A Meta-modeling Framework for Dynamic Reconfiguration of Dataflow Graphs

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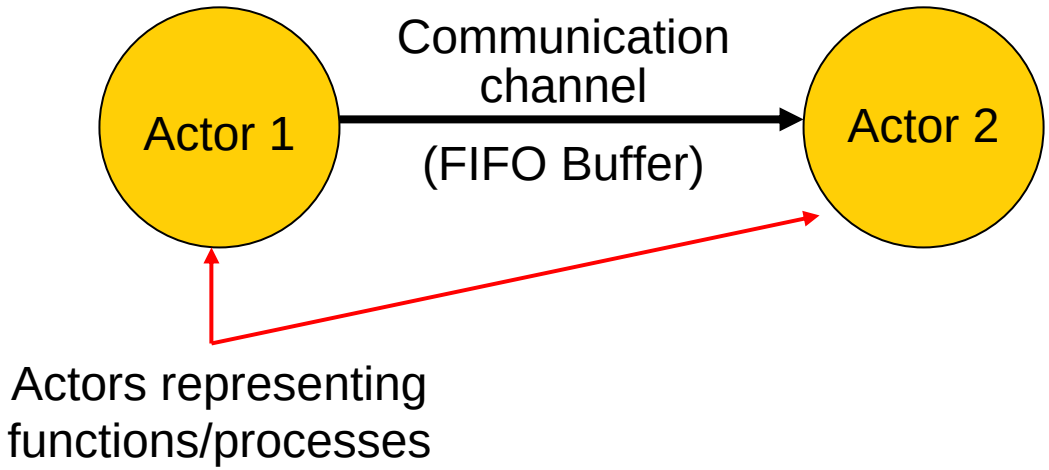
Outline

- Introduction
- Background
- Dataflow Graphs
- Synchronous Dataflow
- Parameterized Dataflow
- Blocked Dataflow
- Dynamic Graph Topology
- Conclusions

Introduction: Dataflow

- Used widely in design tools for DSP.
- Application is modeled as a directed graph.



Introduction: Dataflow

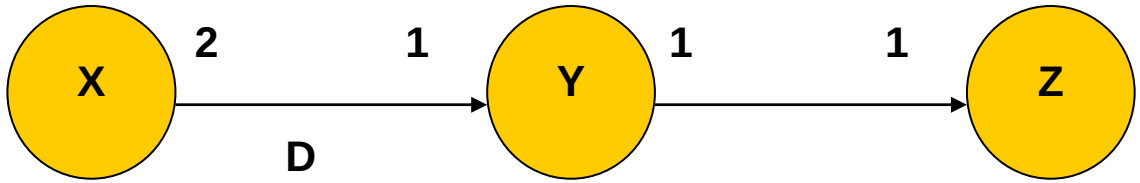
- Data-driven execution model
  - A node can execute whenever it has sufficient data on its input edges.
  - The order in which nodes execute is not part of the specification.
  - The order is typically determined by the compiler, the hardware, or both.
- Iterative execution
  - Body of loop to be iterated a large or infinite number of times.

Background

- Petri nets
  - Depicts structure of a distributed system as a directed bipartite graph consisting of places and transitions. Arcs run between places and transitions.
- Marked Graphs
  - Special case of a Petri net where every place has exactly one incoming arc and one outgoing arc.
- Computation Graphs
  - A finite graph with a set of nodes, each associated with a function and a set of arcs. A branch is a queue of data directed from one node to another.
  - A function can be fired only when the number of tokens present on the arc exceeds a given threshold.
- Kahn Process Networks
  - Consists of nodes representing arbitrary sequential programs communicating via channels of the process networks with blocking read and non-blocking write operations.

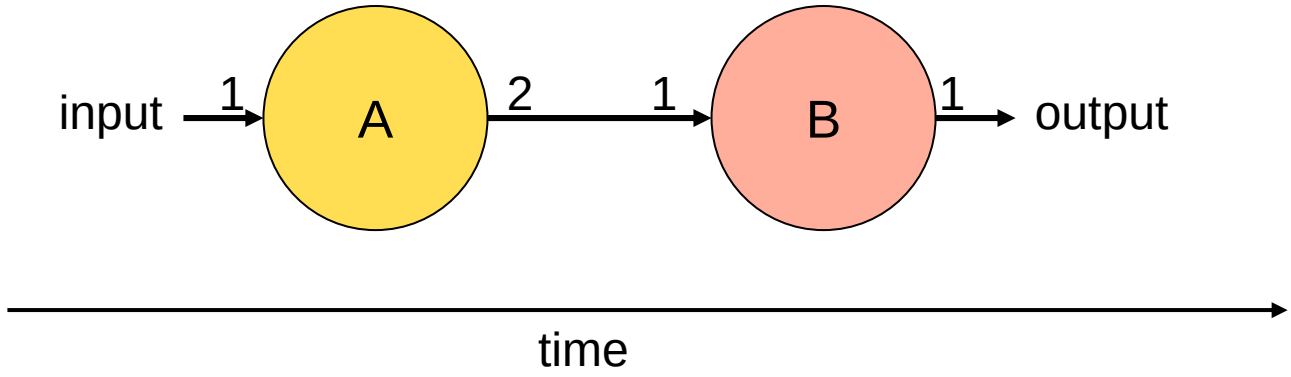
Synchronous Dataflow (SDF)

- The number of tokens produced and consumed is restricted to be a positive integer known at compile time [1].



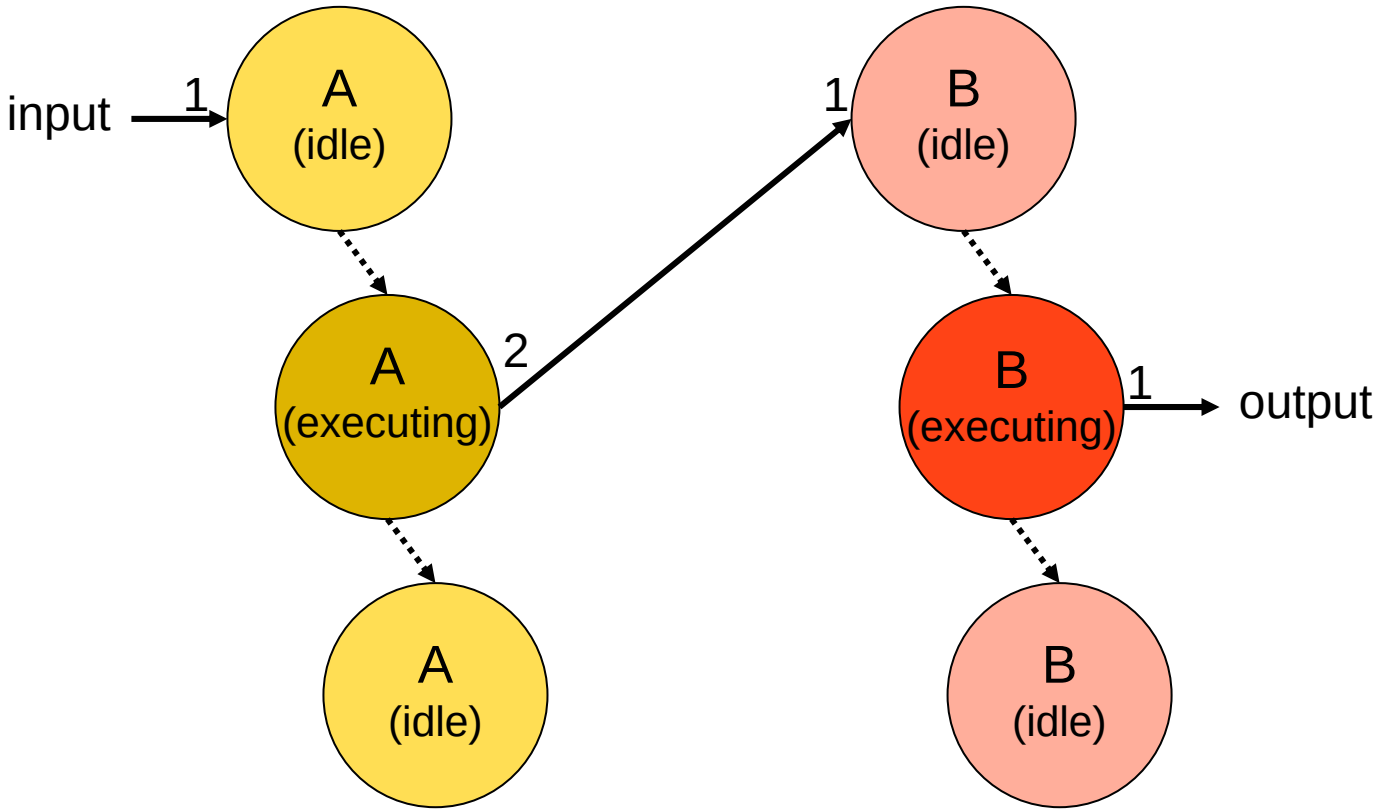
Dataflow: Data-triggered or Event-triggered?

- Dataflow graphs essentially represent data-triggered system.



Dataflow: Data-triggered or Event-triggered?

- Dataflow can model event triggered systems too



Dataflow: Pros and Cons

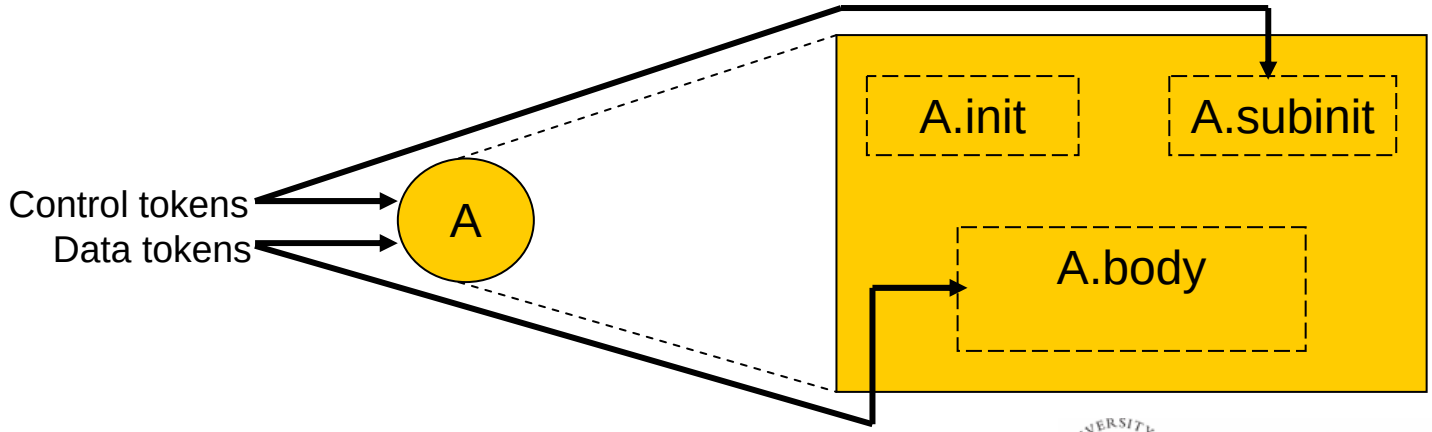
- Advantages
  - Static scheduling and compile-time predictability for useful restricted forms of dataflow
  - Exposes opportunities for coarse-grain optimizations
- Disadvantages
  - Limited expressive power of the static (restricted forms)
  - Lack of intuitive appeal for the dynamic (Turing complete) forms

Parameterized Dataflow

- (PDF) is a meta-modeling framework that can be applied to any underlying form of dataflow graph (“base model”) that has a well-defined notion of graph iteration [2].
- Increases expressive power while allowing many static analysis techniques, and keeping much of the intuitive structure of the base model.

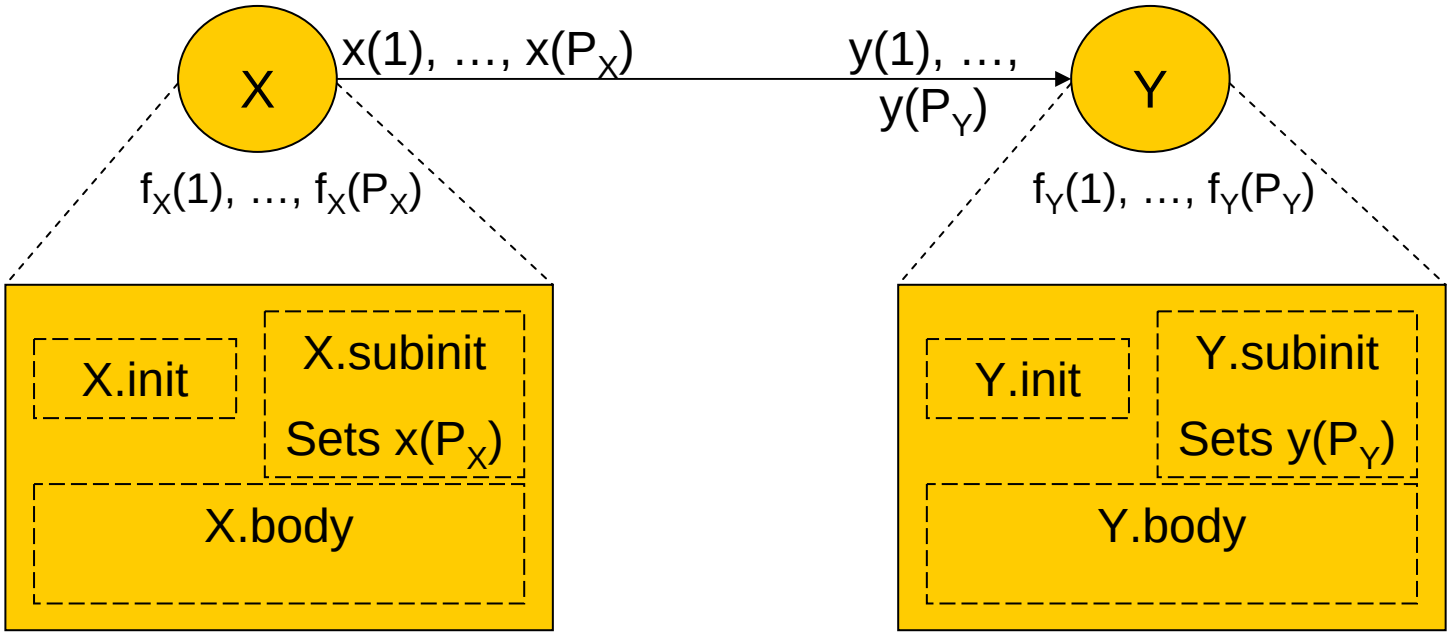
Parameterized SDF (PSDF)

- Parameterized SDF is obtained by parameterizing arbitrary aspects of an SDF graph (actors, edges, dataflow properties) and allowing parameters to be dynamically changed according to a structured hierarchical discipline [2].
  - *init* and *subinit* graphs are dataflow graphs that are responsible for reconfiguring parameters associated with a subsystem.
  - *init* executes less frequently but can perform less restricted reconfiguration operations compared to subinit.
- An actor is characterized by a set of parameters that can control the actor's functionality, as well as its dataflow behavior.



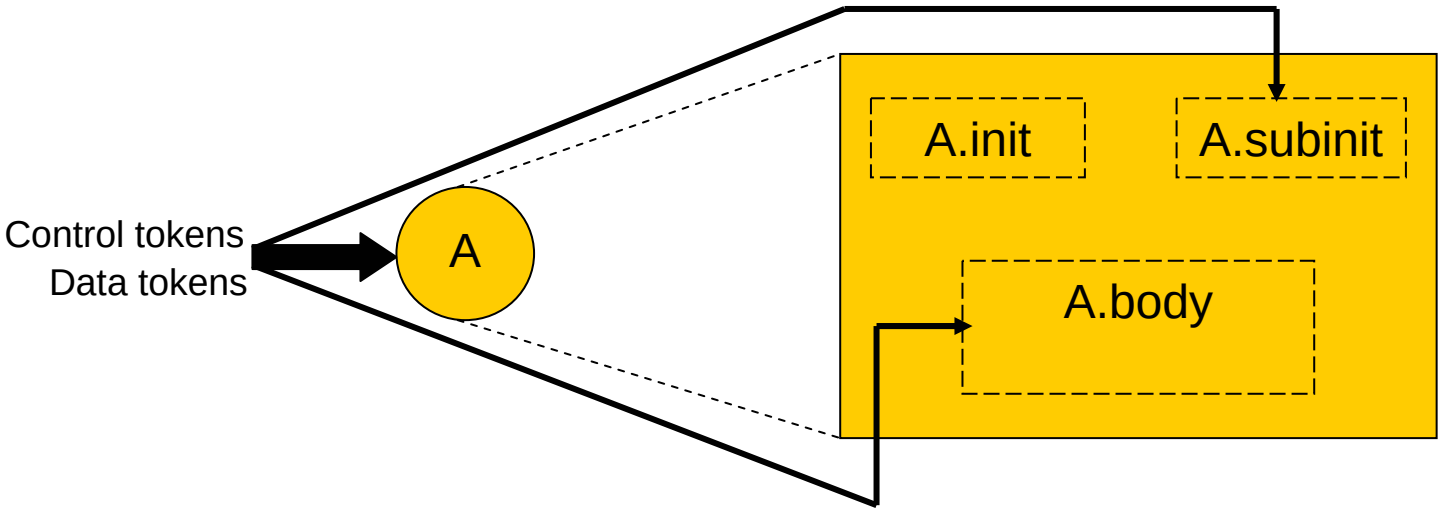
Parameterized Cyclo-static SDF (PCSDF)

- Parameterized CSDF is obtained by parameterizing cyclo-static SDF.
- There are 2 fundamental dataflow properties which can be parameterized
  - period of the cycle of phases
  - data rates associated with each phase



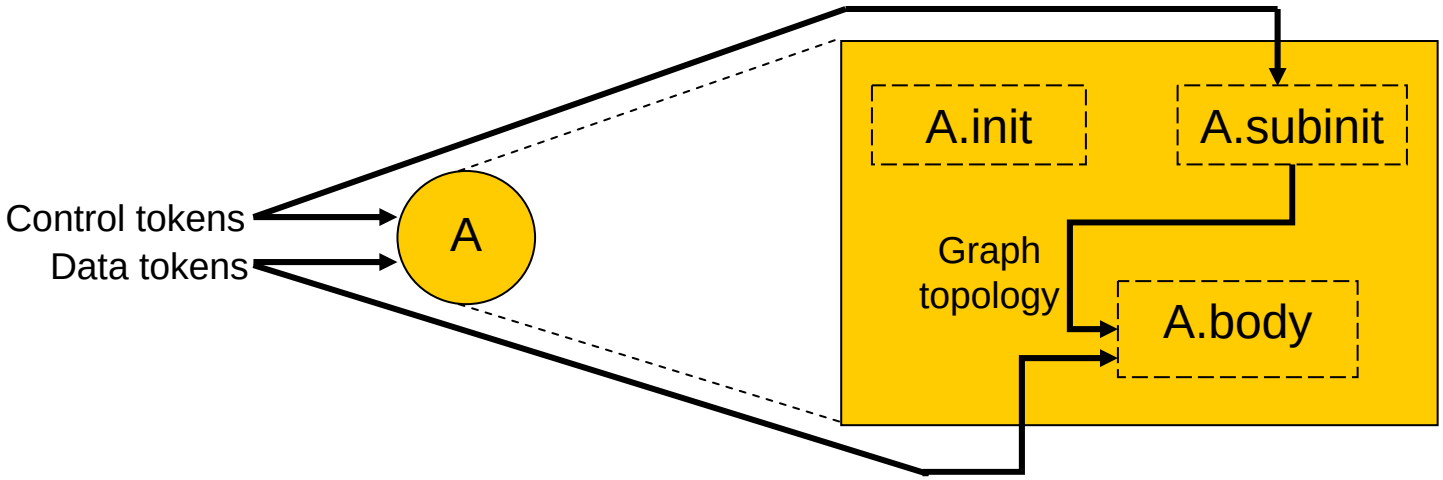
Blocked Dataflow

- Extends parameterized dataflow: the *set* of *parameters* used to reconfigure sub-systems or sub-graphs are extracted from the input data stream [3]

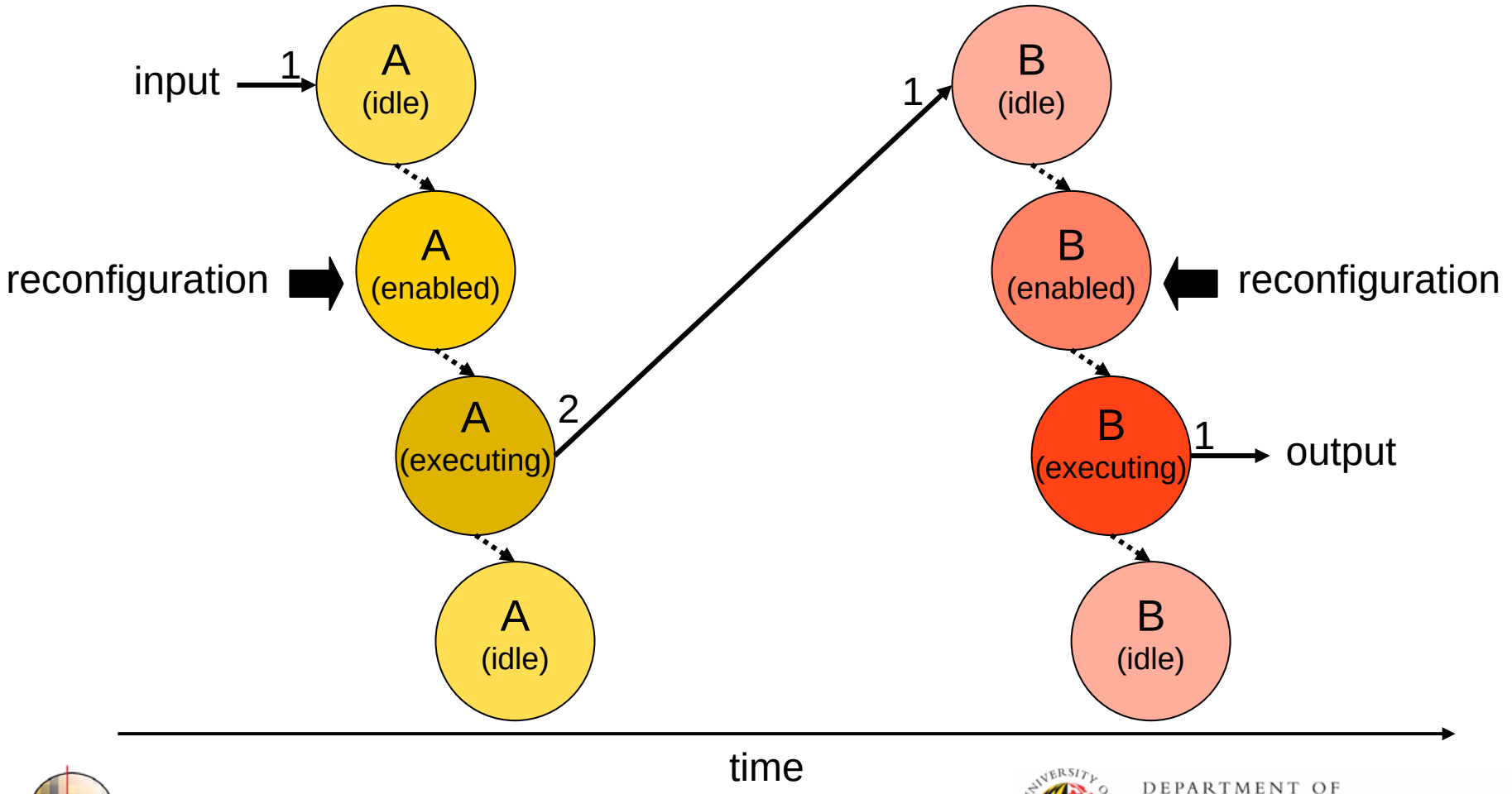


Dynamic Graph Topology

- Extends PSDF to allow dynamic change of graph topology at run-time [4].
  - The *init* graph determines the transfer rate of each port of a graph.
  - The *subinit* graph determines the graph topology of the associated body graph before the invocation of the body graph.



Parameterized Dataflow and Event-triggered Systems



Experiments (DGT)

- An MPEG2 video encoder was implemented.
- Target platform was Texas Instruments C64xx series using Code Composer Studio.
- Two implementations were done
  - Separate graph approach using a combination of SDF and FSM.
  - DGT implementation.
- SAS (Single Appearance Schedule) and MAS (Multiple Appearance Schedule) and a combination of SAS and MAS was used.
- The DGT method selects different scheduling methods (SAS or MAS) depending on graph characteristics.

Experimental Results (DGT)

< DGT Graph >
C1 : SAS
C2 : MAS
C3 : SAS+MAS

< Separate Graph >
C4 : SAS
C5 : MAS
C6 : SAS+MAS

Frame Size		DGT approach			Separate Graph approach		
		C1	C2	C3	C4	C5	C6
128 *128	Code	26,469	31,946	26,469	63,341	79,773	63,341
	Buffer	1,557	1,429	1,557	4,667	4,283	4,667
	Total	28,026	33,375	**28,026**	68,008	84,056	**68,008**
256 *256	Code	26,469	31,946	26,469	63,341	79,773	63,341
	Buffer	6,173	5,661	6,173	18,515	16,979	18,515
	Total	32,642	37,607	**32,642**	81,856	96,752	**81,856**
480 *720	Code	26,469	44,903	31,393	63,341	118,645	94,180
	Buffer	52,852	19,991	21,788	158,551	59,967	65,364
	Total	79,321	64,894	**53,181**	221,892	178,612	**159,544**
768 *1024	Code	26,469	58,074	44,564	63,341	158,157	133,692
	Buffer	130,680	45,320	49,397	392,035	135,955	148,192
	Total	157,149	103,394	**93,961**	455,376	294,112	**281,884**
1080 *1920	Code	26,469	58,074	50,041	63,341	158,157	150,124
	Buffer	1,817,064	100,940	100,937	5,451,187	302,815	302,524
	Total	1,843,533	159,014	**150,978**	5,514,528	460,972	**452,648**

Conclusions

- Parameterized dataflow is powerful modeling paradigm for signal processing applications.
- Various forms of dynamic reconfigurability can be achieved using parameterized dataflow and associated models of computation.
- Though traditional view of dataflow based systems is as data-triggered systems, they can be used to model event-triggered systems as well.

Thank you!

References

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