ETH
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Swiss Federal Institute of Technology Zurich

Computer Engineering and
Networks Laboratory

Modeling Structured Event Streams in System Level Performance Analysis

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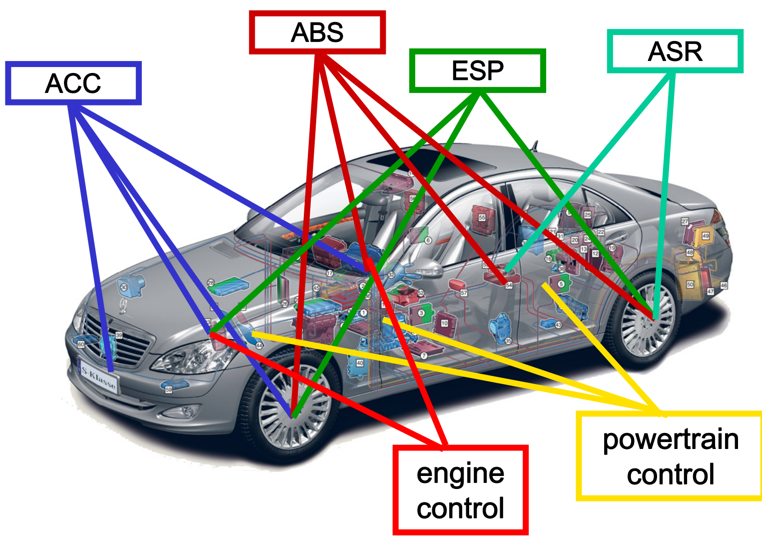
Outline

- Motivation
- Modular Performance Analysis with Real-Time Calculus
- Approach 1: FIFO Scheduling
- Approach 2: Event Count Curves
- Comparison / Case Study
- Conclusion

Motivation

Distributed Stream-based Embedded Systems



Design and analysis are complex due to:

- Concurrency
- Interference on shared resources
- Non-determinism in timing

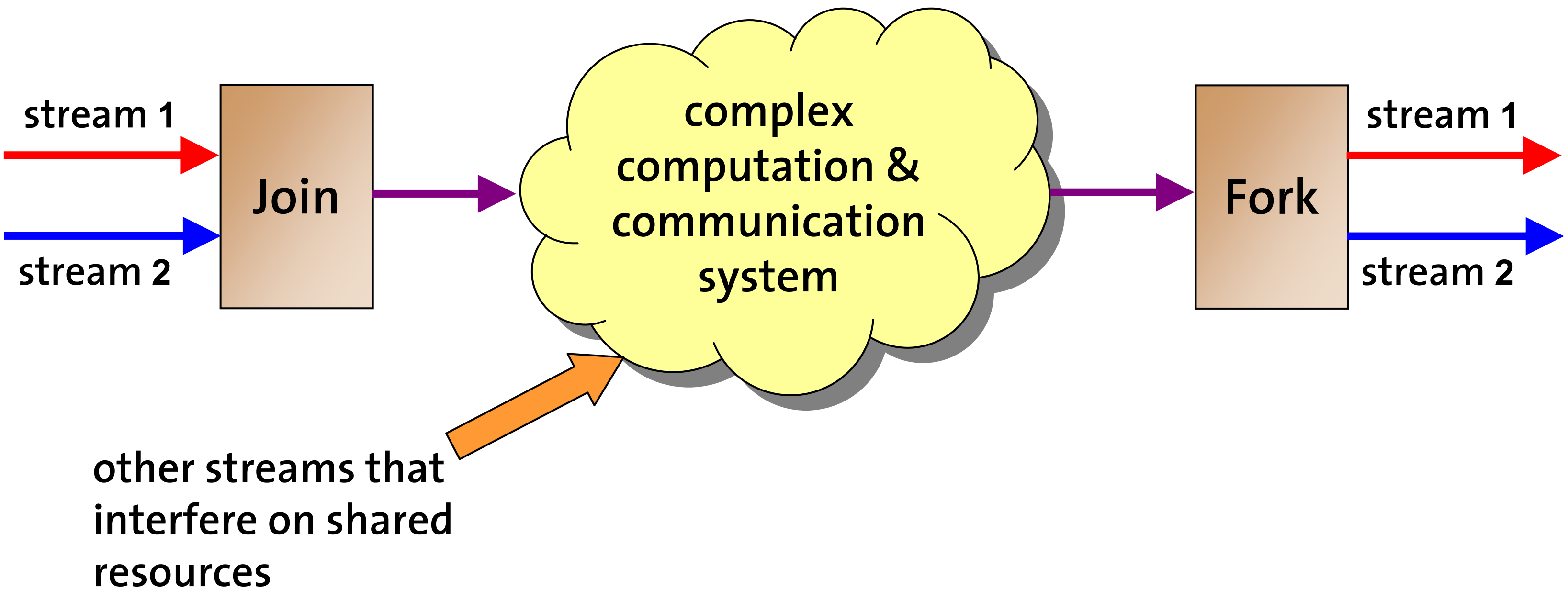
Requirements for Performance Analysis:

- Coverage of system behaviors
- Accuracy of results
- Computational efficiency

Analytic methods for Modular Performance Analysis:
- MPA-RTC (ETHZ)
- SymTA/S (TUBS)

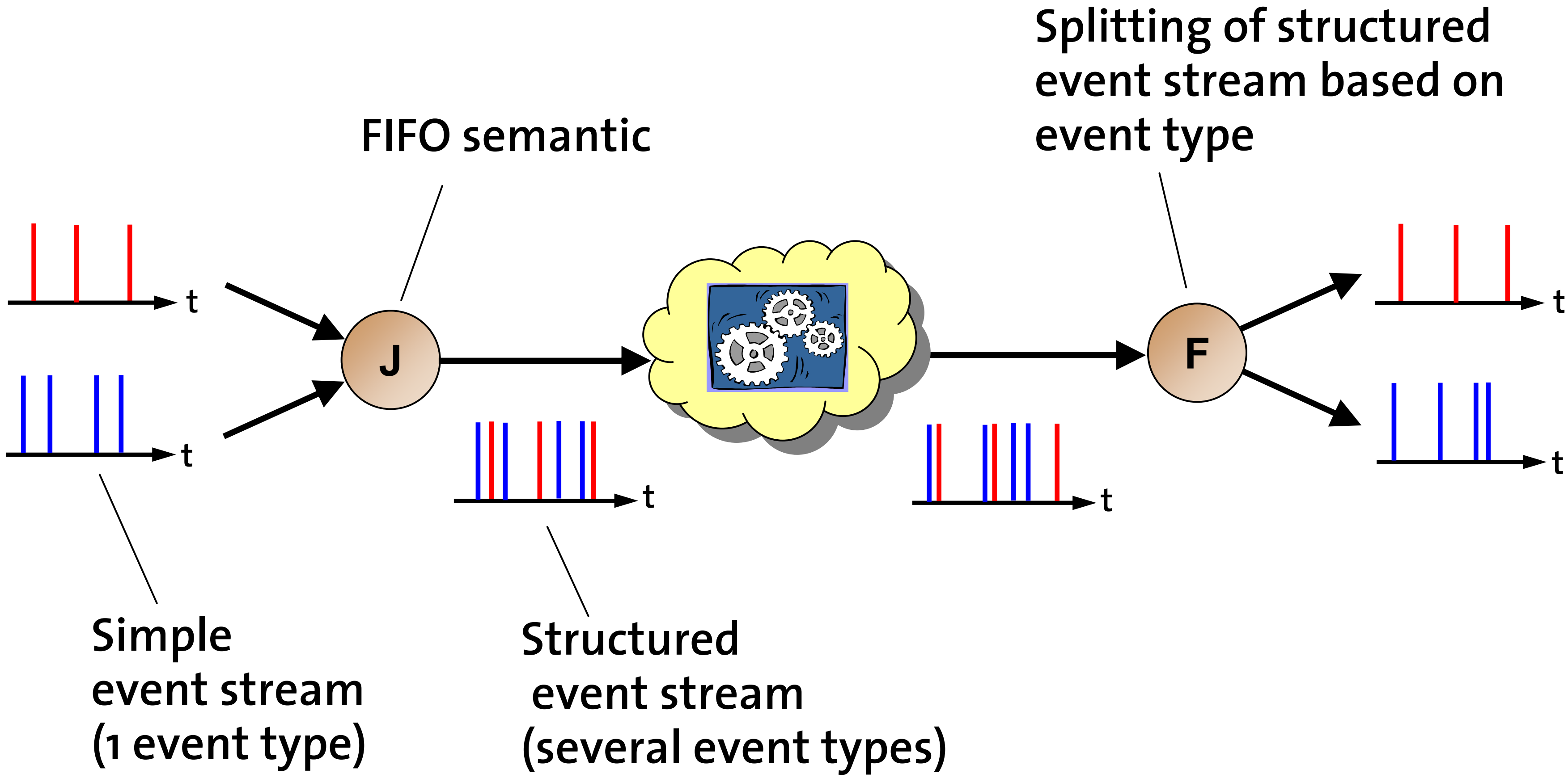
Motivation

Relevant design pattern: Join and Fork of event or data streams



Goal: Extend analytic methods for performance analysis such that join/fork operations on streams can be captured accurately

Definitions

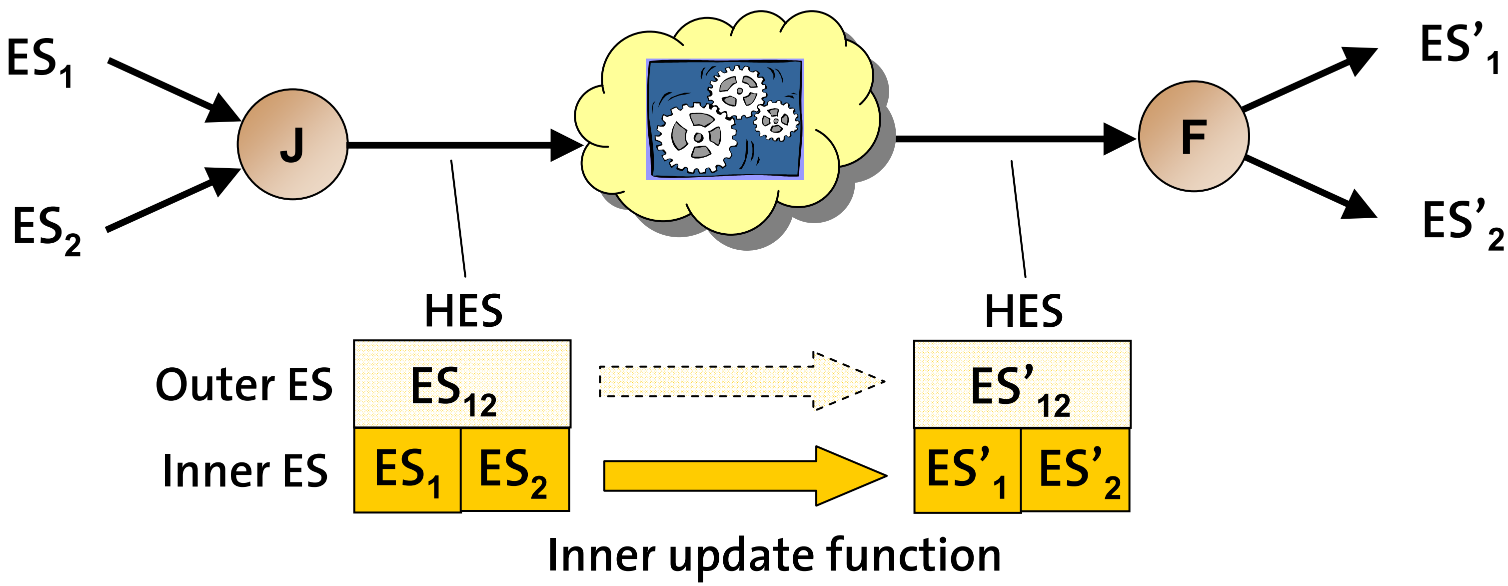


Event type = provenance

Related Work

Hierarchical Event Model (TU Braunschweig)

J. Rox & R. Ernst, *Modeling Event Stream Hierarchies with Hierarchical Event Models,* DATE 2008



Limitations: - Method is not transparent to existing component models

- Deep processing of HES required by component models

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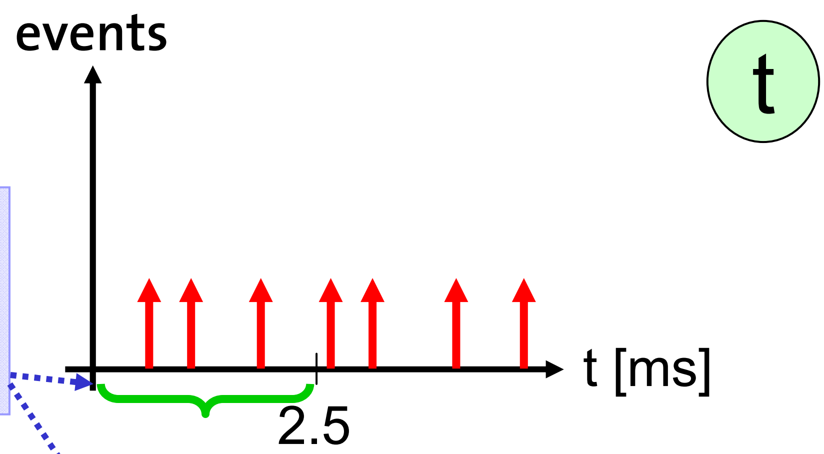
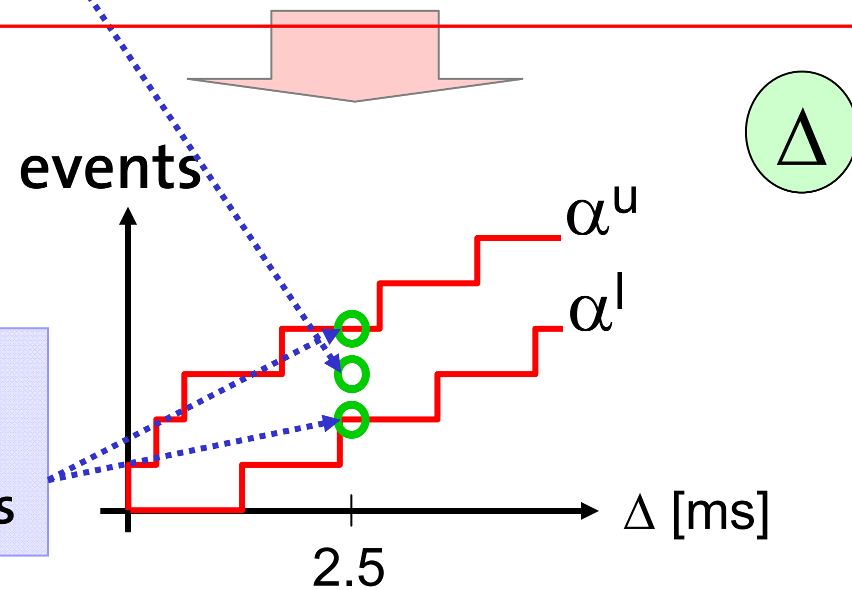
Arrival Curves

Event Stream



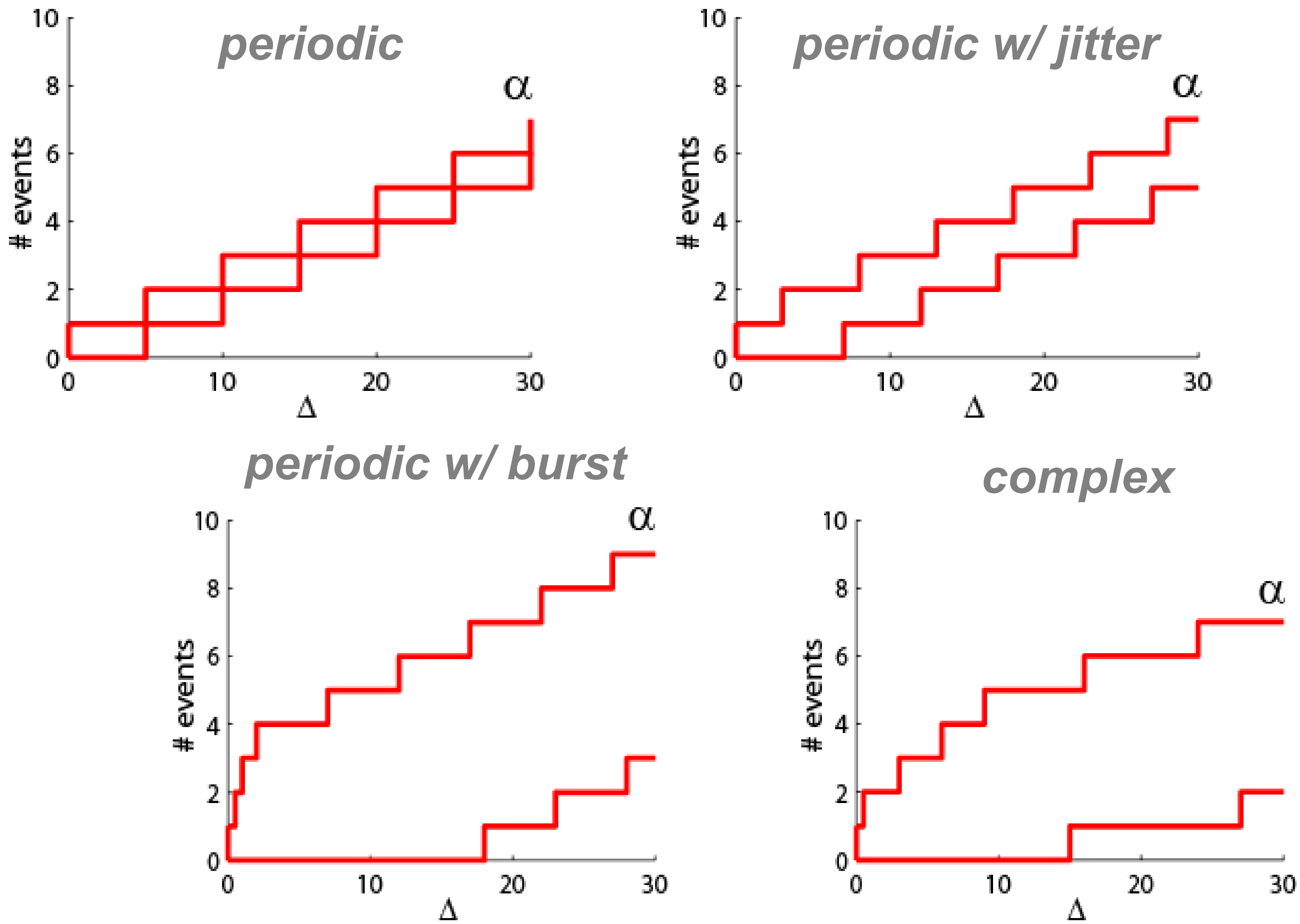
number of events in
in t=[0 .. 2.5] ms

Arrival Curves $[\alpha^l, \alpha^u]$



maximum/minimum
arriving events in *any*
interval of length 2.5 ms

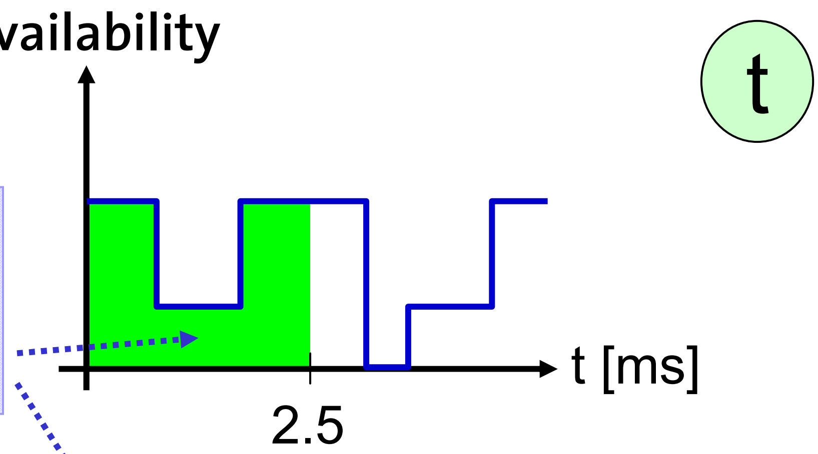
Examples of Arrival Curves



Service Curves

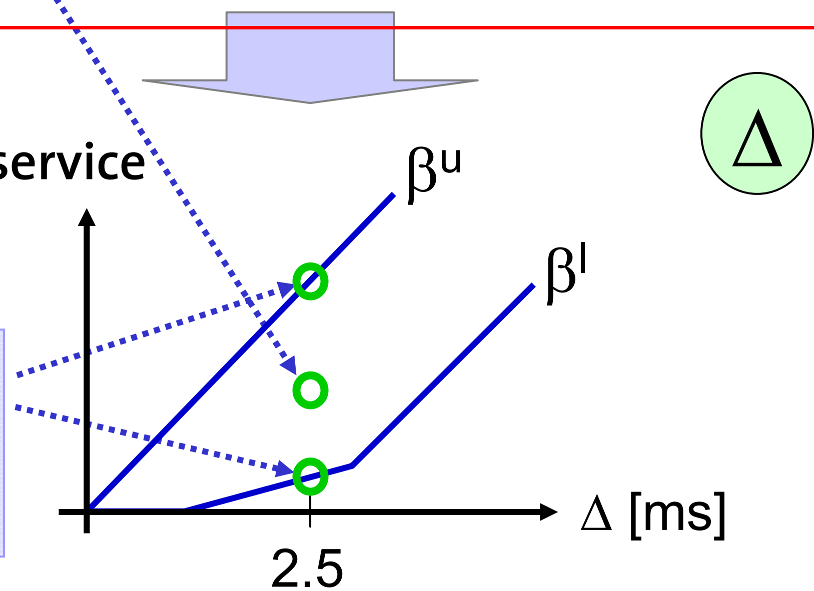
Resource Availability

available service
in t=[0 .. 2.5] ms



Service Curves $[\beta^l, \beta^u]$

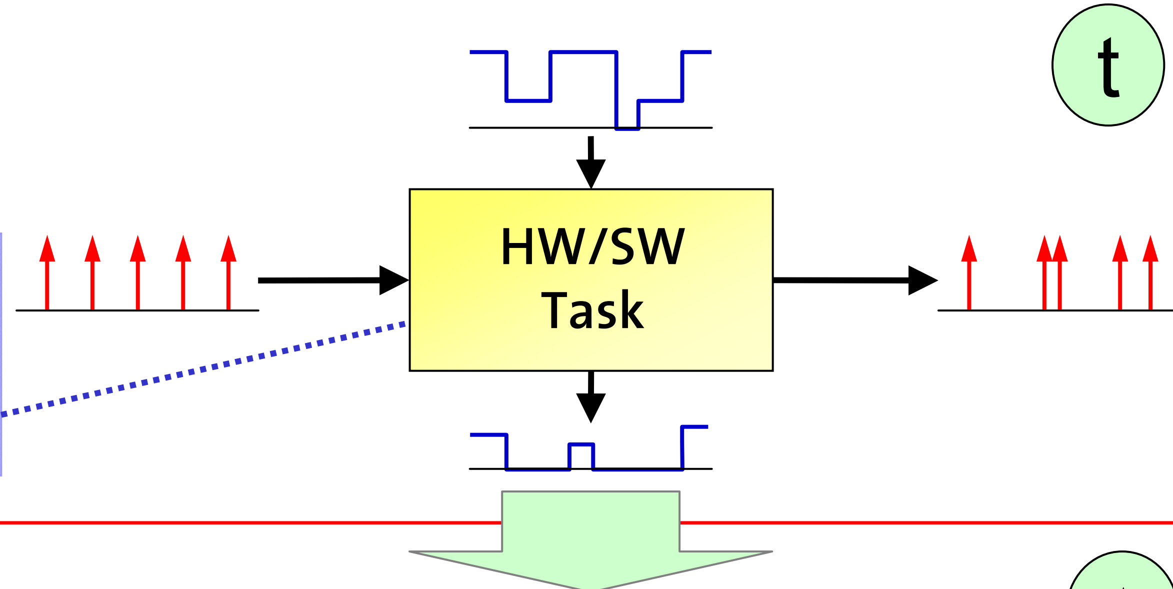
maximum/minimum
available service in *any*
interval of length 2.5 ms



Processing Model (HW/SW)

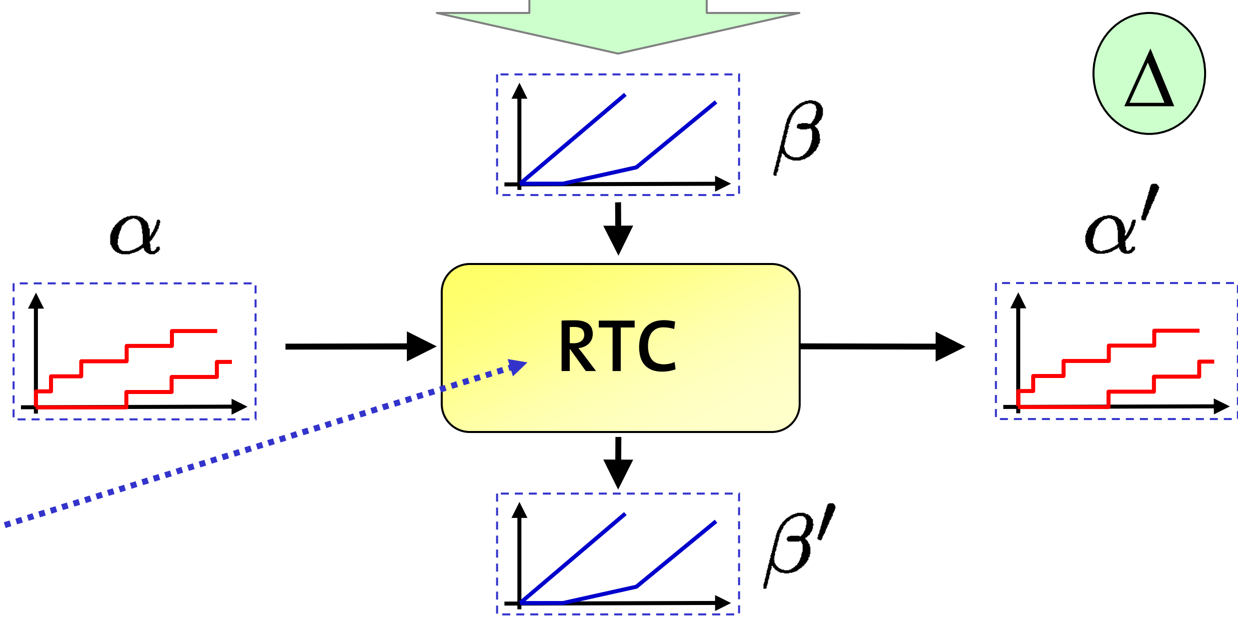
HW/SW Components

Processing semantics and functionality of hardware or software tasks

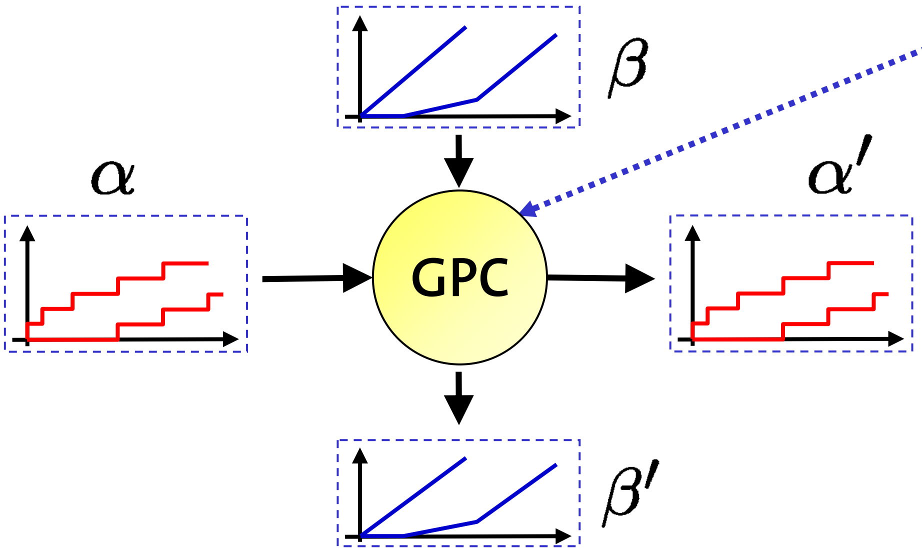


Abstract Components

$$\alpha'(\Delta) = f_\alpha(\alpha, \beta)$$
$$\beta'(\Delta) = f_\beta(\alpha, \beta)$$



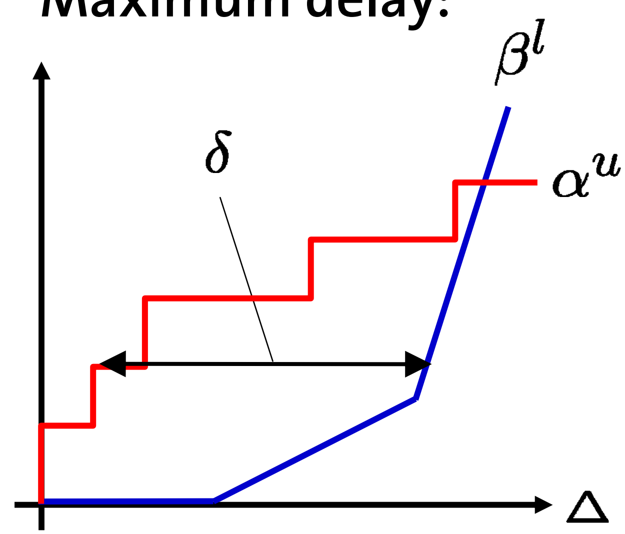
Example: Greedy Processing Component (GPC)



$$\begin{aligned}
\alpha'^u &= GPC_{\alpha'^u}(\alpha^u, \beta^u, \beta^l) \\
\alpha'^l &= GPC_{\alpha'^l}(\alpha^l, \beta^u, \beta^l) \\
\beta'^u &= GPC_{\beta'^u}(\beta^u, \alpha^l) \\
\beta'^l &= GPC_{\beta'^l}(\beta^l, \alpha^u)
\end{aligned}$$

- FIFO input buffer
- Greedy event processing

Maximum delay:



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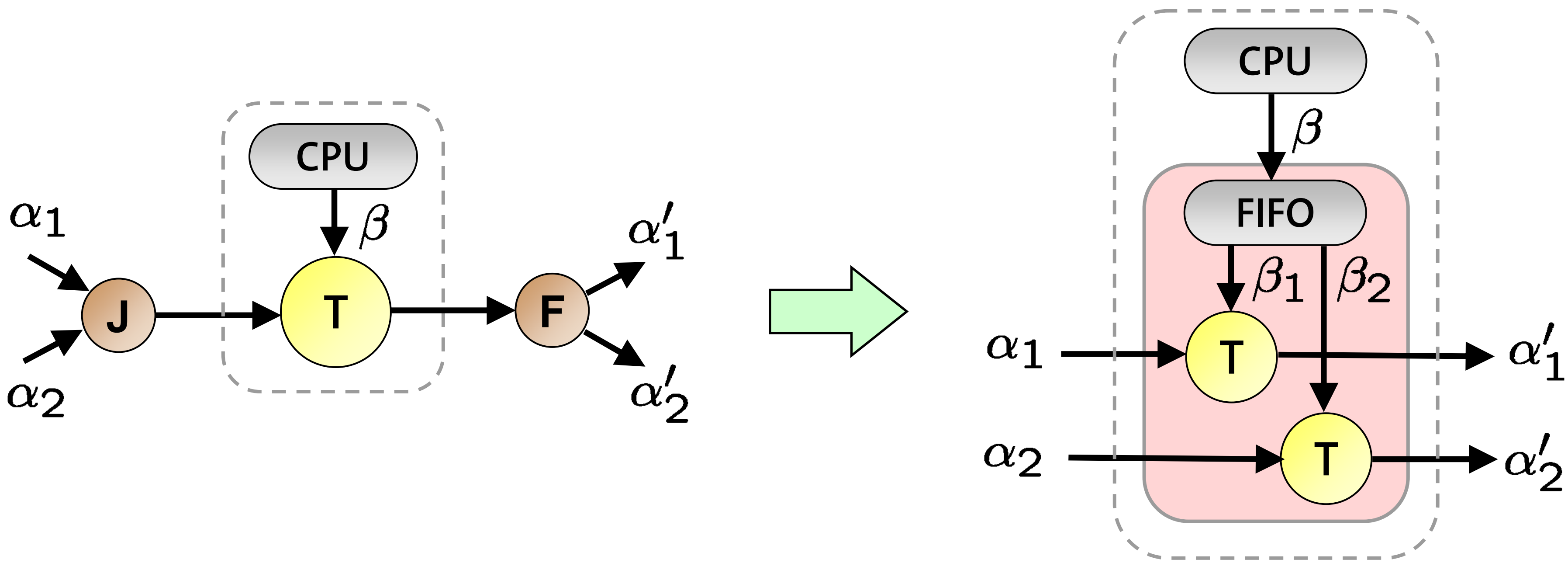
FIFO Scheduling

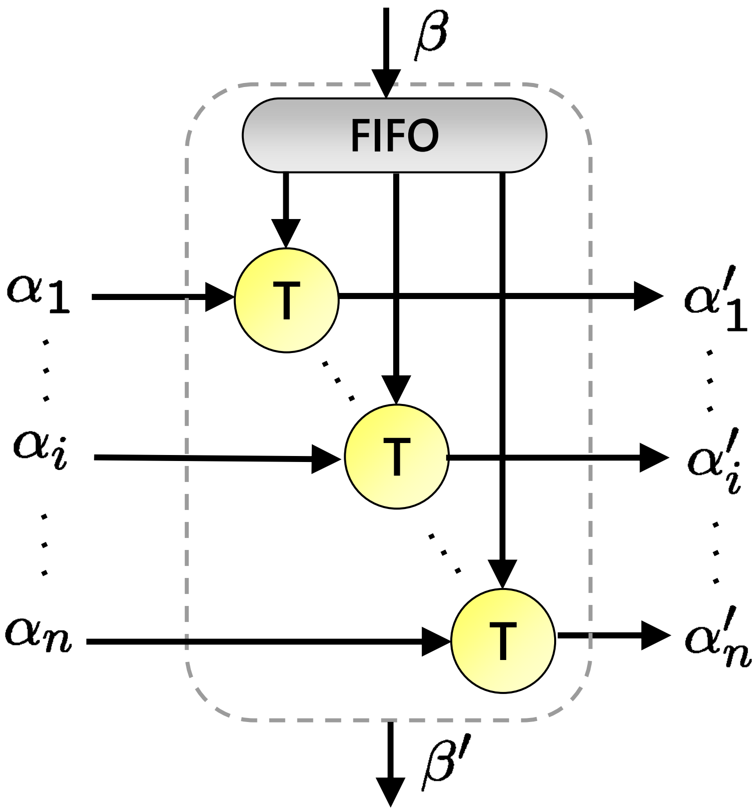
- Keep sub-streams separated in the model
- Adapt existing component models

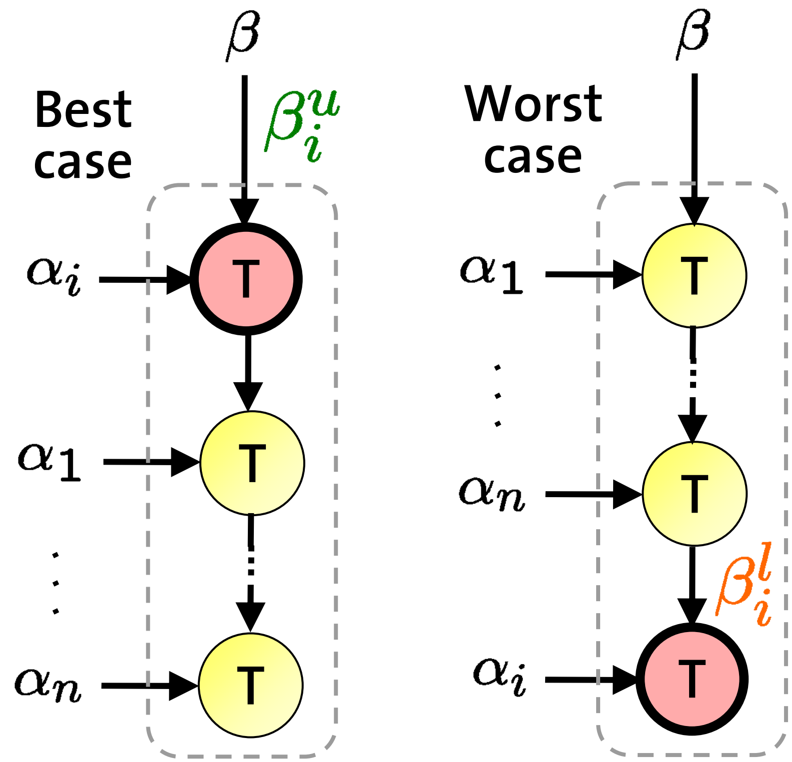
Abstract FIFO component
for the MPA framework



Modeling approach justified by FIFO semantics of Join operator

FIFO Component in MPA





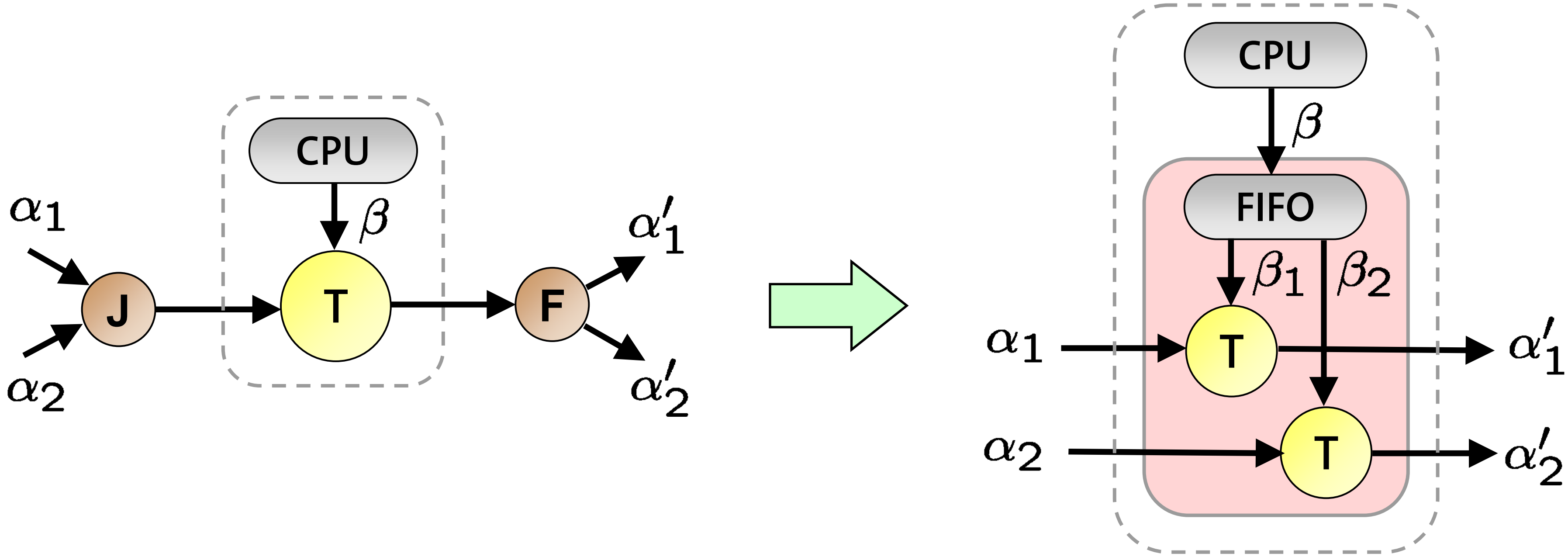
$$\beta'^u = GPC_{\beta'^u}(\beta^u, \sum_i \alpha_i^l)$$

$$\beta'^l = GPC_{\beta'^l}(\beta^l, \sum_i \alpha_i^u)$$

$$\alpha_i'^u = GPC_{\alpha'^u}(\alpha_i^u, \beta_i^u, \beta_i^l)$$

$$\alpha_i'^l = GPC_{\alpha'^l}(\alpha_i^l, \beta_i^u, \beta_i^l)$$

FIFO Scheduling



Abstract processing component handles structure of input stream explicitly

$\Rightarrow$ **Method is not transparent to existing component models!**

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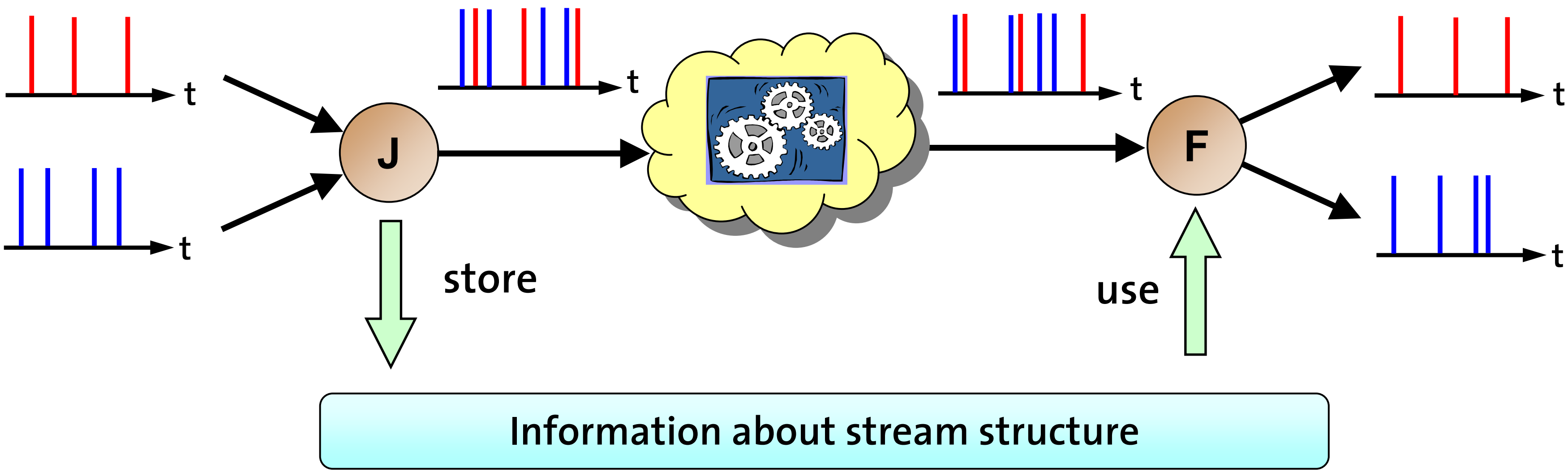
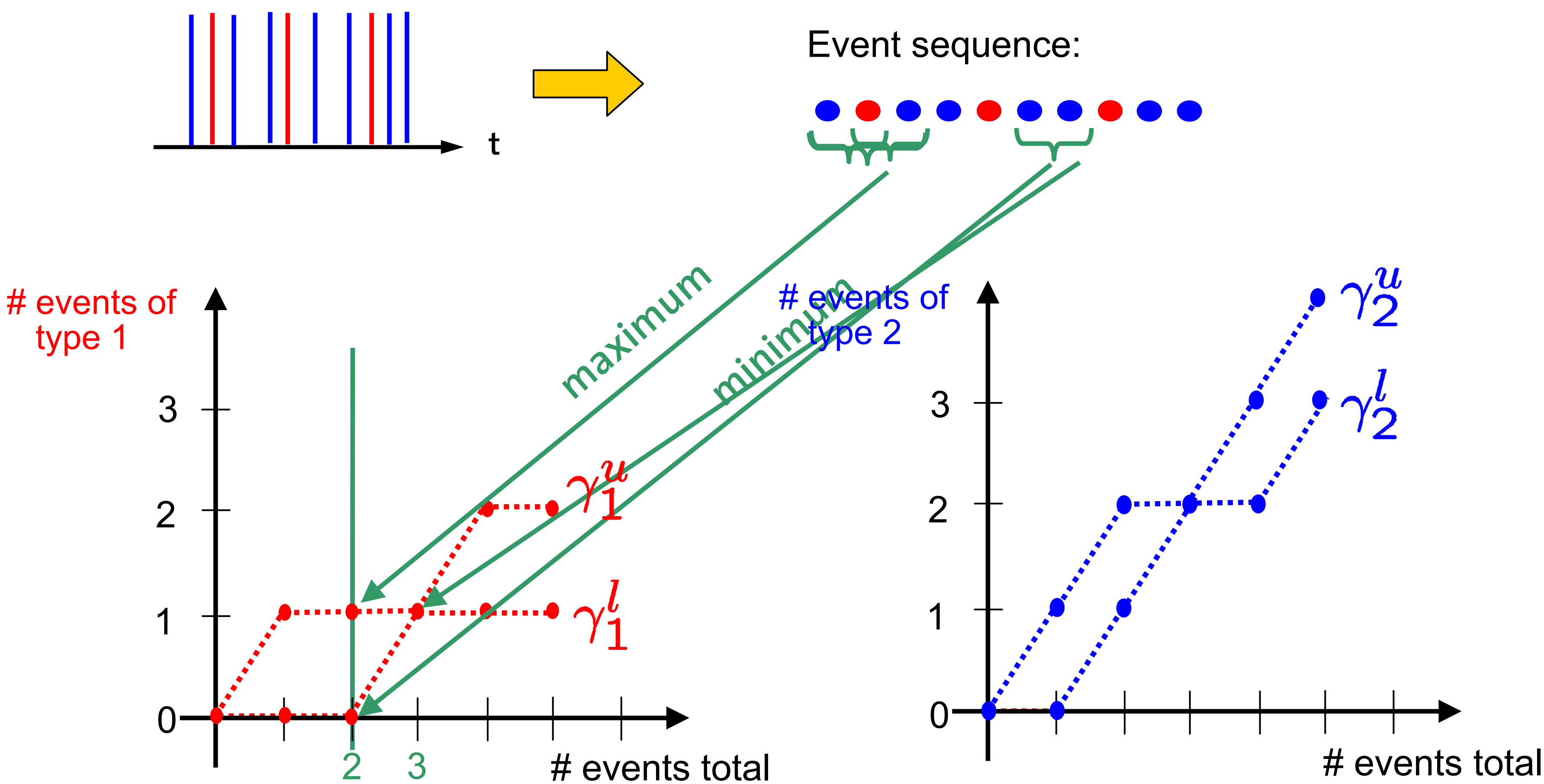
Event Count Curves: Basic Idea

The processing components in MPA preserve the order of the events in a stream

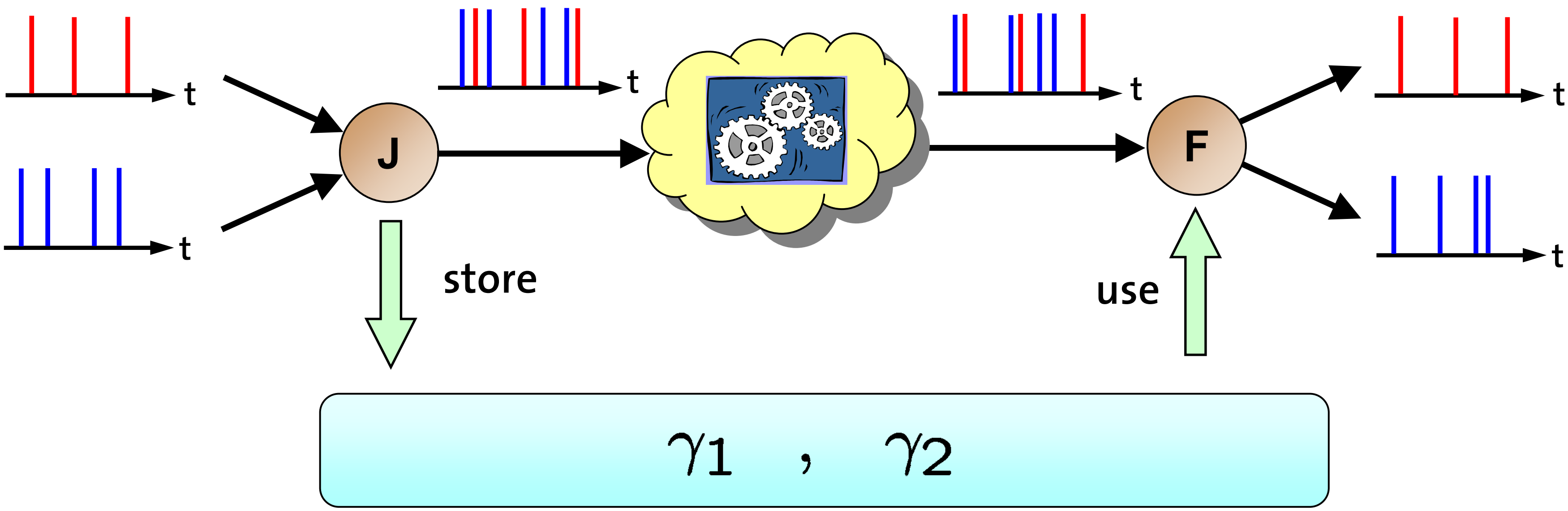


Event Count Curves: Definition

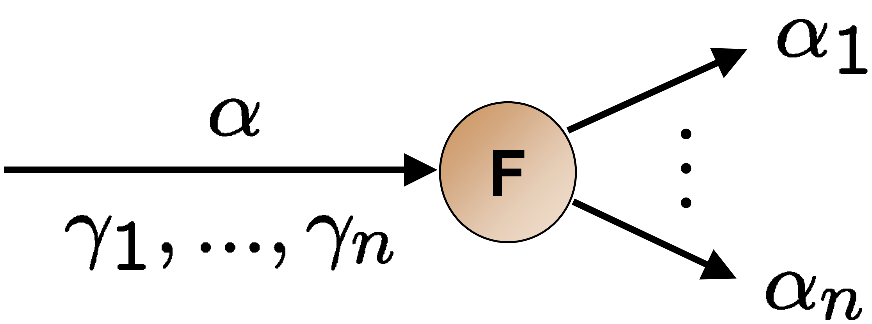
For a fixed number of events in the structured stream the lower (upper) ECC γ_i^l (γ_i^u) bounds the min (max) number of events of type i.



Event Count Curves

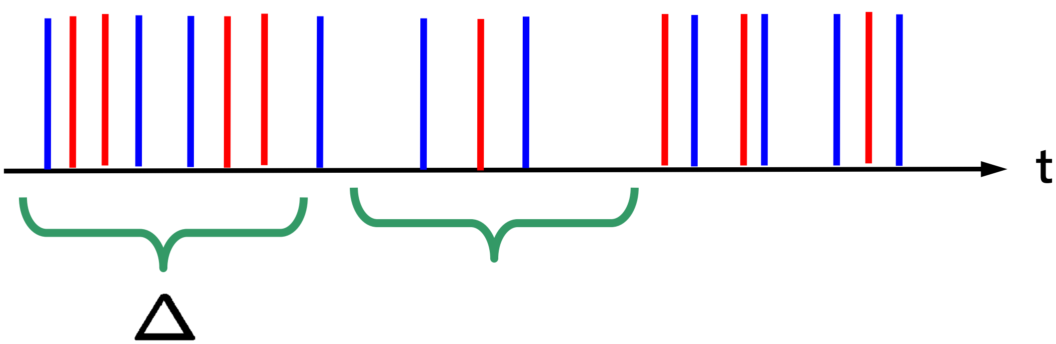


Fork (Simple Event Streams)



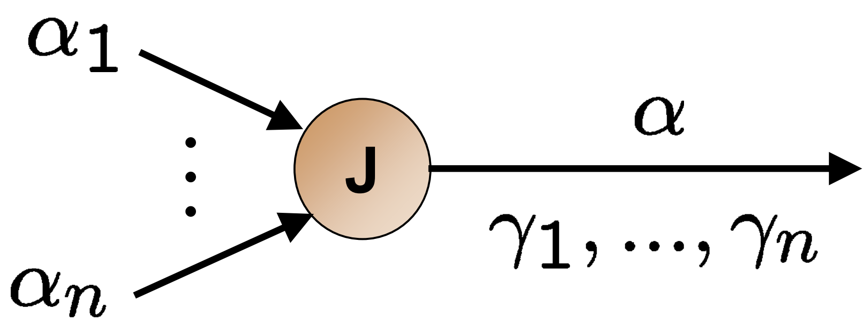
$$\alpha_i^l(\Delta) = \gamma_i^l(\alpha^l(\Delta))$$

$$\alpha_i^u(\Delta) = \gamma_i^u(\alpha^u(\Delta))$$



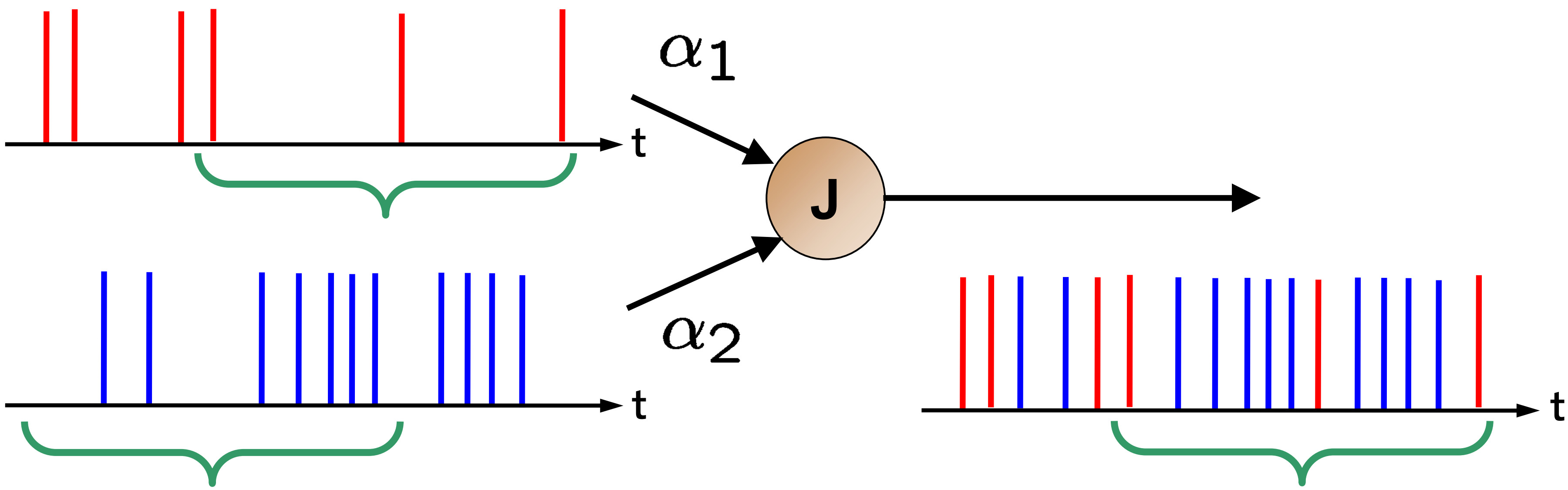
$$\gamma_1^l(\alpha^l(\Delta)) = 1$$

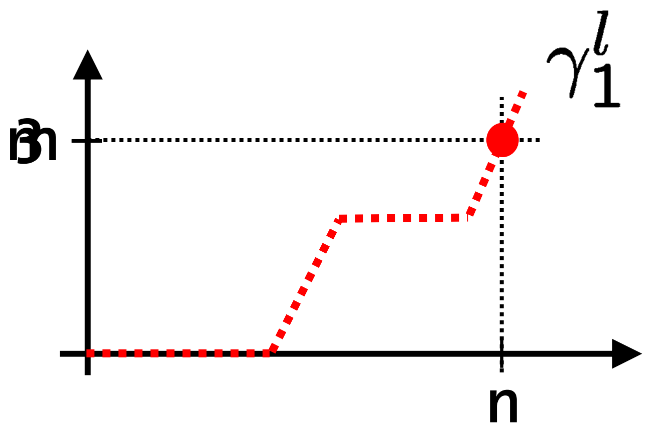
Join (Simple Event Streams)



$$\alpha^l(\Delta) = \sum_i \alpha_i^l \quad ; \quad \alpha^u(\Delta) = \sum_i \alpha_i^u$$

Join (Simple Event Streams)

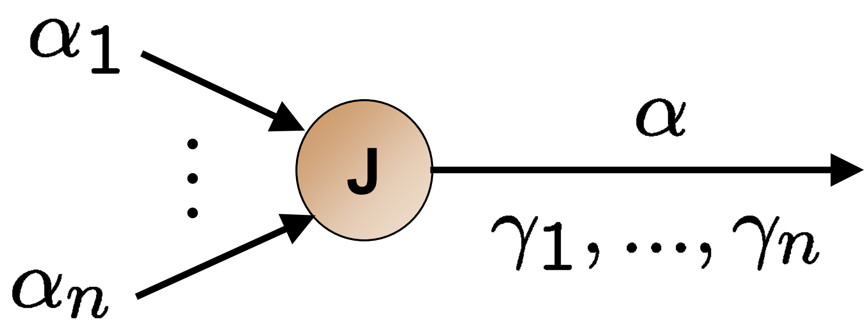




$$n = 3 + \alpha_2^u(\alpha_1^{-l}(3)) = 12$$

$$\gamma_1^l(12) = 3$$

Join (Simple Event Streams)

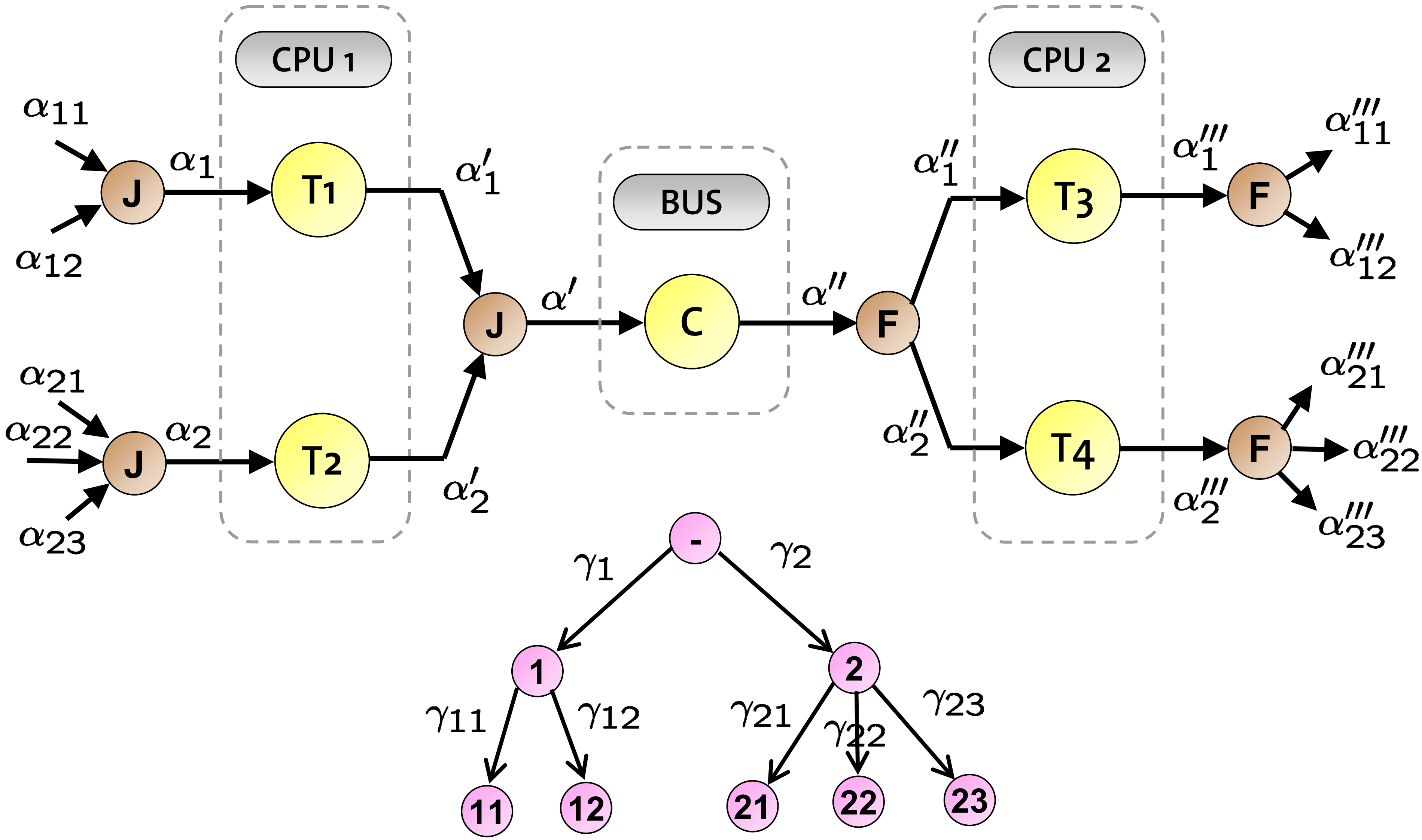


$$\alpha^l(\Delta) = \sum_i \alpha_i^l \quad ; \quad \alpha^u(\Delta) = \sum_i \alpha_i^u$$

$$\gamma_i^l(n) = \epsilon_i^{-u}(n) \qquad \epsilon_i^u(n_i) = n_i + \sum_{j \neq i} \alpha_j^u(\alpha_i^{-l}(n_i))$$

$$\gamma_i^u(n) = \epsilon_i^{-l}(n) \qquad \epsilon_i^l(n_i) = n_i + \sum_{j \neq i} \alpha_j^l(\alpha_i^{-u}(n_i))$$

Hierarchical application of ECCs

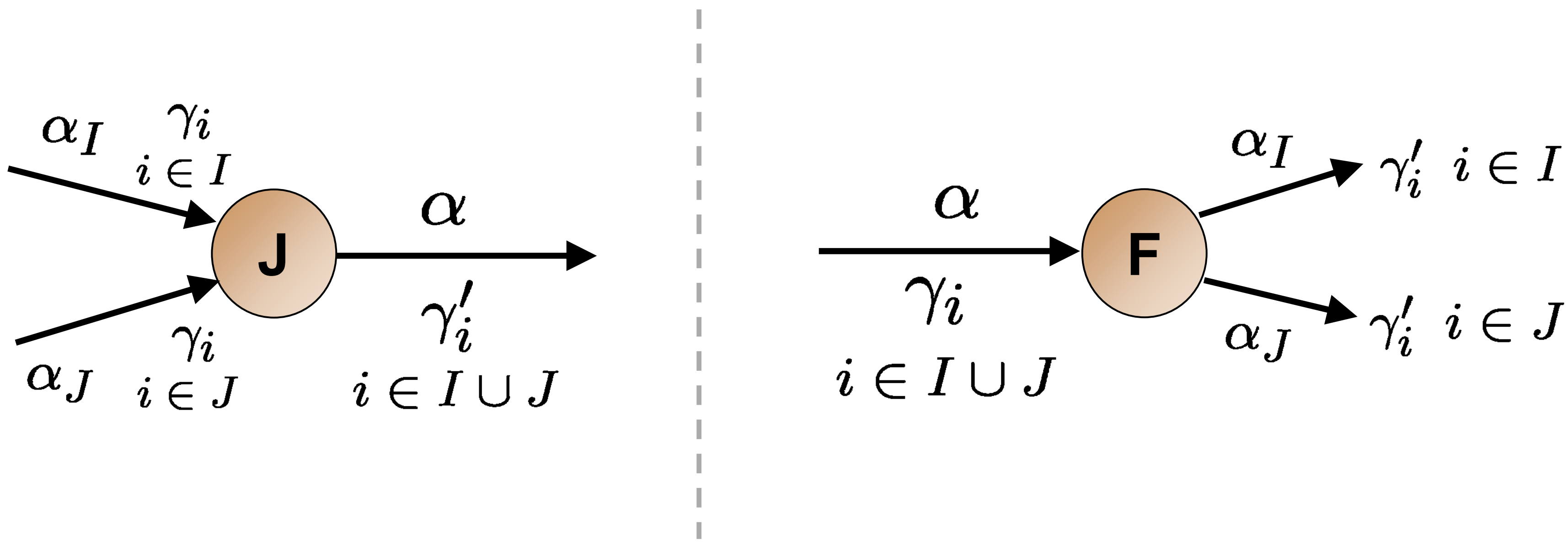


Arbitrary Join and Fork of Structured Streams

Limitation of hierarchical ECC organization:

Structured streams can be decomposed only in the way they have been composed!

⇒ More general join/fork operators are desirable



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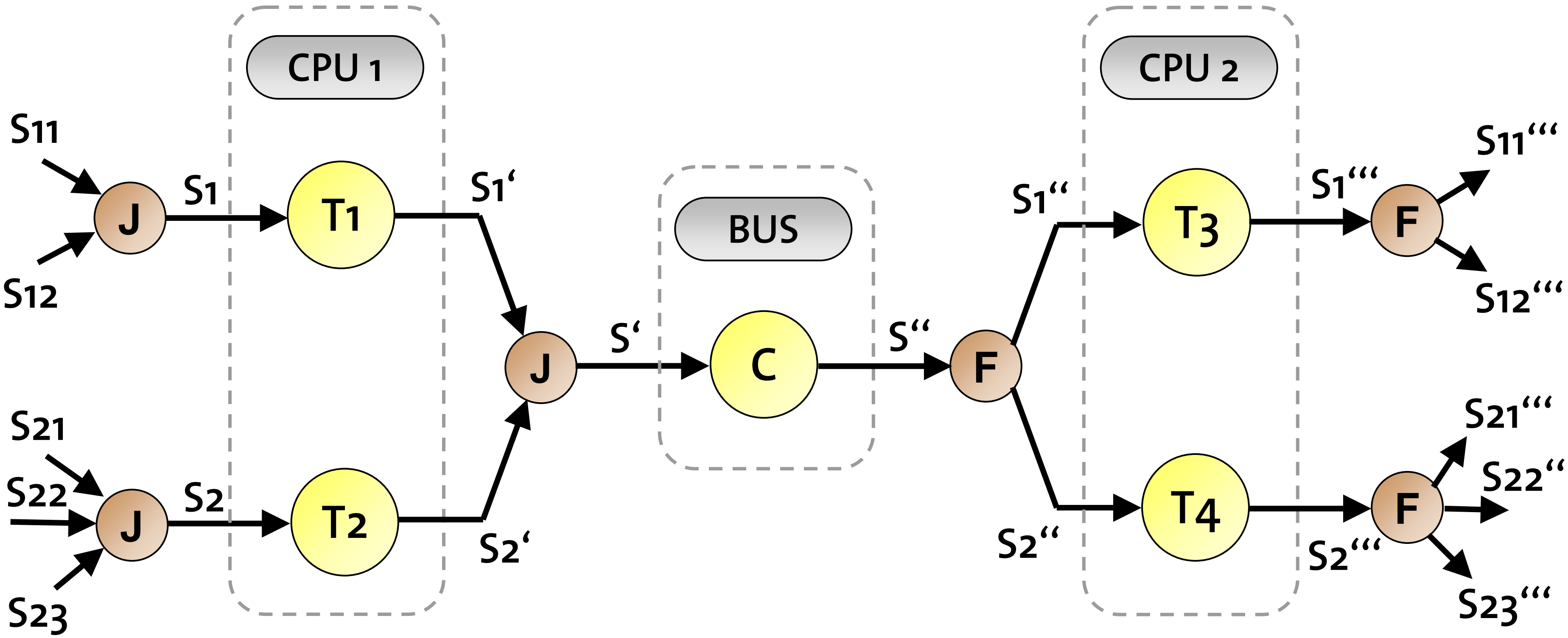
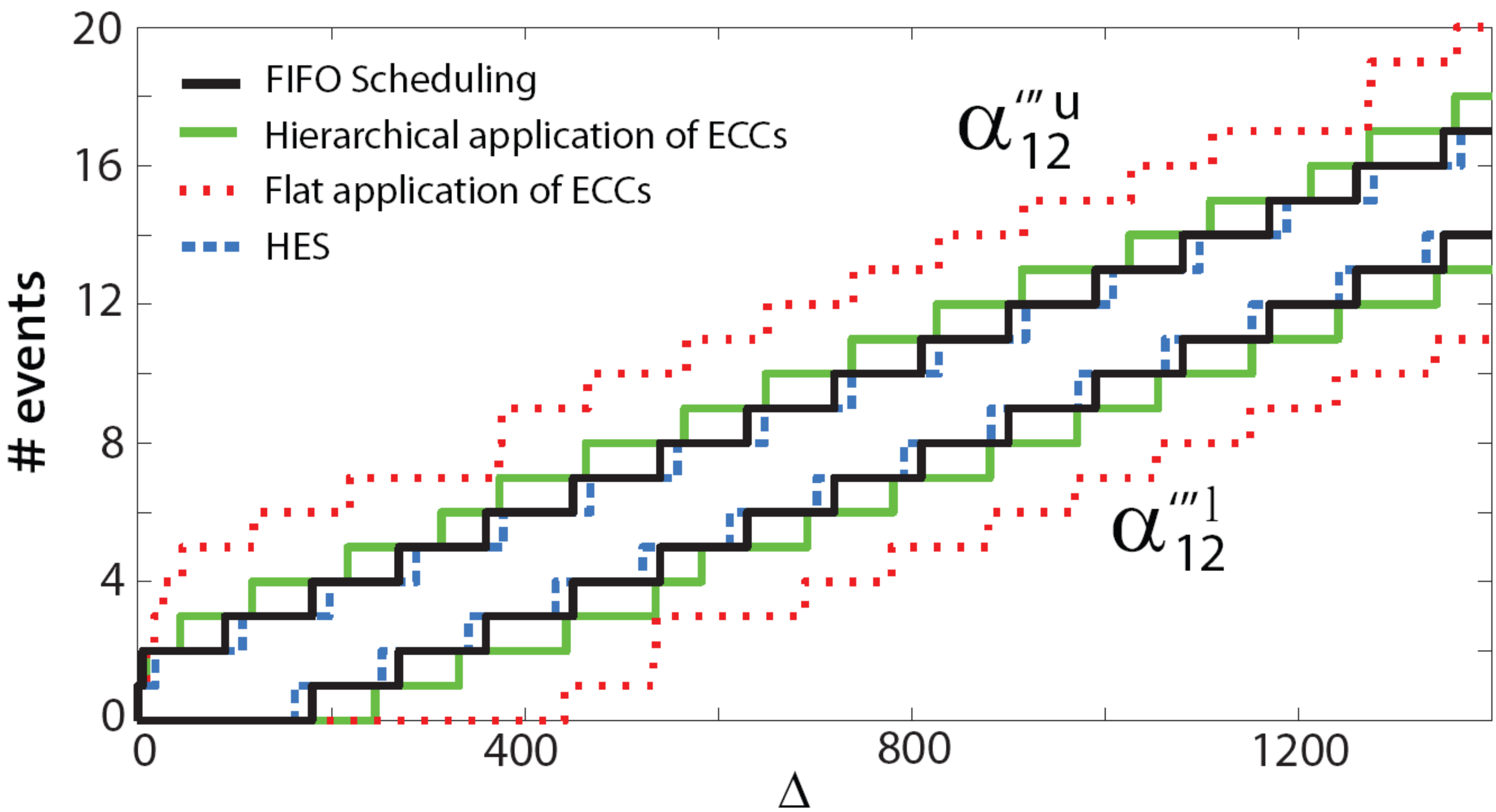
Example



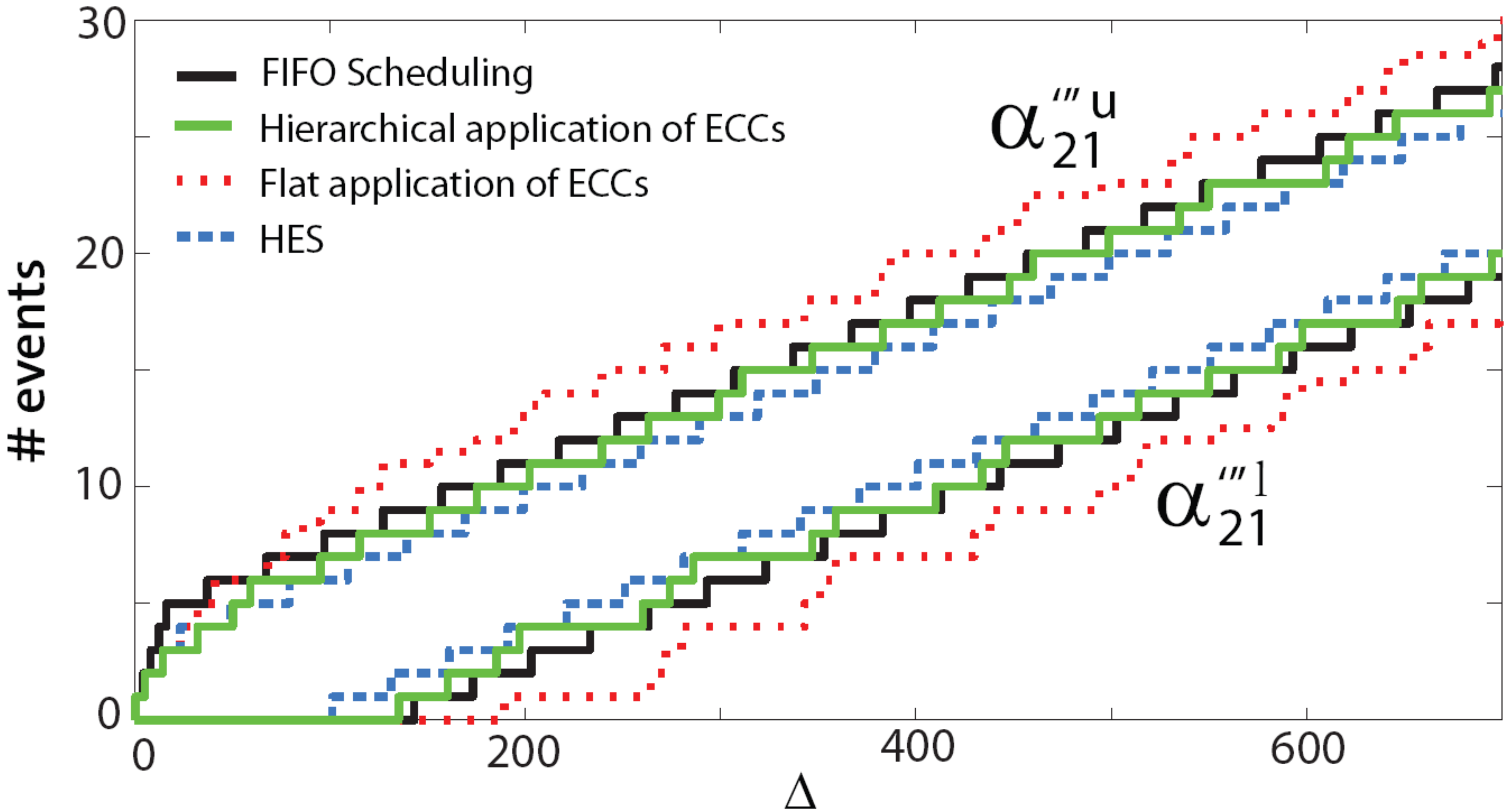
Stream	Period	Jitter
S11	100	30
S12	90	15
S21	30	0
S22	80	20
S23	75	5

Task	BCET	WCET
T1	2	3
T2	3	4
C	9	12
T3	2	3
T4	4	5

Analysis Results

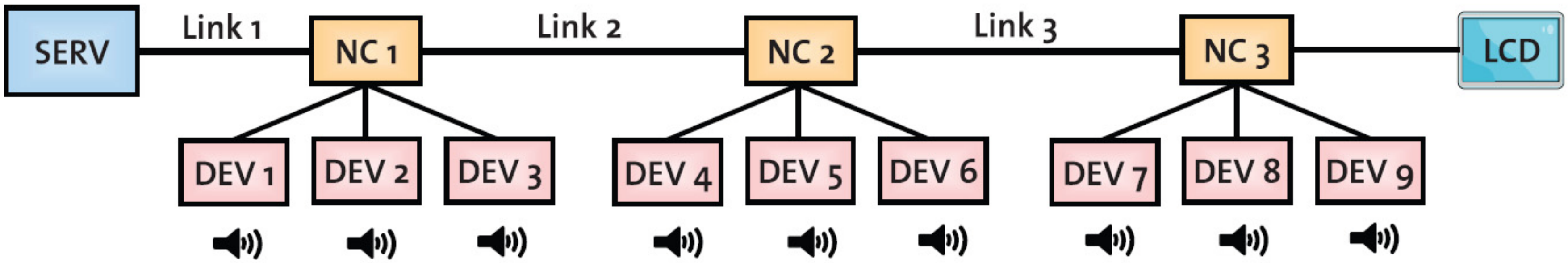


Analysis Results



Case Study: Specification

Distributed information/entertainment application

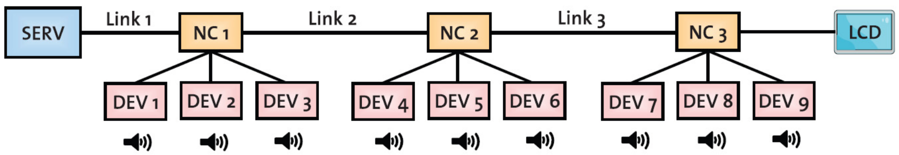


2 classes of network traffic:

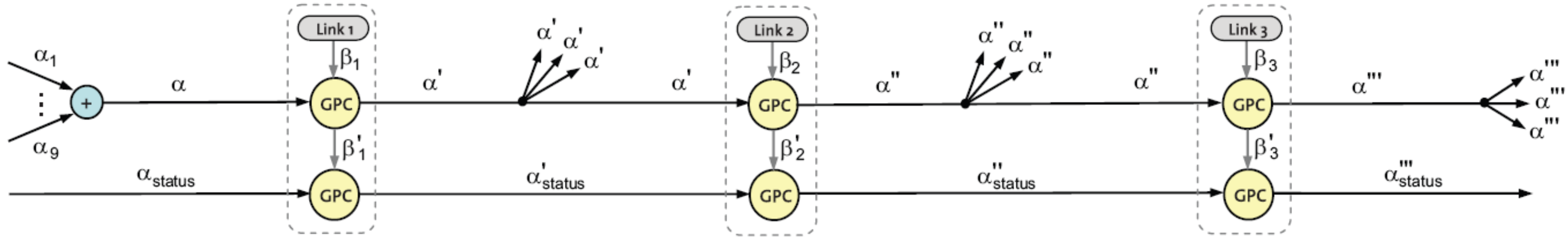
- On-demand audio streaming (high prior.)
- Real-time status information (low prior.)

	Size	Period	Jitter	Deadline
Audio Frames	1'518 Bytes	30 ms	5 ms	100 ms
Status Frames	106'500 Bytes	5 s	0 s	1.5 s

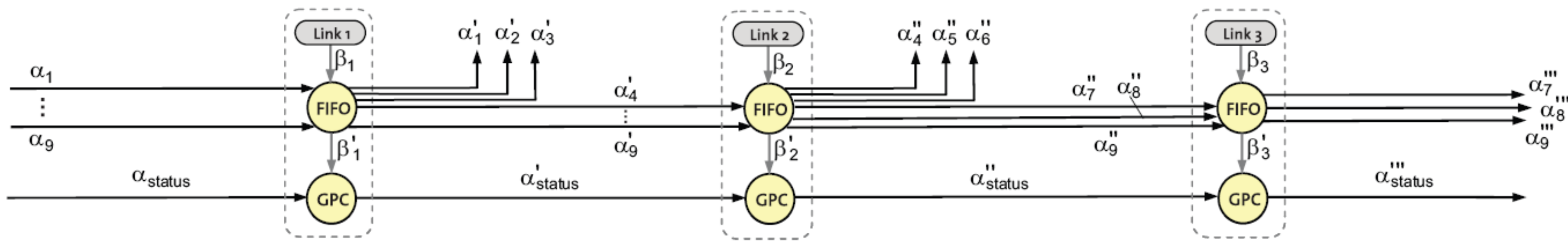
Case Study: Models (1)



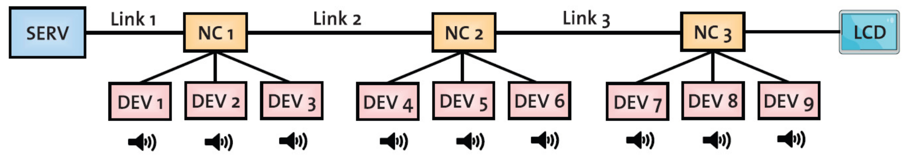
Classic MPA



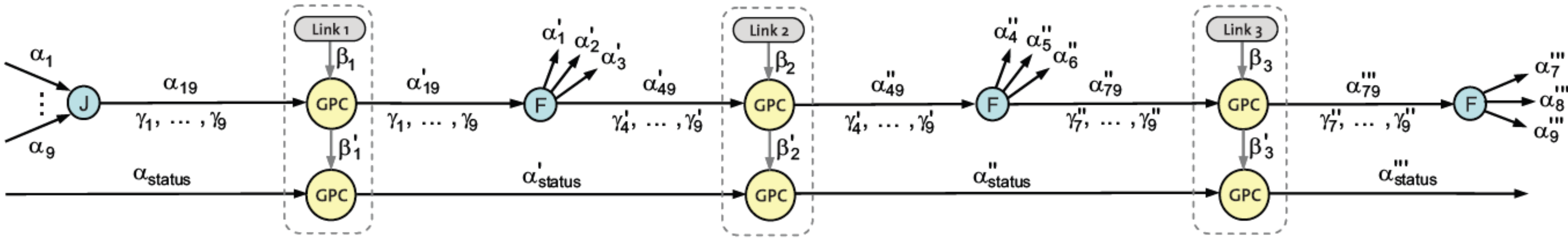
FIFO components



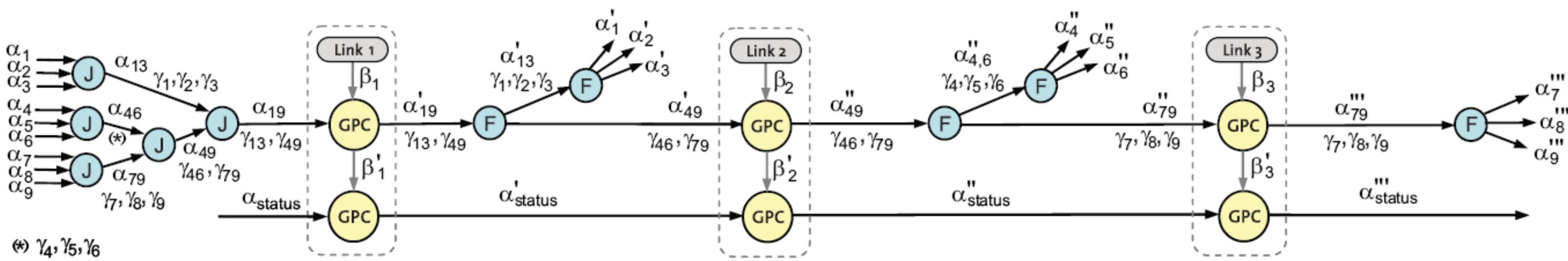
Case Study: Models (2)



ECC (flat)

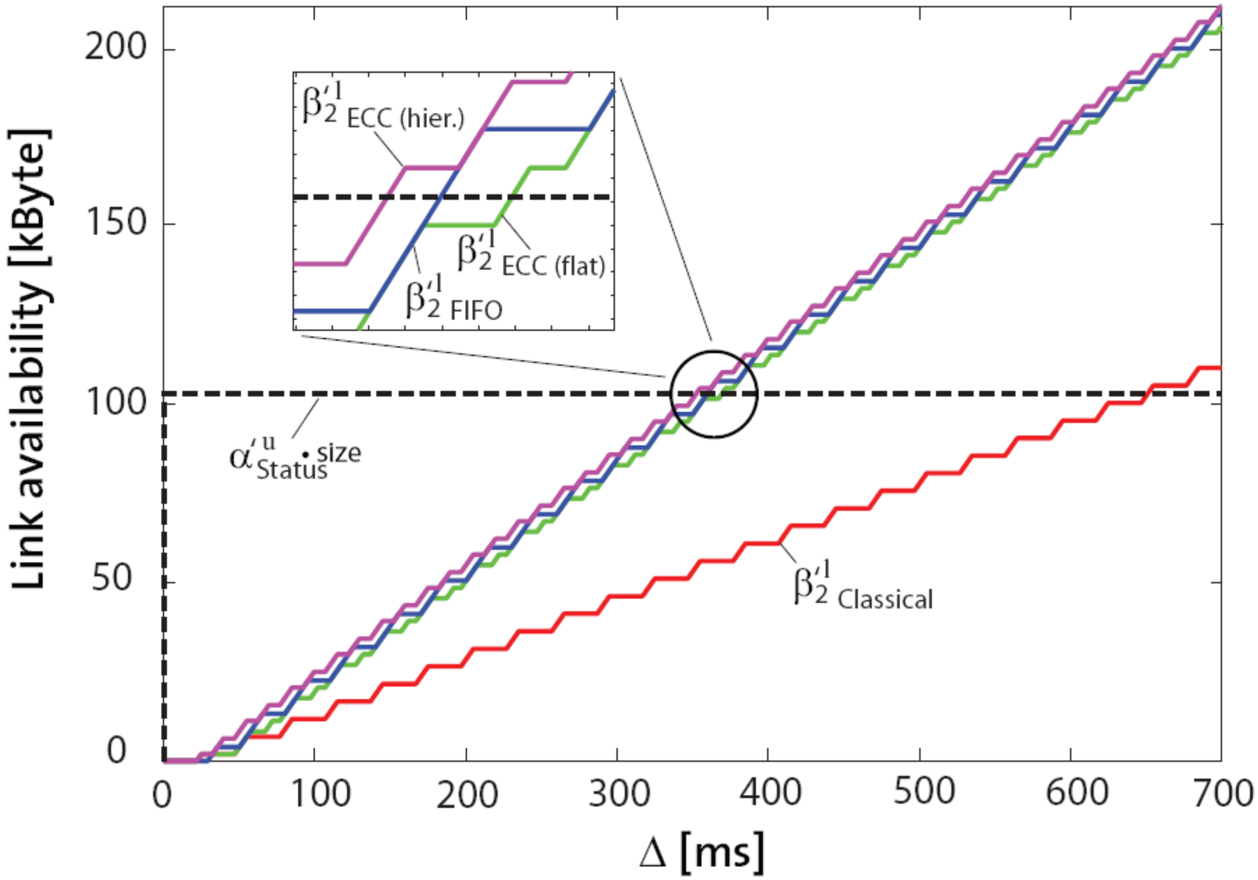


ECC (hierarchic)



Case Study: Results

	Classic	FIFO	ECC (flat)	ECC (hierar.)
Max. delay	1.954 s	1.255 s	1.316 s	1.248 s



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Conclusion

- Two new methods for modeling and analysis of joined event streams in modular performance analysis

- The concept of Event Count Curves is orthogonal to existing event stream models (PJD, arrival curves) and transparent to all analysis components $\Rightarrow$ Compositionality of methods is not affected

- ECC operators for structured streams allow *arbitrary* decomposition of streams

- Comparisons and Case Study highlight the utility of the proposed methods

Thank you!

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