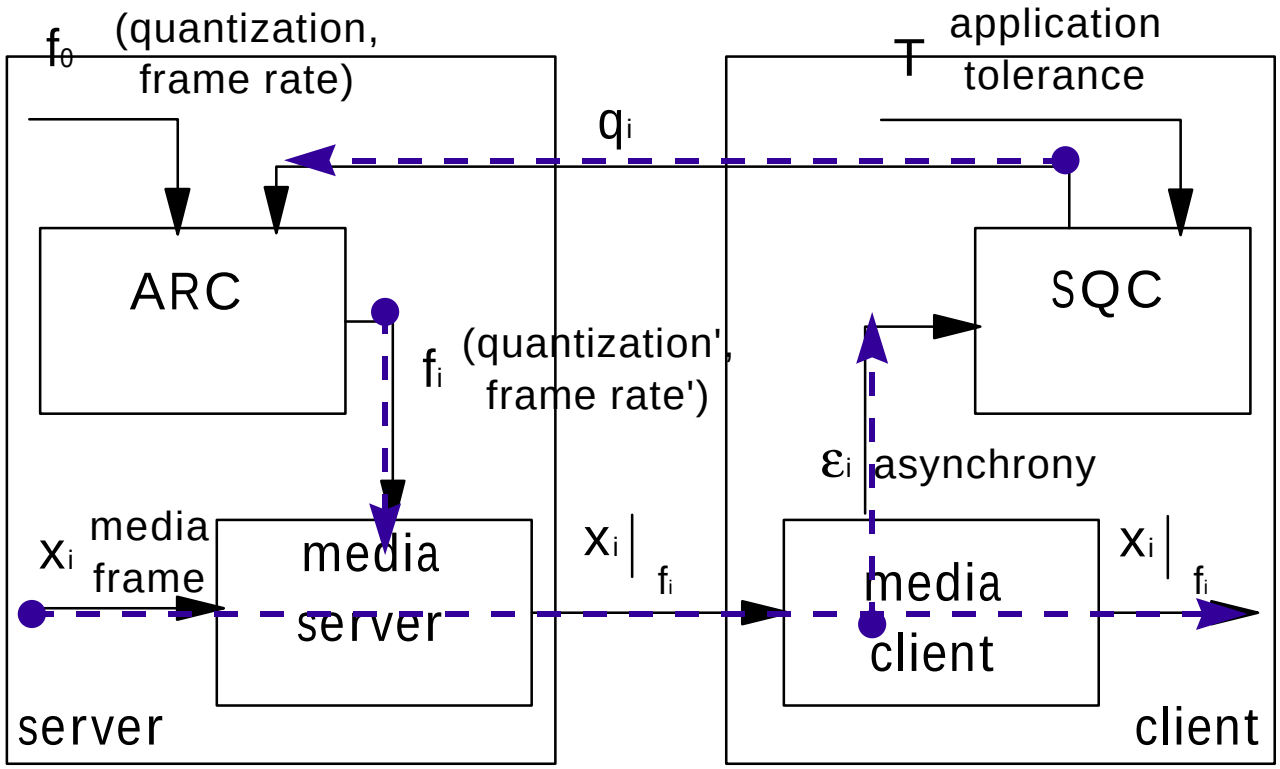
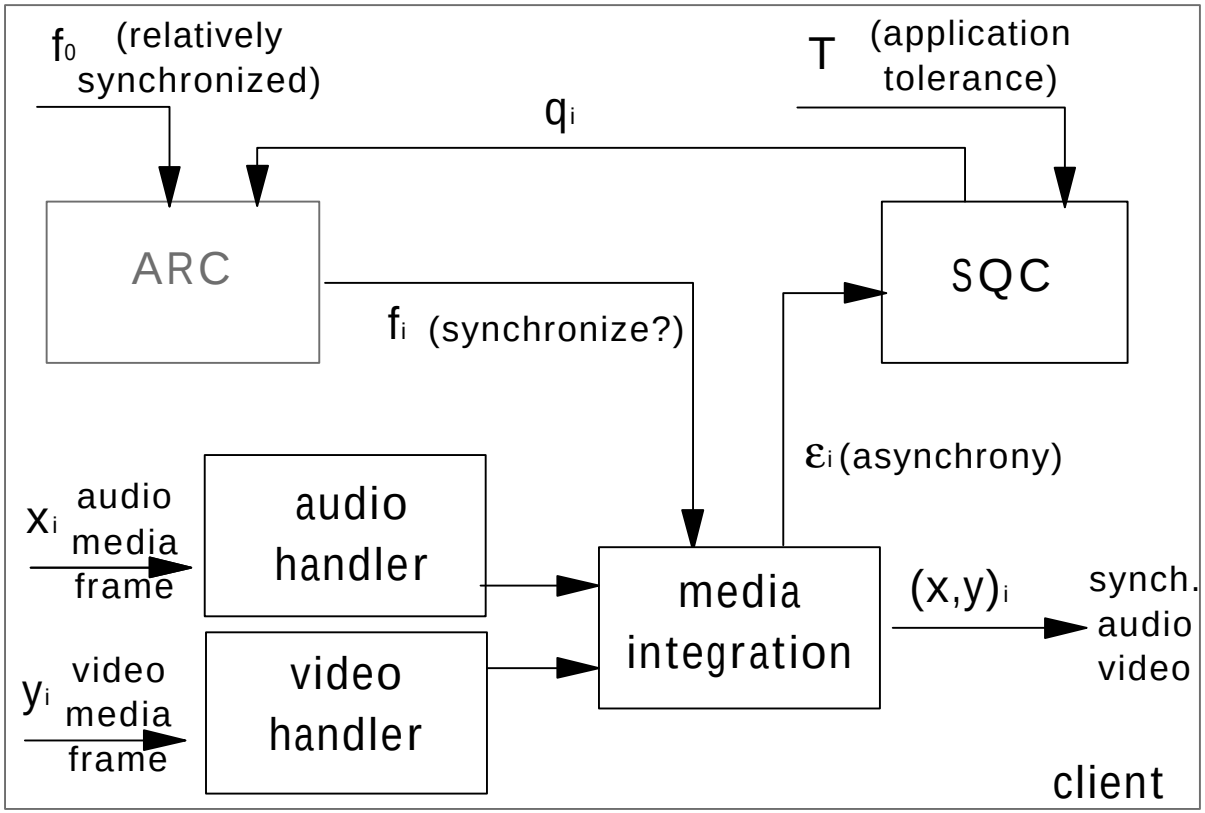


Adaptive Media Synchronization



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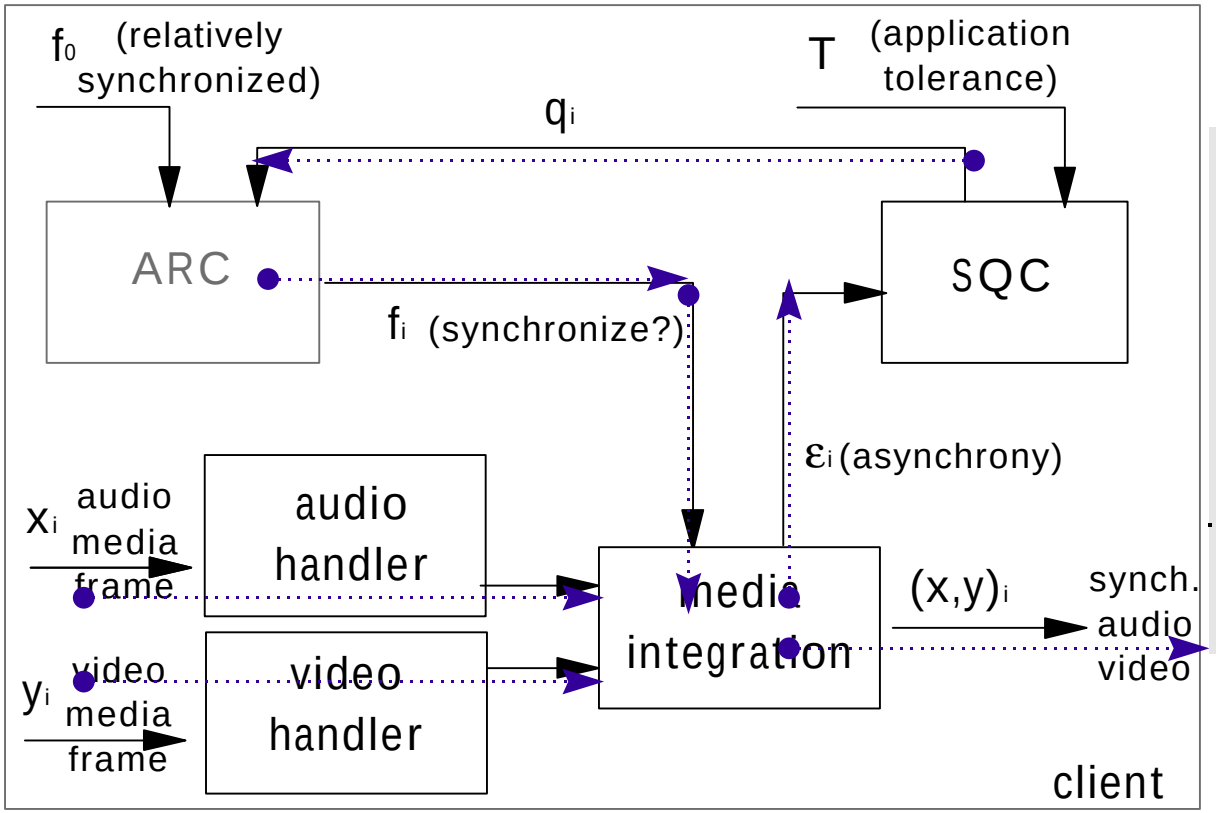
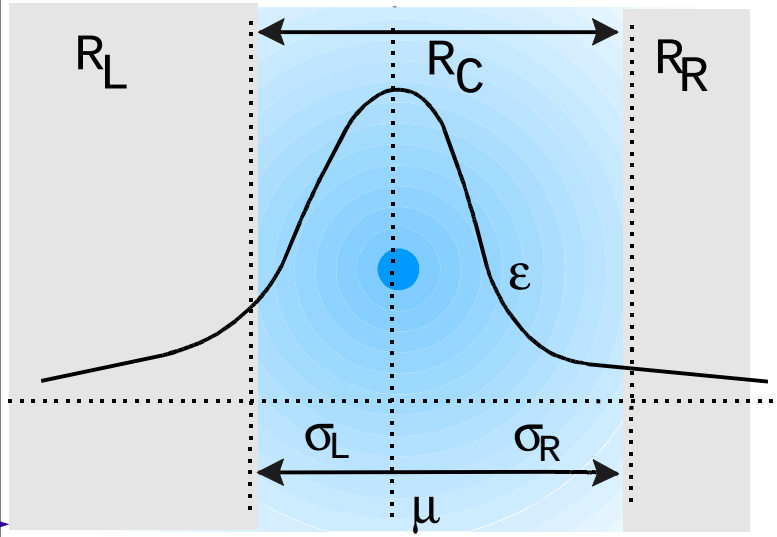




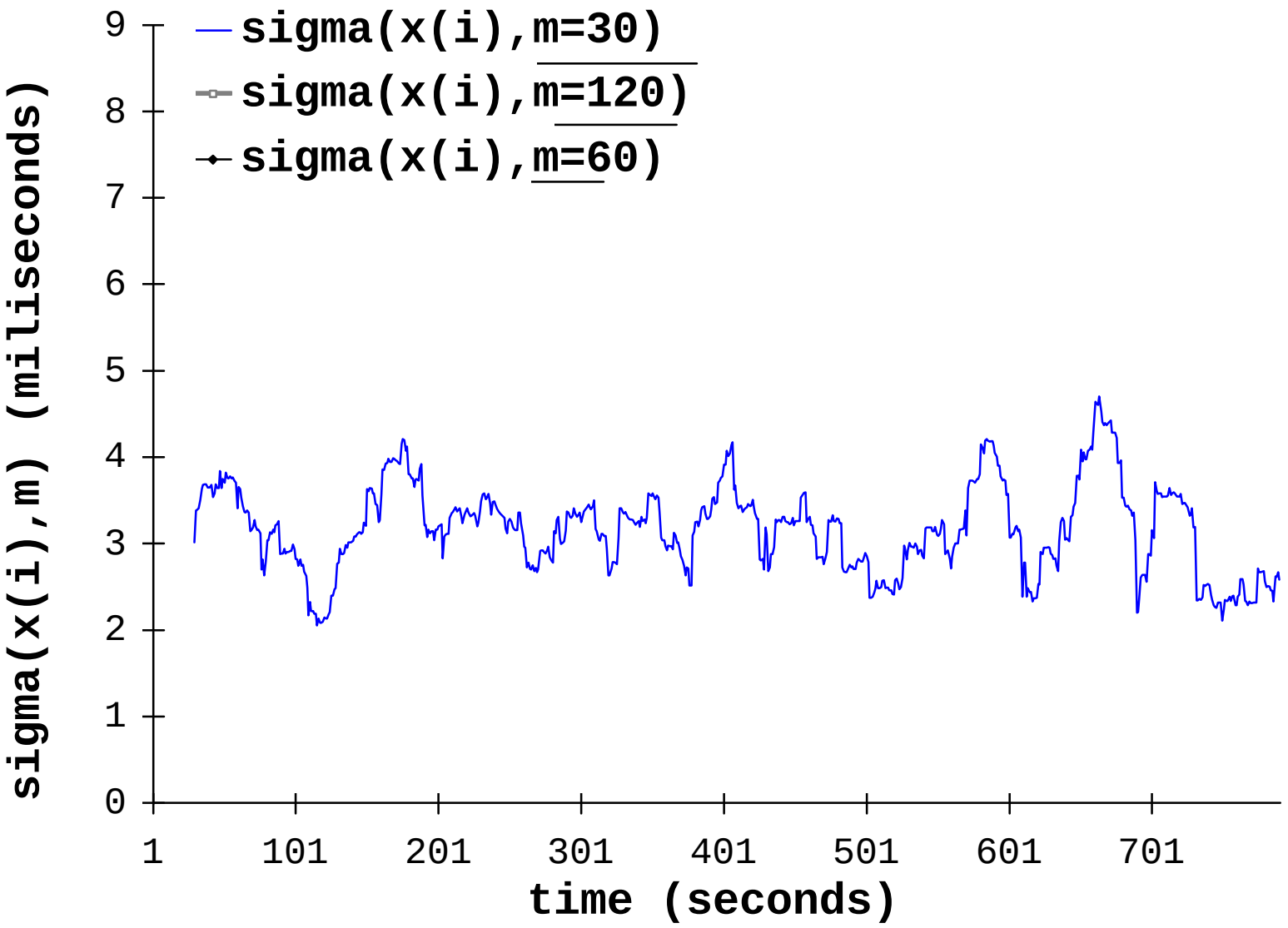
- **way for specifying long-term performance of its media integration in terms of tradeoffs between:**
  - the playback continuity of audio and
  - the asynchrony tolerance between audio & video.

Concluding Remarks

- Introduced application and relevance of online SPC for multimedia networking
- Proposed a framework for the streaming of heterogeneous media with application-oriented requirements
- Showed the detection and forecast of long-term stationary conditions on network performance indicators

End of Presentation

Long-Term Process Performance



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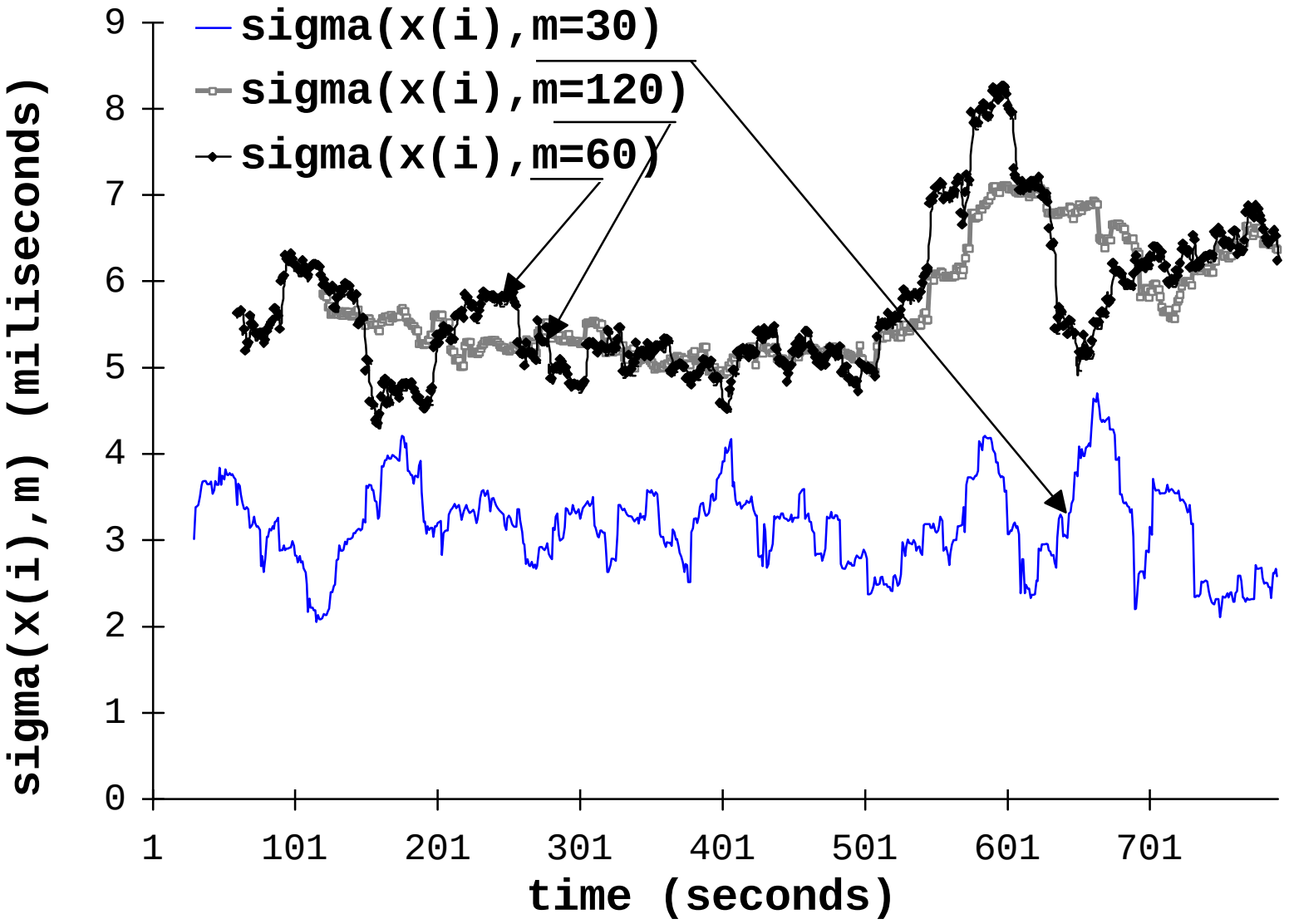

Assumptions

- **distribution of samples**
  - UWMA smoothed over large horizon
  - central limit theorem … “roughly” normal
- **autocorrelation between smoothers**
  - sampling frequency between measurements
  - time scale of smoothers (approx. random sampling)
  - relative weight horizons of smoothers (m and m’)
- **stationarity**
  - hypothesis testing discards random fluctuations
  - variance prediction confidence over forecast