On the Use of Balking for Estimation of the Blocking Probability for OBS Routers with FDL Lines

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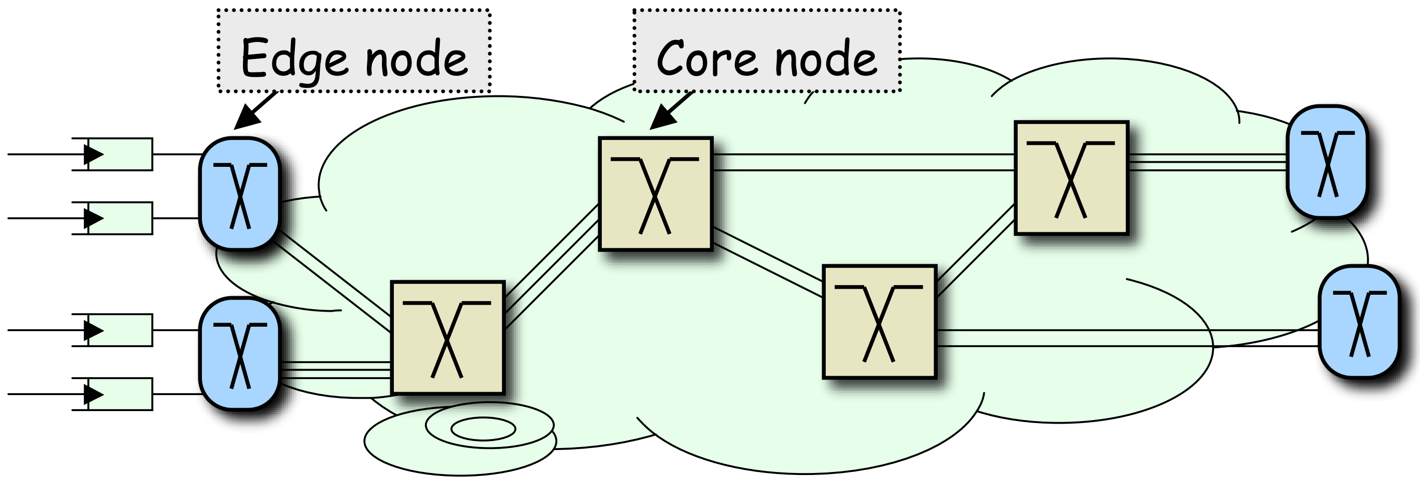
What is this paper about?

- Blocking probability in OBS switches with FDLs …
- Analytical models for calculating the blocking probability and dimensioning the switch …
- **The problems** in analytical models for computing loss probability in OBS switches with FDLs

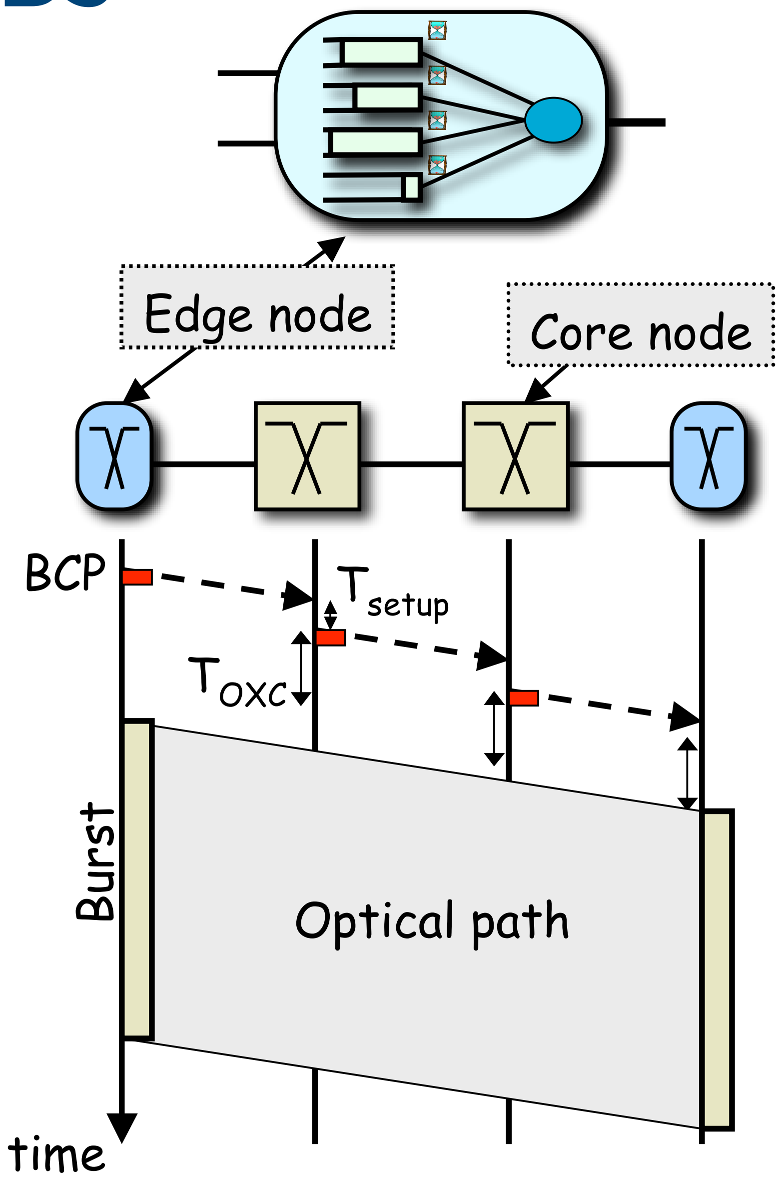


Contents

- Short & Fast introduction to OBS
- The problem and the scenario
- Models for the blocking probability
- Balking model: Analysis
- Conclusions

Introduction to OBS

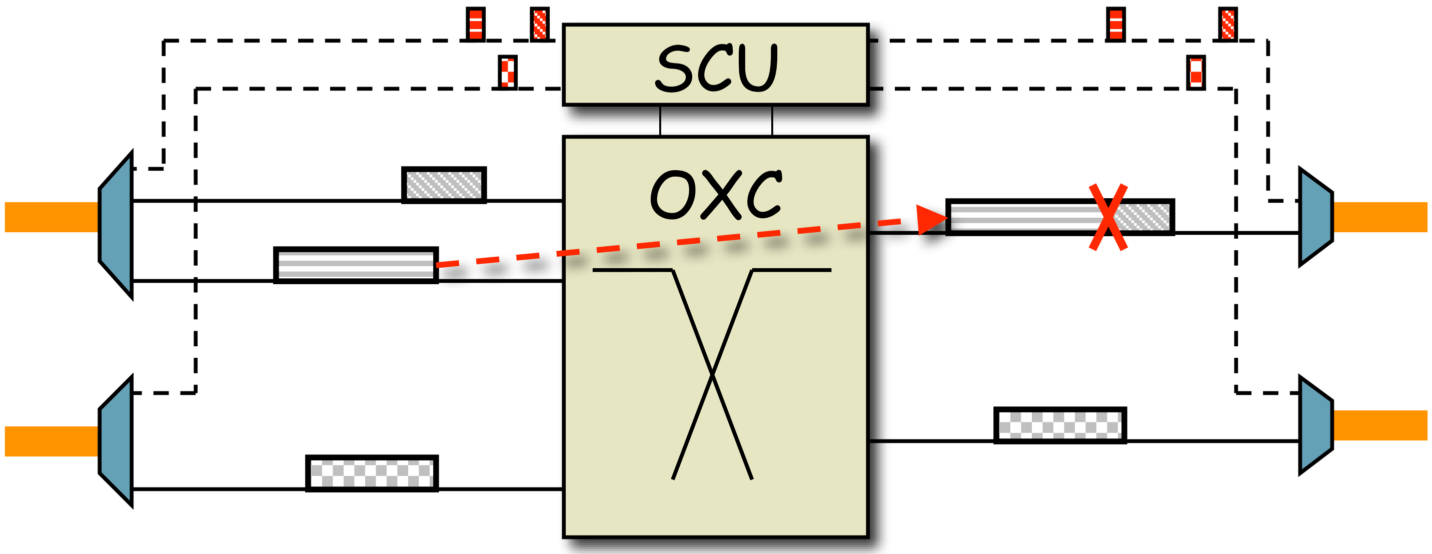
- Halfway between OCS and OPS
- Payload entirely in the optical domain (no O/E/O conversion)
- Aggregation in the edge nodes creates bursts
- Switched path established with the information in the BCPs
- BCPs (Burst Control Packets) are sent before the payload
- BCPs are transmitted through a separated channel
- BCPs suffer O/E/O conversion



Introduction to OBS

Problem

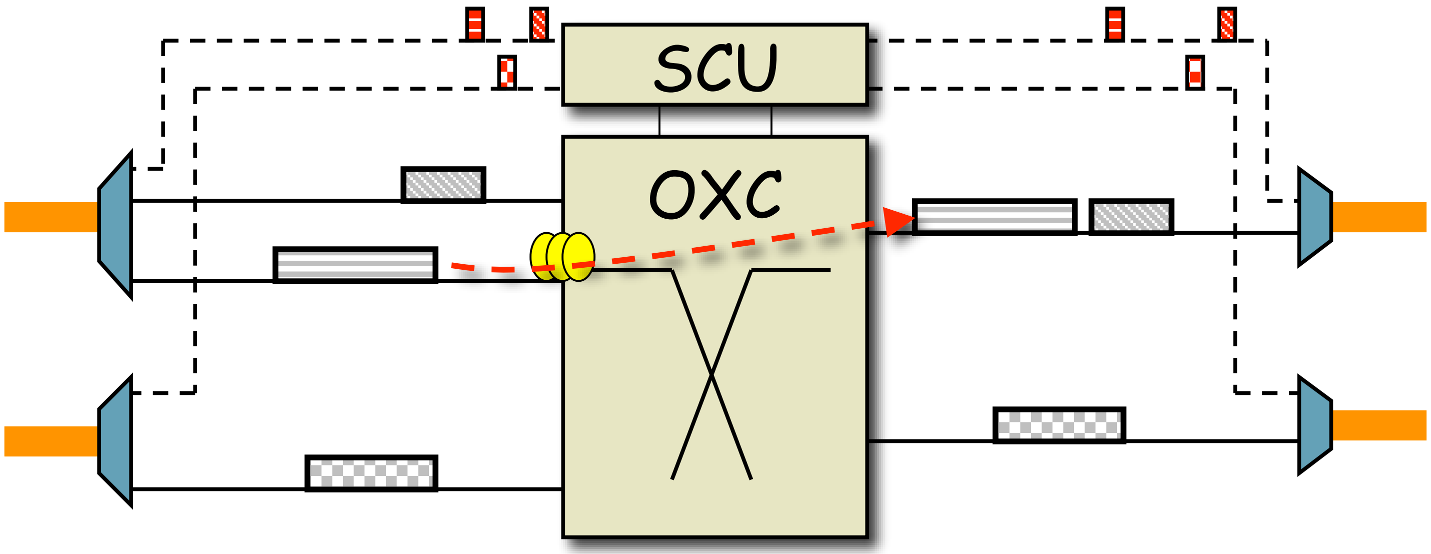
- Output port contention
- High loss probability
- Optical memory is not available
- One solution: Fiber Delay Lines (FDLs)
- FDLs provide a delay equal to the propagation time (…)



Introduction to OBS

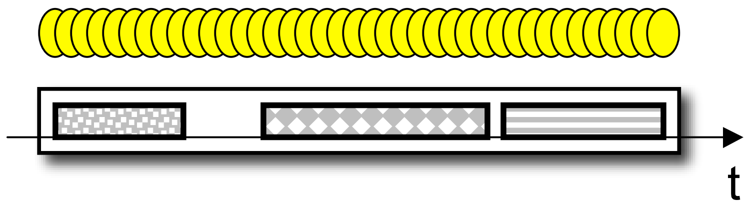
Problem

- Output port contention
- High loss probability
- Optical memory is not available
- One solution: Fiber Delay Lines (FDLs)
- FDLs provide a delay equal to the propagation time (…)
- How long should be the fiber?

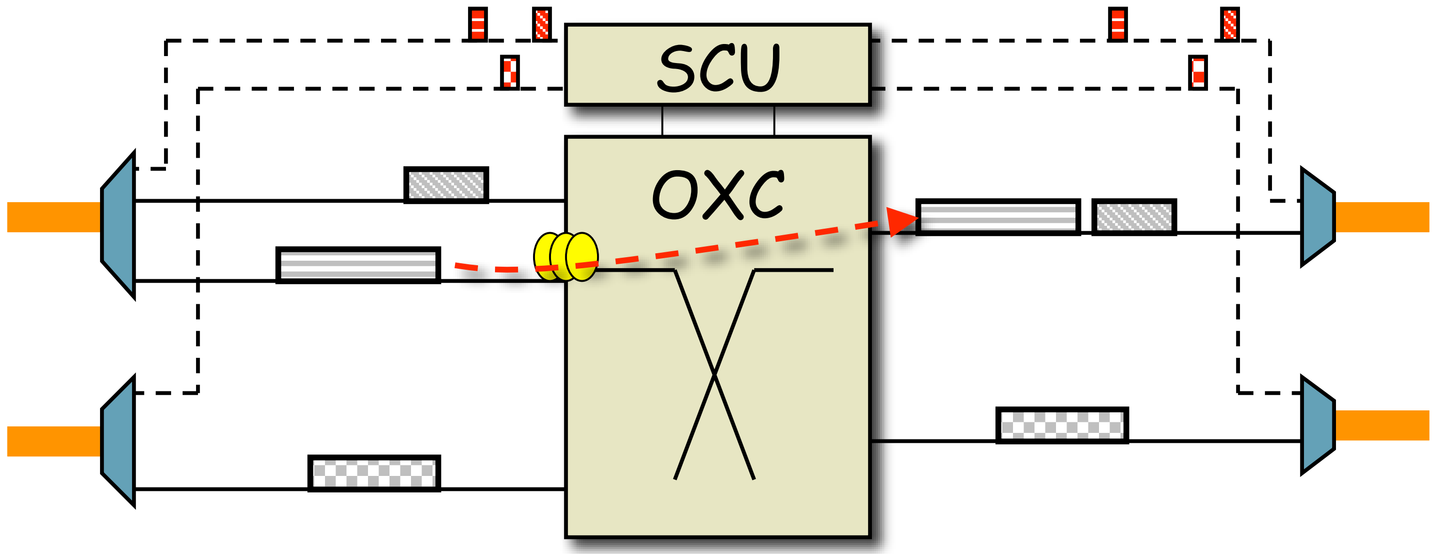


The problem

- How long should be the fiber?
- Maximum delay (Length) needed for a target loss probability ?
- Traditional models?

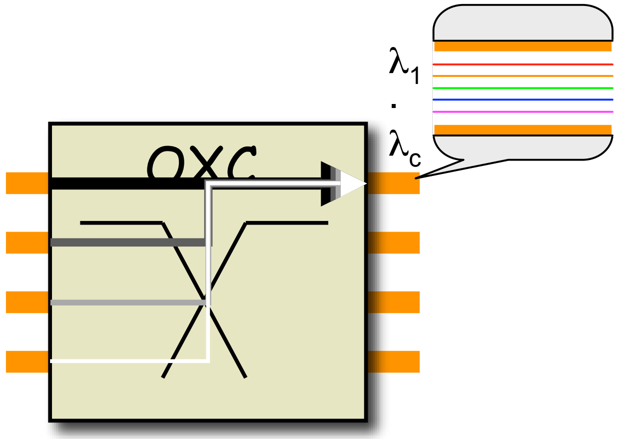


- FDLs are not memory
  - The burst cannot stay for longer than the fiber delay
  - Fiber is available when the burst is completely transmitted
  - Time the FDL is occupied ≠ Time the burst is inside the FDL
  - Time the FDL is occupied depends on the burst size



Scenario

- OBS Switch with variable-delay FDLs (D_{max})
- Input traffic:
  - FGN ⇒ Poisson arrivals (λ) + gaussian burst sizes [IzalGCOM02]
  - Use exponential sizes (μ) for comparison purposes (1/ μ =15KB)
- Uniform output selection
- Single output port analysis
- "c" data wavelengths (10Gbps) per fiber
- Total wavelength conver. (→multiserver)
- Popular hypothesis [LuTrans04]

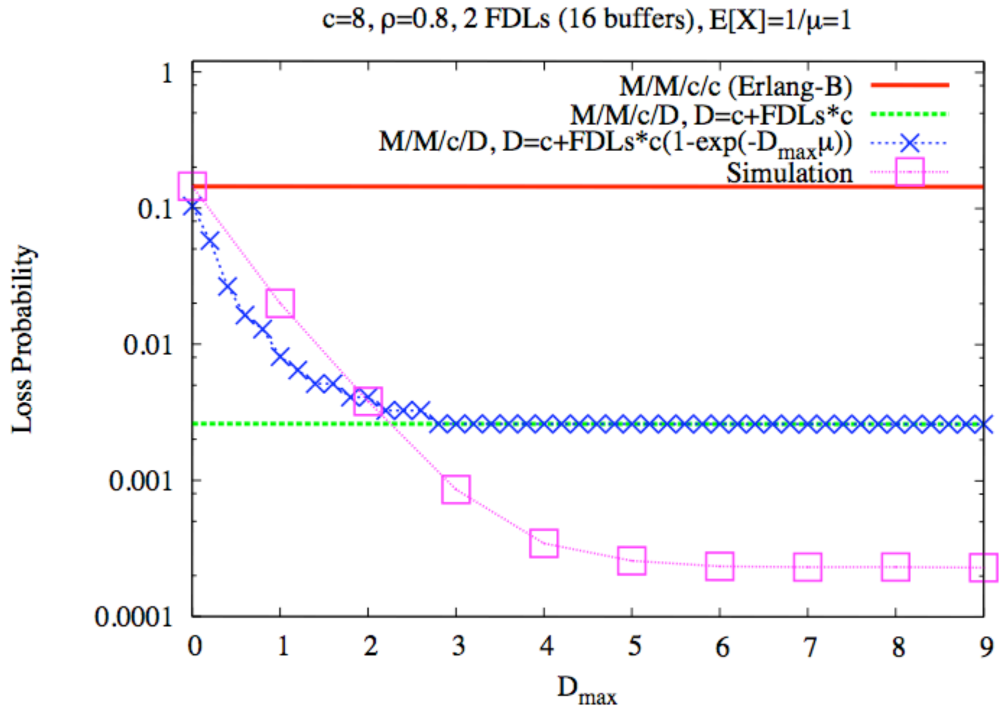


[IzalGCOM02] M.Izal, J.Aracil. *"On the influence of self similarity on Optical Burst Switching traffic"*. Proceedings of Globecom 2002

[LuTrans04] X.Lu, B.Mark. *"Performance Modeling of Optical Burst Switching with Fiber Delay Lines"*. IEEE Transactions on Communications, Dec 2004

Simple queueing models

- M/M/c/c, Erlang-B
  - No buffering
  - Upper bound
- M/M/c/D [YooJSAC00]
  - D=c+FDLs*c
  - Virtual buffers
  - No bound
- M/M/c/D [FanICC02]
  - $D=c+FDLs*c*(1-e^{(-D_{max}\mu)})$
  - Tries to include the time the burst occupies the FDL input
  - Better approximation
  - No bound

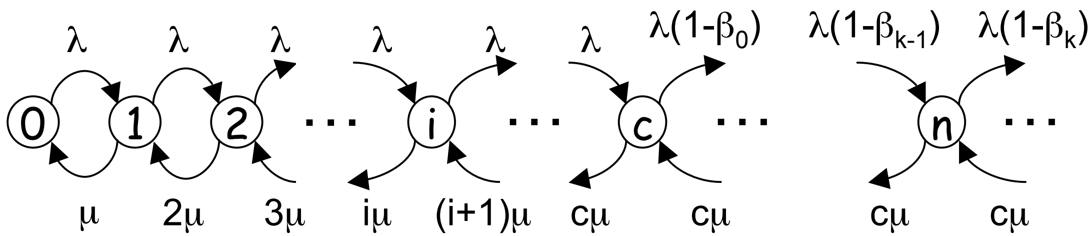


[YooJSAC00] M.Yoo, C.Qiao, S.Dixit. *"QoS Performance of Optical Burst Switching in IP-Over-WDM Networks"*, IEEE Journal on Selected Areas in Communications, Oct 2000

[FanICC02] P.Fan, C.Feng, Y.Wang, N.Ge. *"Investigation of the time-offset-based QoS support with Optical Burst Switching networks"*. Proceedings of ICC 2002

Queue with balking

- Continuous-time Markov chain
- State: Number of users in the system
- Balking:
  - Form of impatience
  - User decides whether to join the queue or not
  - Expressed by a decreasing series $\{\beta_k\}$ that mutiplies the arrival rate to each state
- β_k: Probability that an arrival is lost when the system has every channel occupied and k bursts waiting in FDLs



¿β_k?

Queue with balking

- β_k: *Probability that an arrival is lost when the system has every channel occupied and k bursts waiting in FDLs (discouraged arrival probability)*
- Arrival is lost
  - If there are no more virtual buffers available (assume large number)
  - Or if delay before an output wavelength gets free is longer than the maximum delay offered by the FDLs
- Time until a wavelength gets free: $T_n = \hat{R} + \sum_{i=1}^{n-c} \hat{U}$

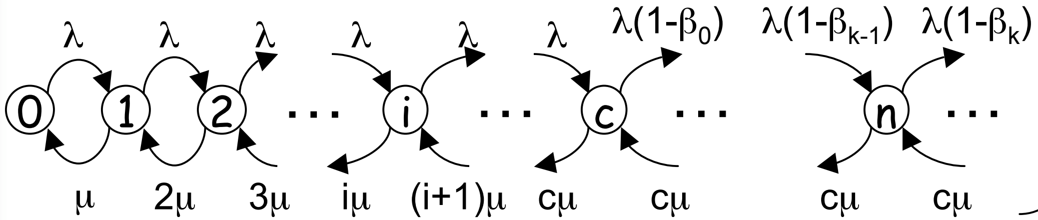
$\hat{R}$: Time until first burst departs

$\hat{U}$: Time between departures

$$P(T_n > x) = P\left(\sum_{i=0}^{n-c} \hat{R} > x\right) = e^{-c\mu x} \sum_{h=0}^{n-c} \frac{(c\mu x)^h}{h!}$$

Erlang Distribution

$$\beta_k = P(T_n > D_{\max}) = e^{-c\mu L} \sum_{h=0}^{k} \frac{(c\mu D_{\max})^h}{h!}, \quad k = n - c$$



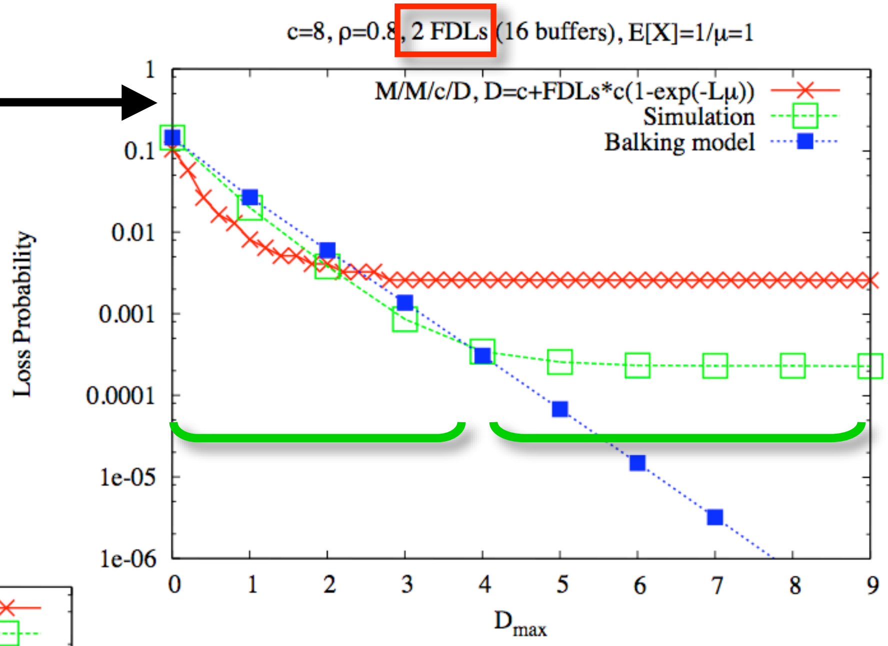
$$P(loss) = \sum_{k=0}^{\infty} \pi_{k+c} \beta_k$$

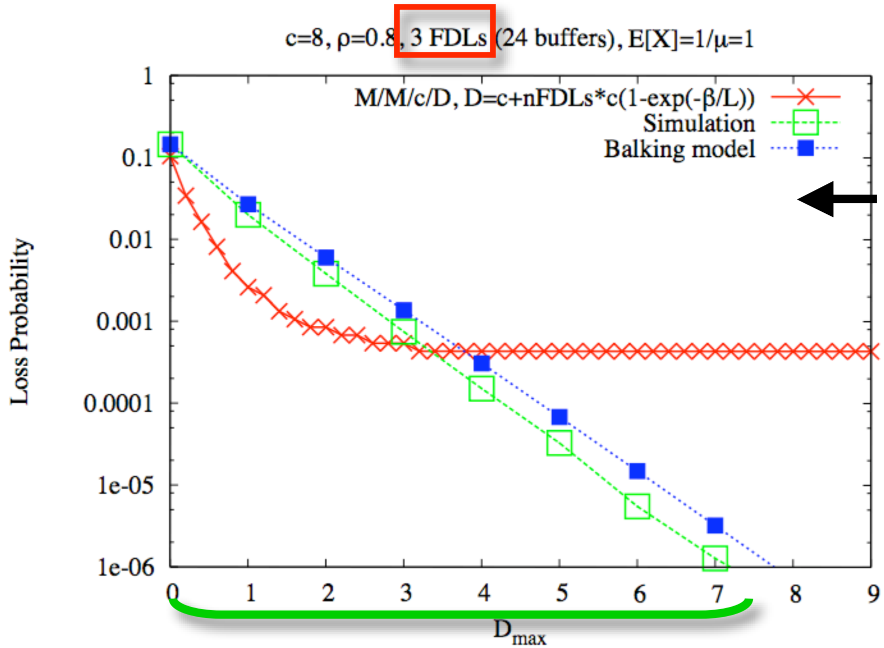
[LuTrans04]

Known results for this model

¿Results for c=8 wavelengths?

- More accurate than the simpler models
- Close in the range with exponential decay (…)
- For large FDLs it underestimates (…)
- It does not consider the limited number of buffers





Increasing the number of FDLs:

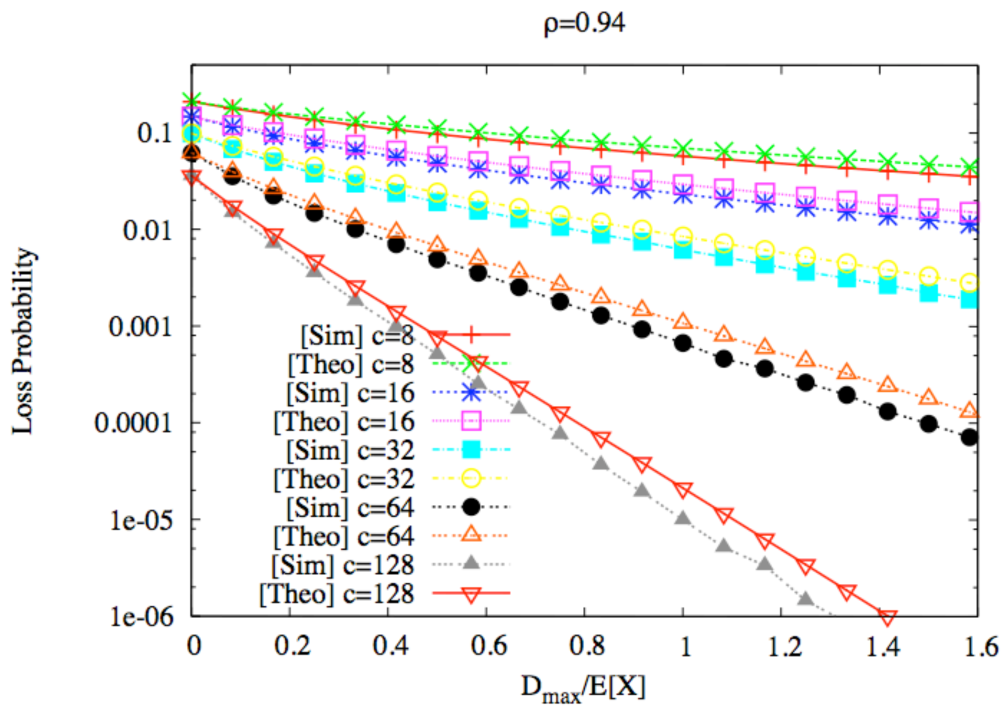
- Increases the range where the balking model provides a close upper bound (…)

Motivation

- In the literature, results only for 1-10 wavelengths
- However, nowadays: 8 wavelengths (CWDM) to 128 wavelengths (DWDM)
- Our question: Is the model still accurate enough?

Blocking results (fixed *c*)

- Different number of wavelengths per fiber
- X-axis: normalized maximum delay ($D_{max}/E[X]$)
- For $D_{max}=0$: Erlang-B
- As $D_{max}/E[X]$ increases so does the discrepancy between model and simulation (… …)



Blocking results (fixed c)

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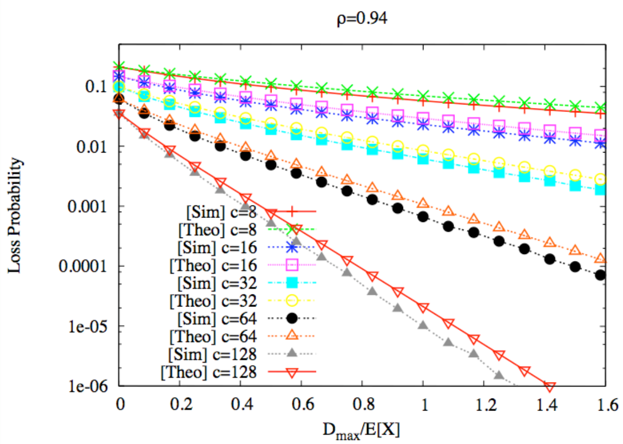
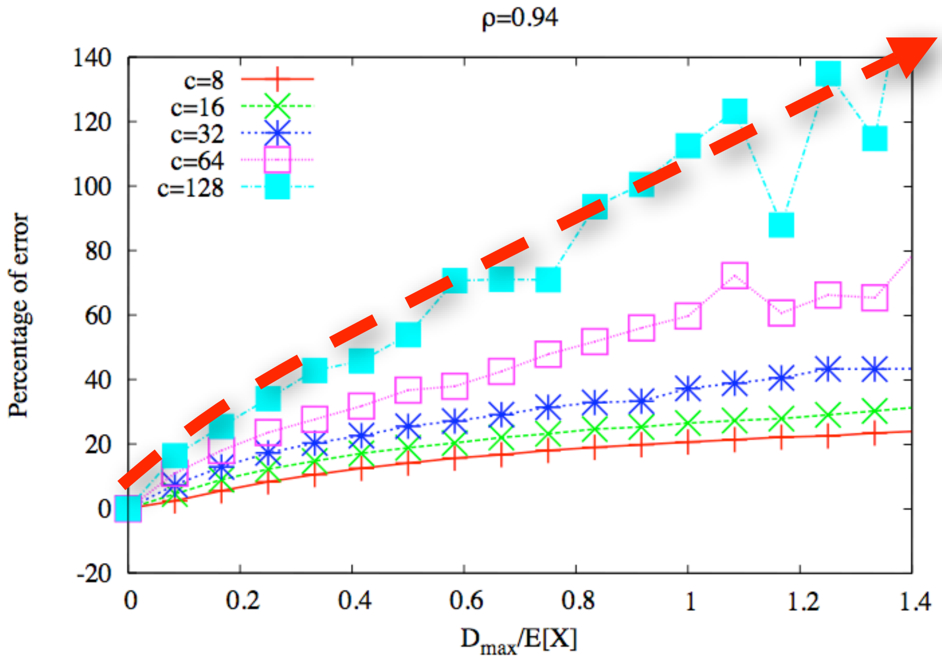
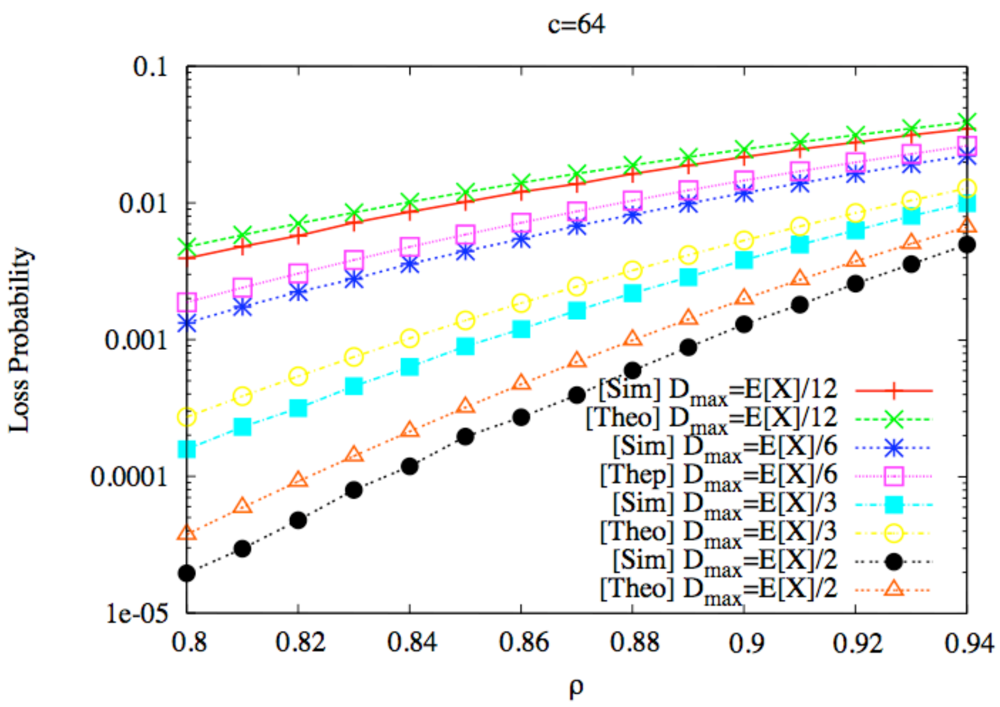
- X-axis: normalized maximum delay ($D_{max}/E[X]$)
- For D_{max}=0: Erlang-B
- As $D_{max}/E[X]$ increases so does the discrepancy between model and simulation (… …)
- Percentage of error in the estimation increases with $D_{max}/E[X]$
- Worse the larger the number of wavelengths !





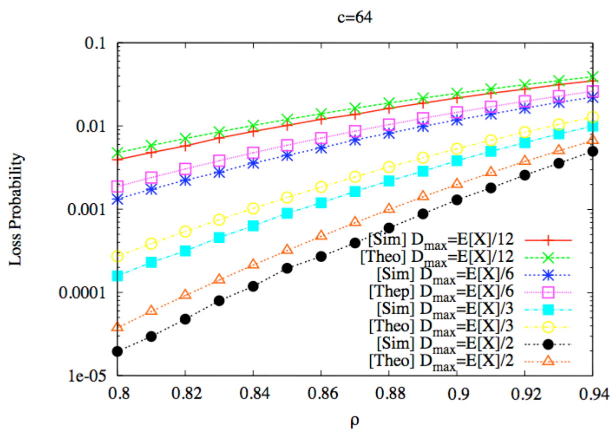
Blocking results (fixed D_{max})

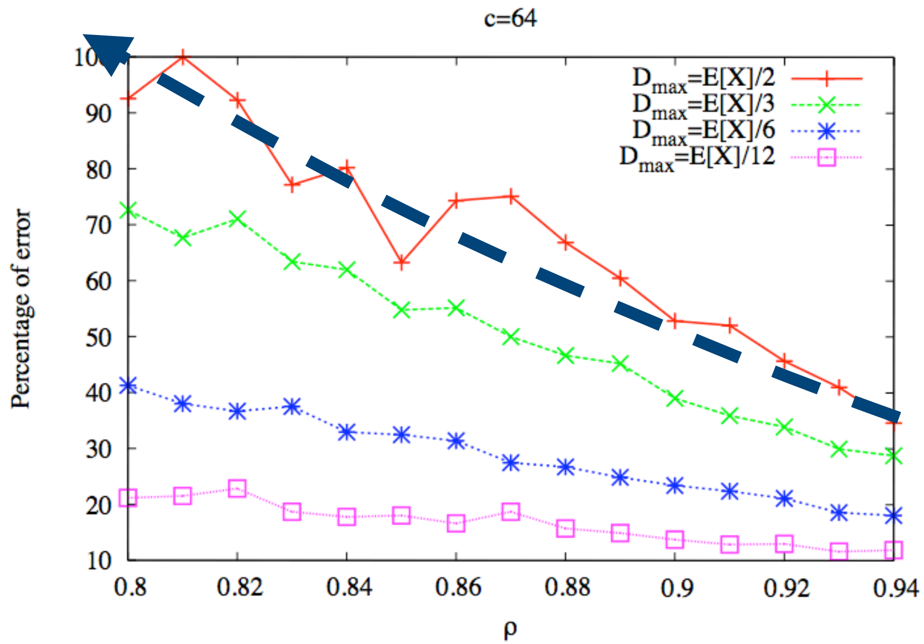
- Different values of maximum delay D_{max}
- X-axis: ρ
- As ρ decreases, the discrepancy between model and simulation increases (… …)



Blocking results (fixed D_{max})

- Different values of maximum delay D_{max}
- X-axis: ρ
- As ρ decreases, the discrepancy between model and simulation increases (… …)
- Percentage of error in the estimation increases inverse to ρ (… …)





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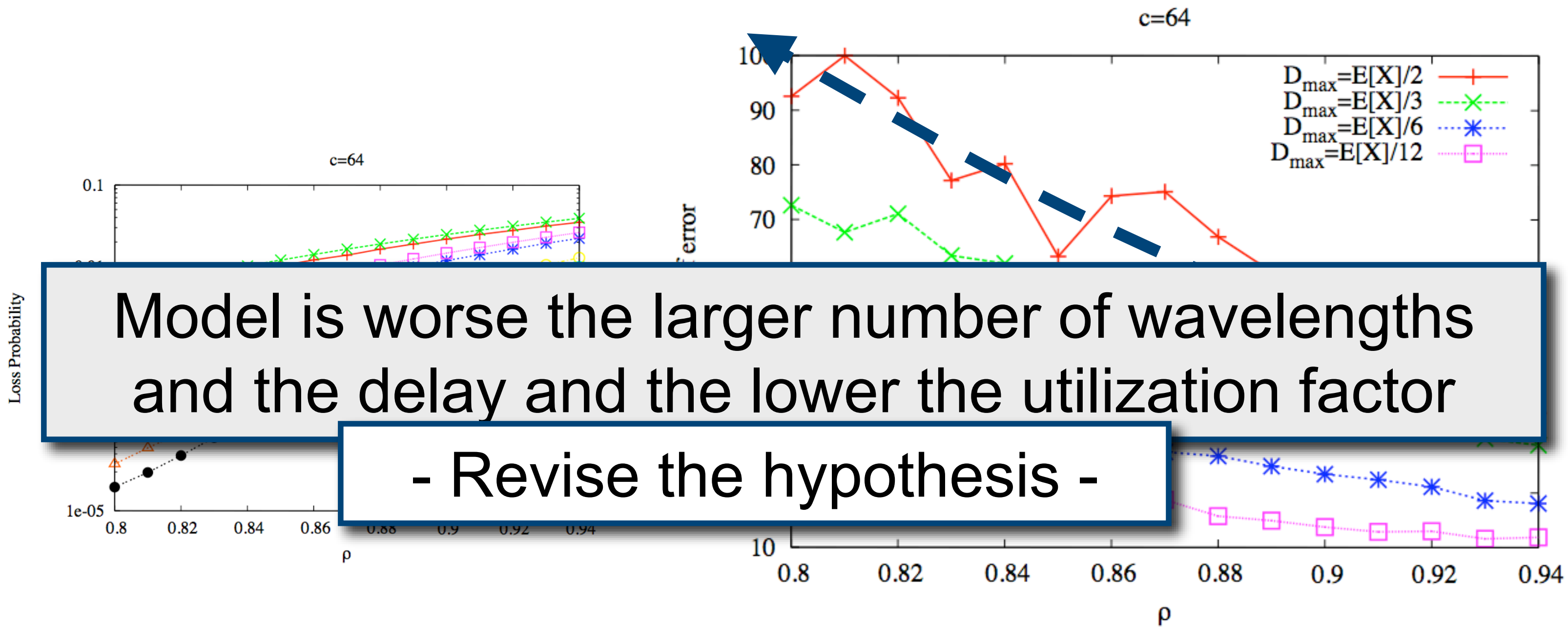

Model is worse the larger number of wavelengths and the delay and the lower the utilization factor

- Revise the hypothesis -

Queue with balking

- β_k: *Probability that an arrival is lost when the system has every channel occupied and k bursts waiting in FDLs*

System residual life T_n can be approximated by an Erlang distribution

... ge number)

... nger than the maximum delay offered by the FDLs

- Time until a wavelength gets free:

$$T_n = \hat{R} + \sum_{i=1}^{n-c} \hat{U}_i$$

$$P(T_n > x) = P\left(\sum_{i=0}^{n-c} \hat{R} > x\right) = e^{-c\mu x} \sum_{h=0}^{n-c} \frac{(c\mu x)^h}{h!}$$

Erlang Distribution

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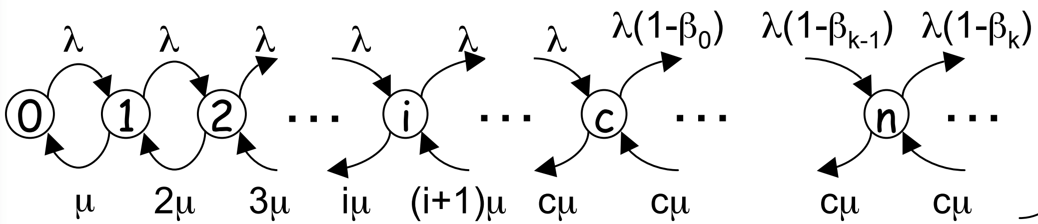
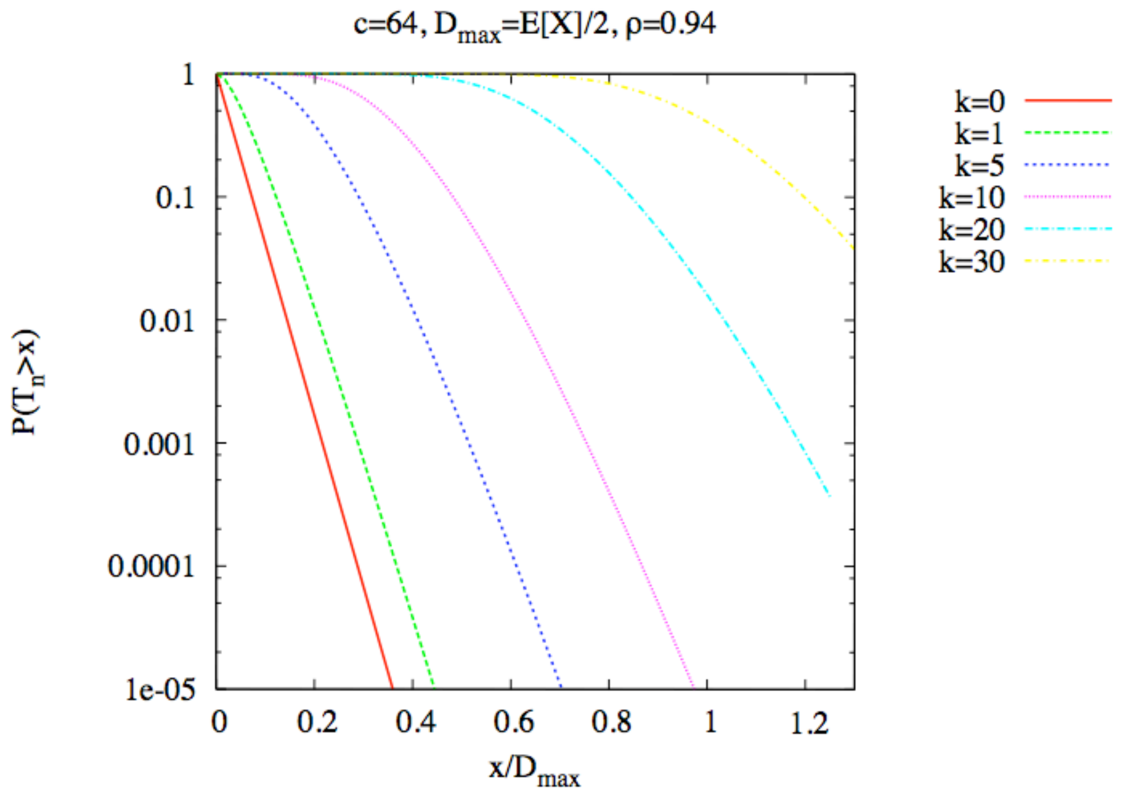


$$P(loss) = \sum_{k=0}^{\infty} \pi_{k+c} \beta_k$$

[LuTrans04]

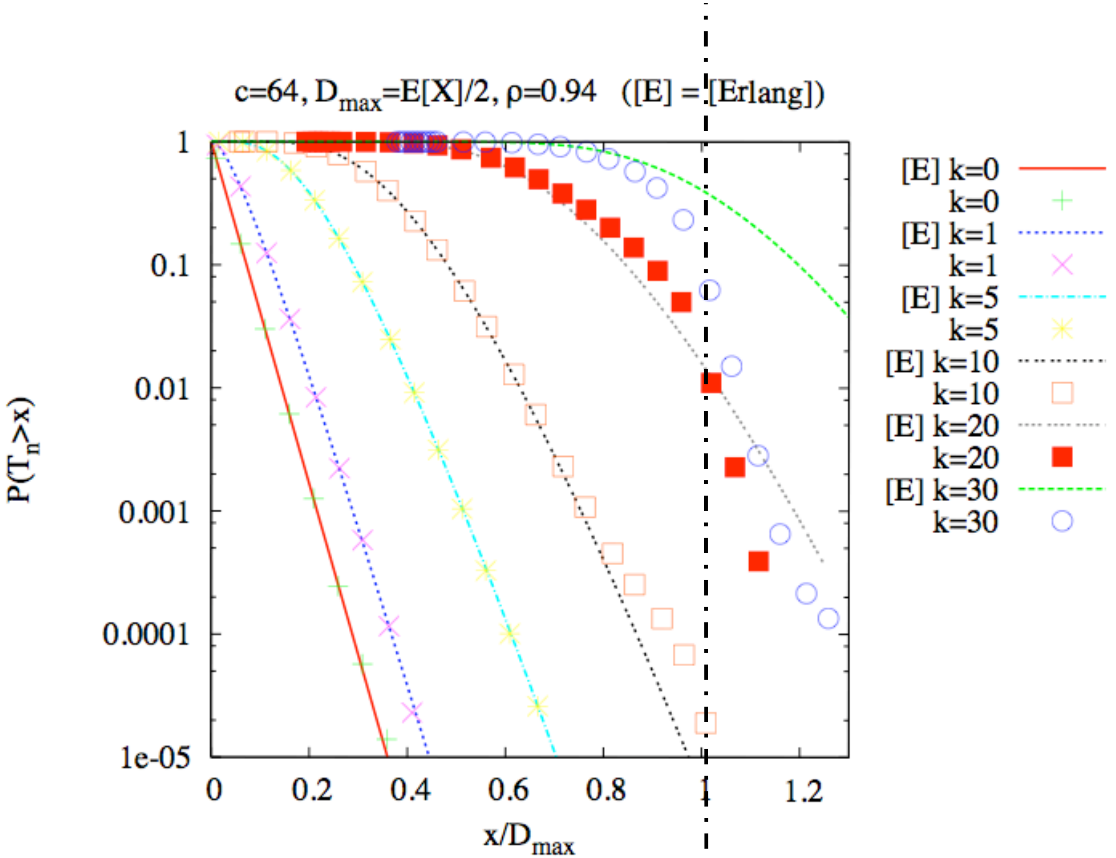
System residual life

- X-axis: Normalized residual life (…)



System residual life

- X-axis: Normalized residual life (…)
- Deviation as the system occupancy grows
- Specially when *x* gets close to D_{max} (…)



Queue with balking

- β_k: *Probability that an arrival is lost when the system has every channel occupied and k bursts waiting in FDLs*

Discouraged arrival probability computed from the Erlang distribution

… e large number)

… is longer than the maximum delay offered by the FDLs

- Time until a wavelength gets free:

$$T_n = \hat{R} + \sum_{i=1}^{n-c} \hat{U}$$

$$P(T_n > x) = P\left(\sum_{i=0}^{n-c} \hat{R} > x\right) = e^{-c\mu x} \sum_{h=0}^{n-c} \frac{(c\mu x)^h}{h!}$$

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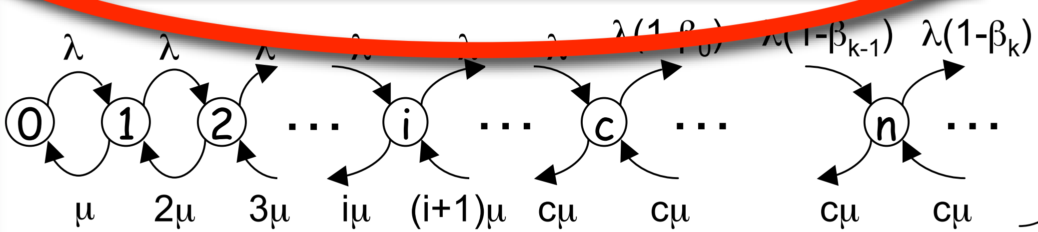
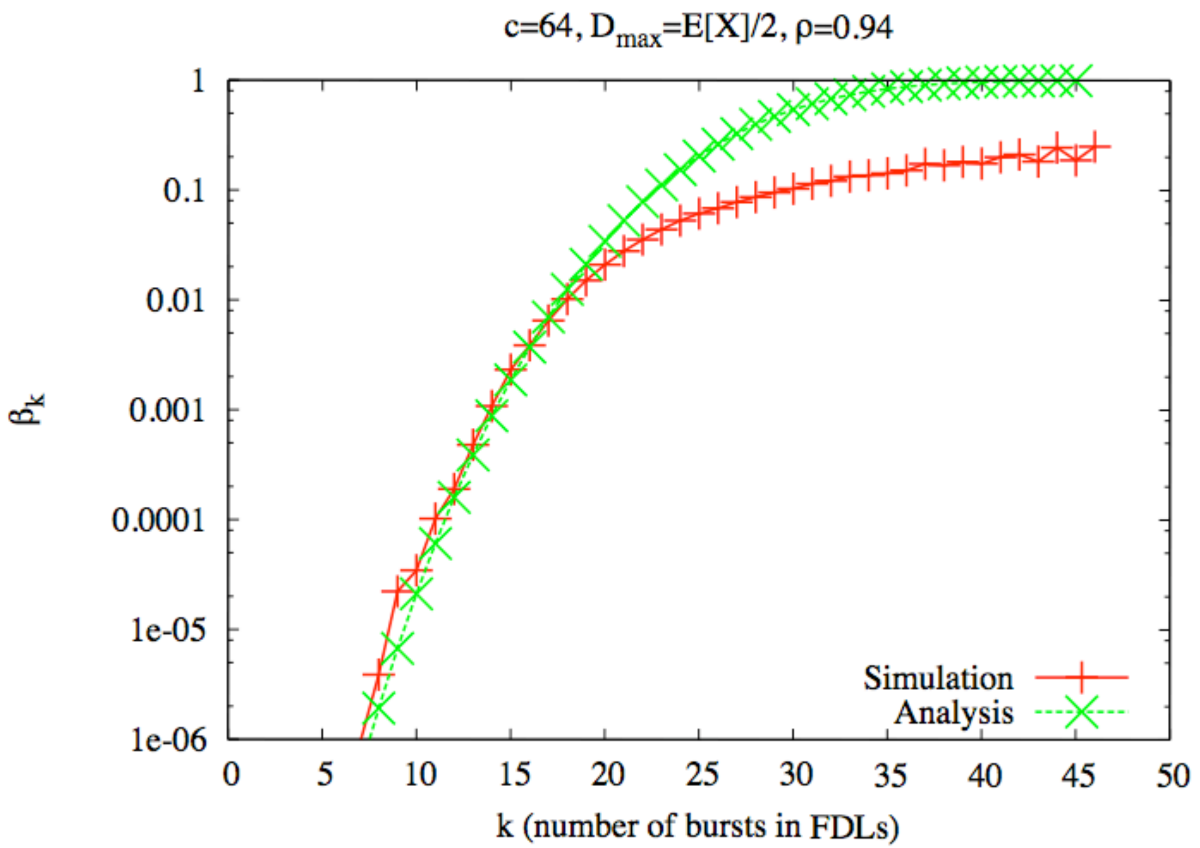


$$P(loss) = \sum_{k=0}^{\infty} \pi_{k+c} \beta_k$$

[LuTrans04]

Discouraged arrival probability (β_k)

- Larger deviation as the system occupancy grows



Queue with balking

- β_k: *Probability that an arrival is lost when the system has every channel occupied and k bursts waiting in FDLs*

Discouraged arrival probability affects the calculation of the state probabilities

ge number)

onger than the maximum delay offered by the FDLs

- Time until a wavelength gets free:

$$T_n = \hat{R} + \sum_{i=1}^{n-c} \hat{U}$$

$$P(T_n > x) = P\left(\sum_{i=0}^{n-c} \hat{R} > x\right) = e^{-c\mu x} \sum_{h=0}^{n-c} \frac{(c\mu x)^h}{h!}$$

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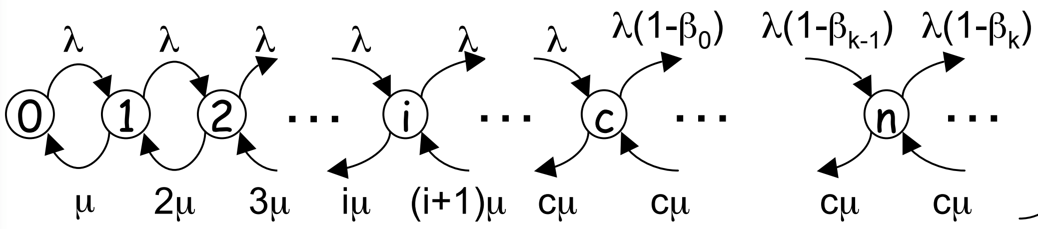


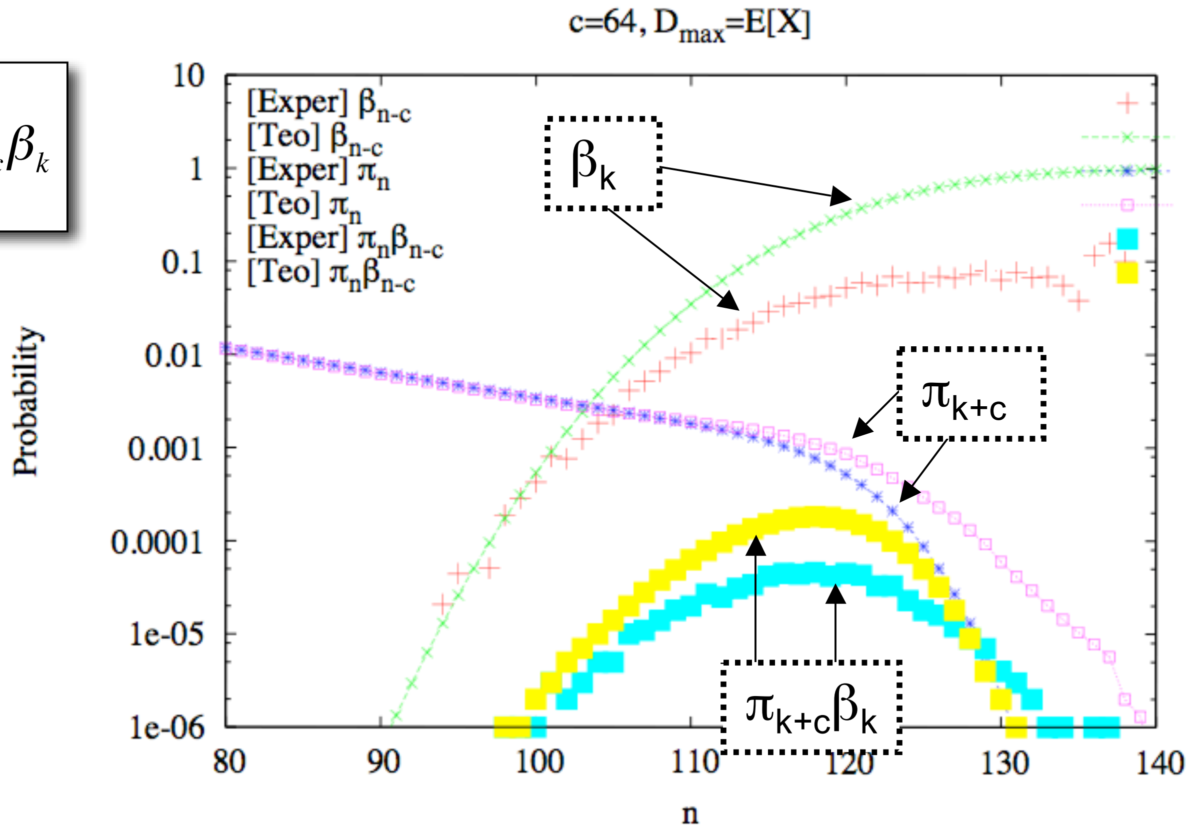
$$P(loss) = \sum_{k=0}^{\infty} \pi_{k+c}\beta_k$$

[LuTrans04]

State probabilities (π_n)

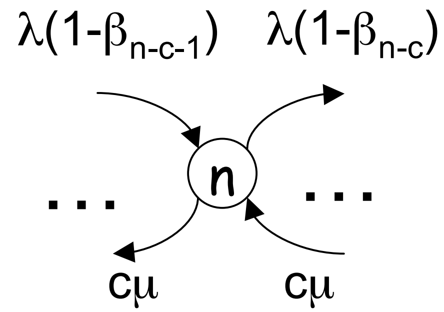
- Discrepancy happens in high occupancy states, hence those with low state probability
- But those are the states where losses take place

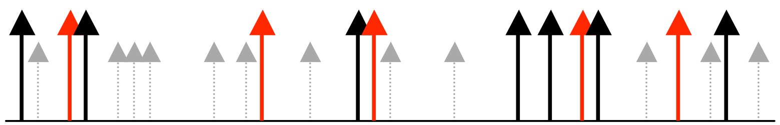
$$P(loss) = \sum_{k=0}^{\infty} \pi_{k+c}\beta_k$$



What is wrong in the model?

- We assume that the arrivals to state n are lost with probability β_{n-c}
- For the markovian model this probability must depend only on the state
- Lets try a simple experiment:
  - Select the arrivals to the state n (n>c)



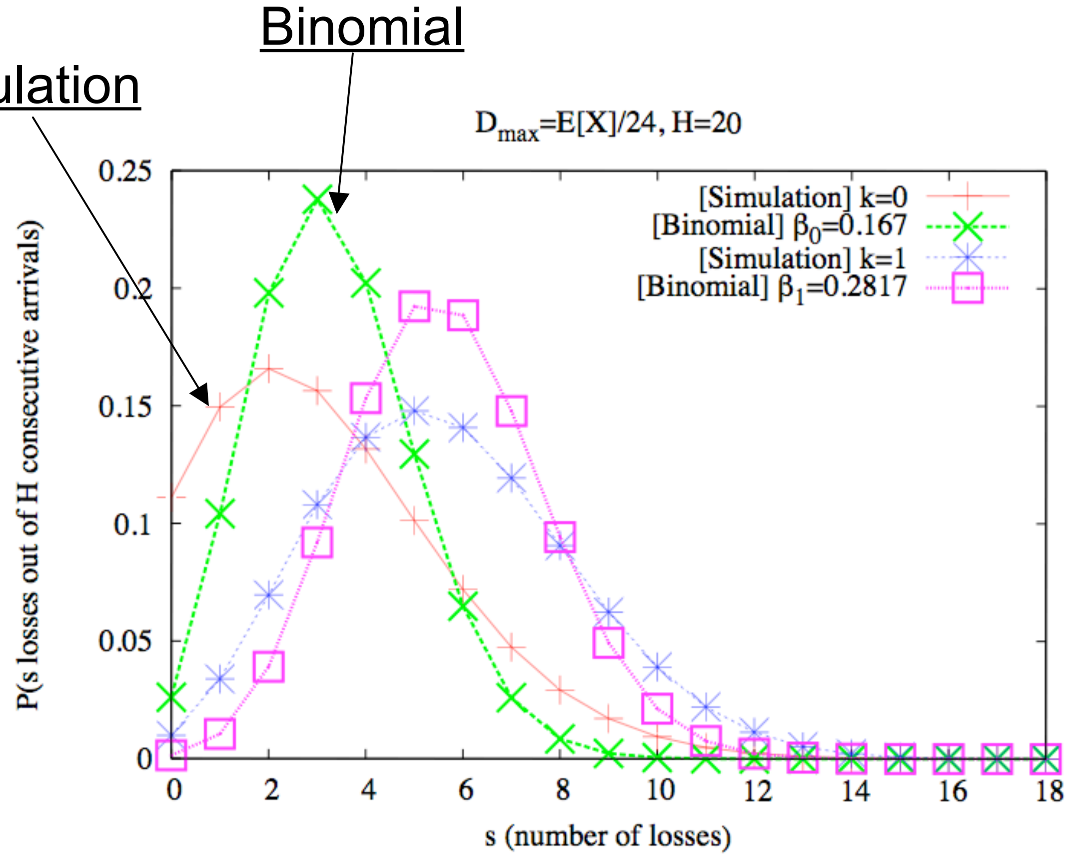


  - Each one is lost with probability β_{n-c}
  - Those are independent Bernouilli random variables
  - The number of losses out of H consecutive arrivals must be Binomial distributed

$$P(\text{s losses in H consecutive arrivals}) = \binom{H}{s} \beta_{n-c}{}^{n} (1-\beta_{n-c})^{H-s}$$

What is wrong in the model?

- Both differ significantly
- *The discouraged arrival probability does not depend only on the number of bursts in the system (cause it also depends on the residual life)*



Conclusions

- The balking model accuracy depends on the ratio between fiber delay and service time
- Larger FDLs provide smaller blocking probability but the model is less accurate
- As the number of wavelengths per port increase so does the inaccuracy in the model
- Higher number of wavelengths… smaller loss probabilities… but those are the interesting scenarios!
- Hence, the model becomes less accurate for the foreseen and more interested scenarios