EE382N.23: Embedded System Design and Modeling

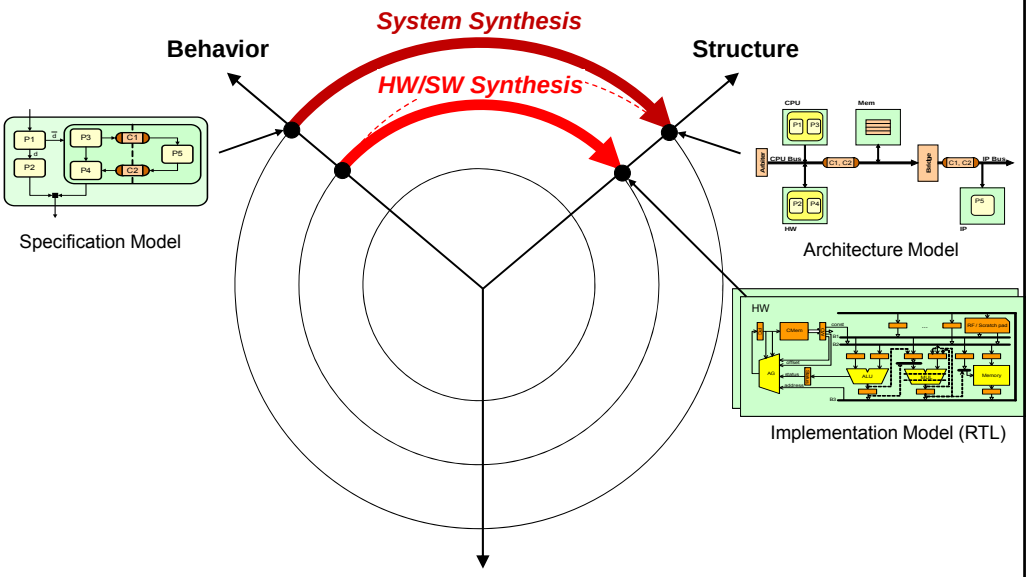
Lecture 7 – System Refinement

Andreas Gerstlauer
Electrical and Computer Engineering
University of Texas at Austin
gerstl@ece.utexas.edu

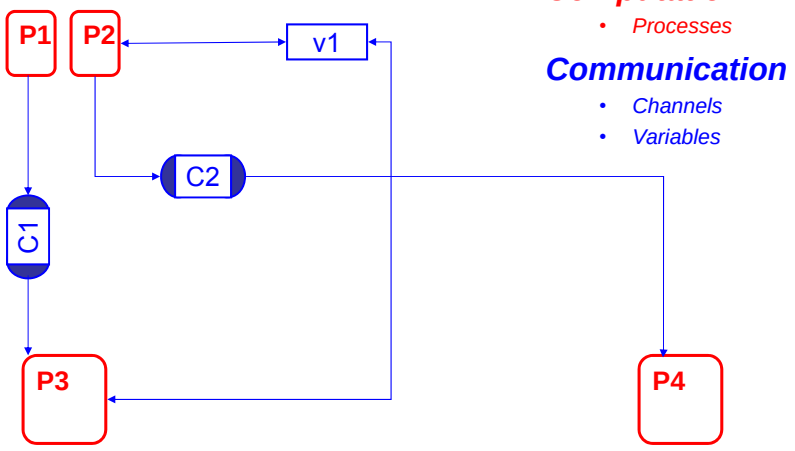
Lecture 7: Outline

- **System-level design flow**
  - From specification to implementation
- **System-level refinement**
  - Modeling flow & refinement process
- **System-level modeling**
  - Virtual protoyping & virtual platform models

System-Level Design Flow



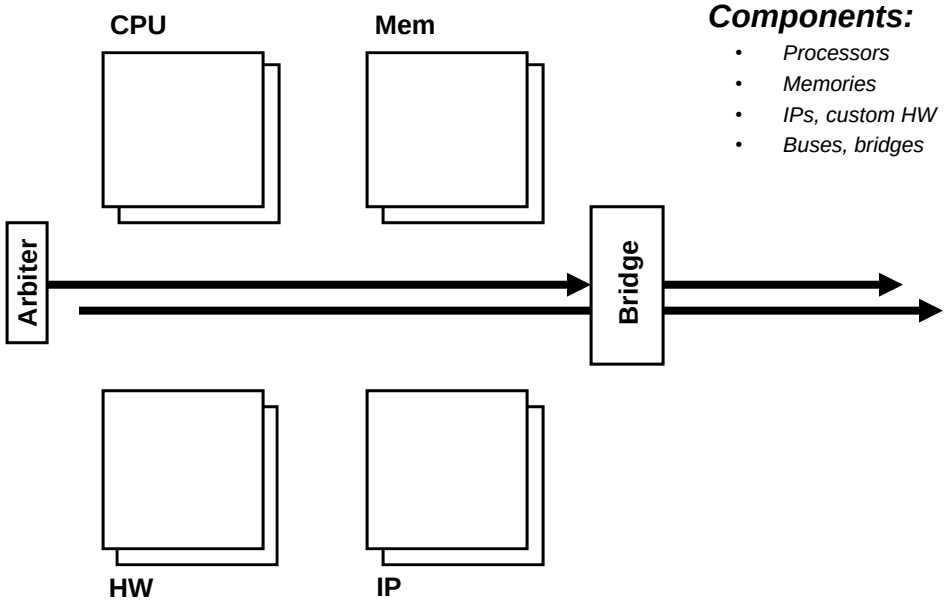
Application Specification (MoC)



Computation
- *Processes*

Communication
- *Channels*
- *Variables*

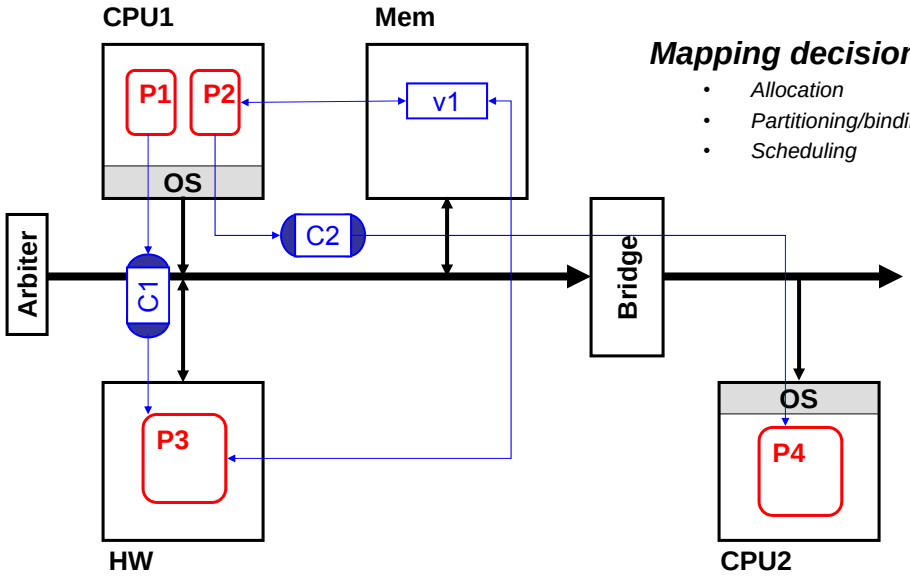
Platform Architecture Template



Components:

- *Processors*
- *Memories*
- *IPs, custom HW*
- *Buses, bridges*

System Definition

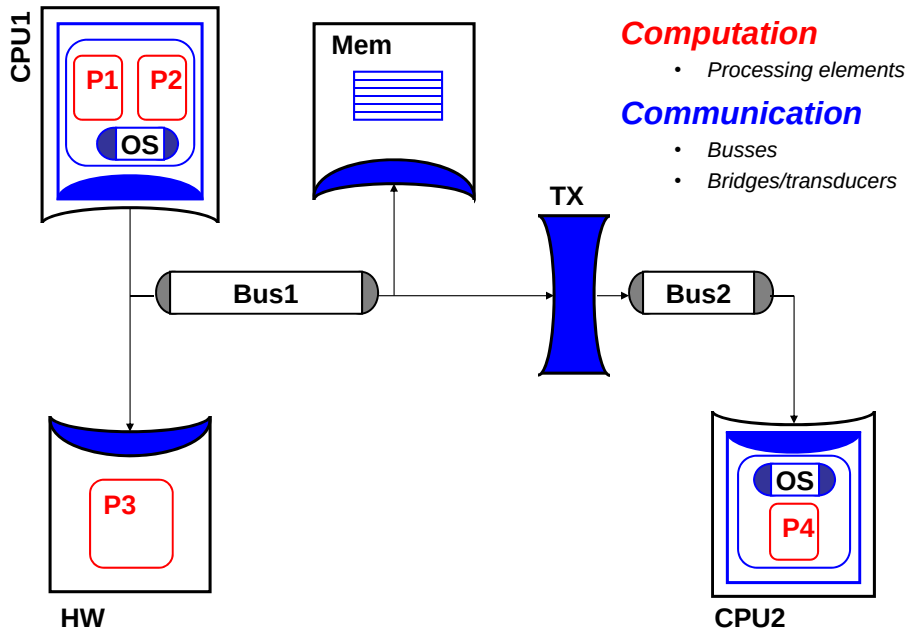


Mapping decisions:

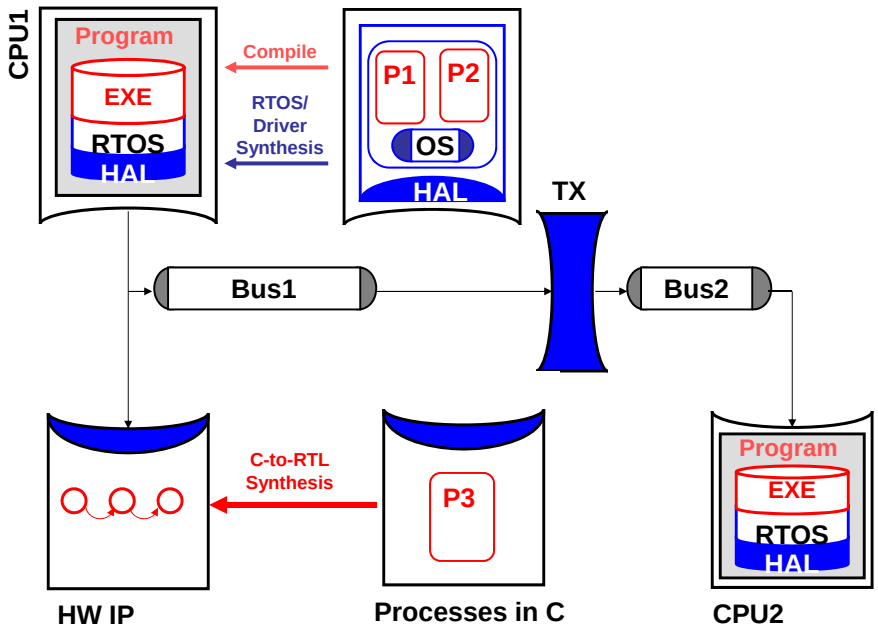
- *Allocation*
- *Partitioning/binding*
- *Scheduling*

System Definition = Application + Platform + Mapping

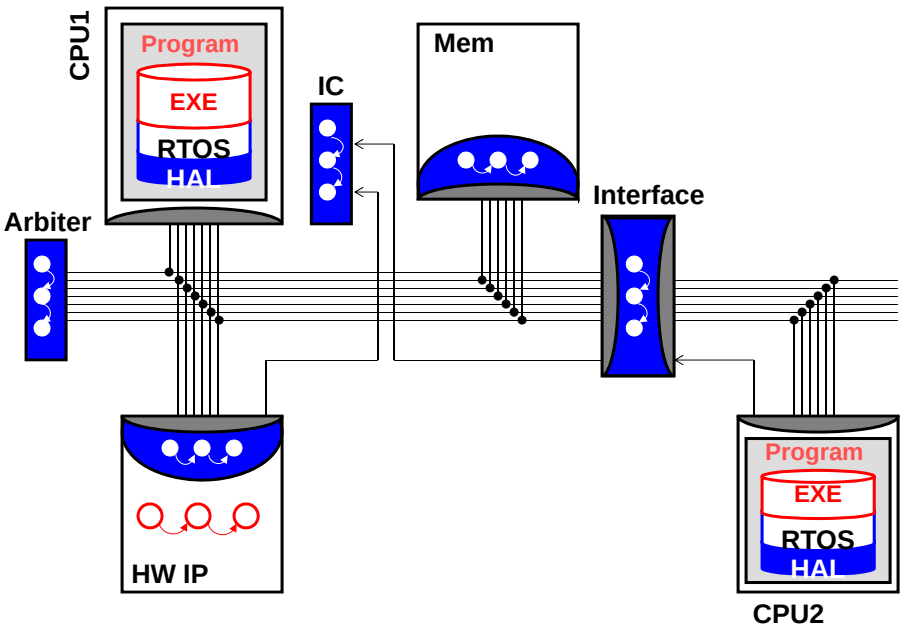
Architecture Model



Backend Hardware/Software Synthesis



Implementation Model

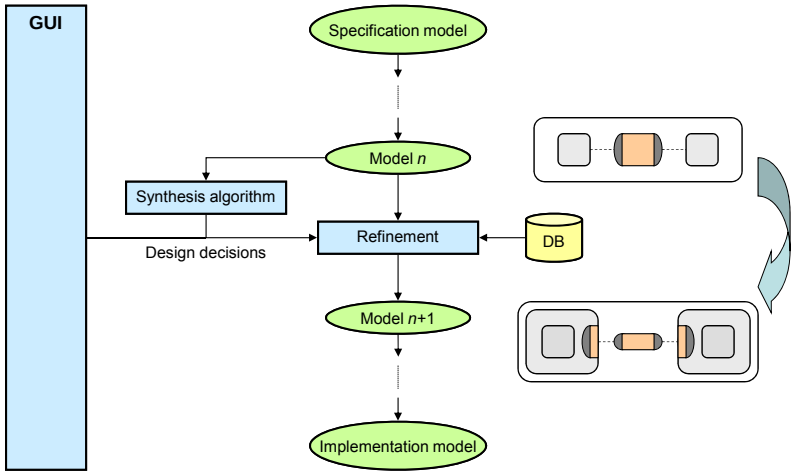


Modeling

- **Basis of any design flow and design automation**
  - Inputs and outputs of design steps
    - Capability to capture complex systems
    - Precise, complete and unambiguous
  - Models at varying levels of abstraction
    - Level and granularity of implementation detail
    - Speed vs. accuracy
- **Design models as an abstraction of a design instance**
  - Representation of some aspect of reality
    - Virtual prototyping for validation through simulation or formal analysis
  - Specification for further implementation
    - Describe desired functionality
  - Documentation & Specification (Simulation & Synthesis)
    - Abstraction to hide details that are not relevant or not yet known
    - Different parts of the model or different use cases for the same model

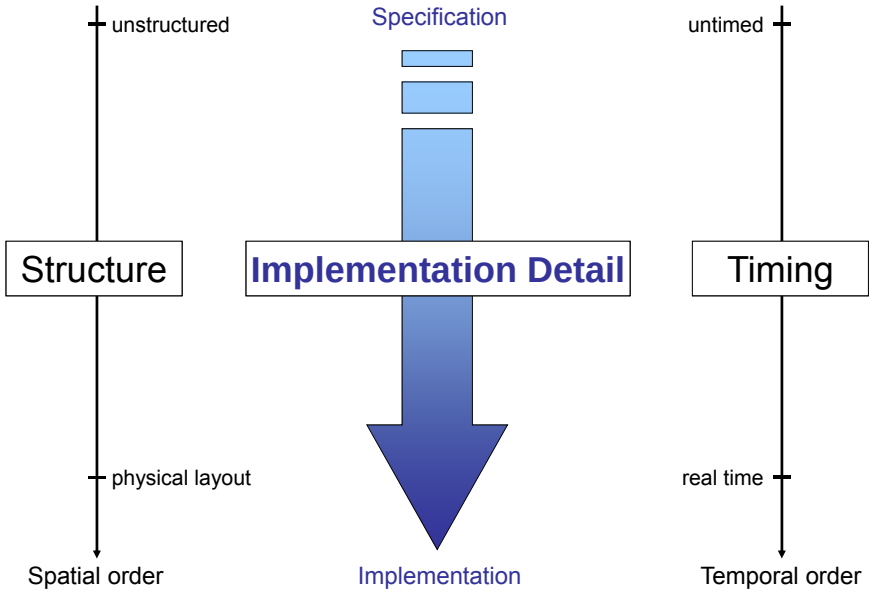
Synthesis Flow

- **Synthesis = Decision making + model refinement**



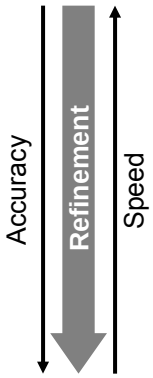
- **Successive, stepwise model refinement**
- **Layers of implementation detail**

Refinement

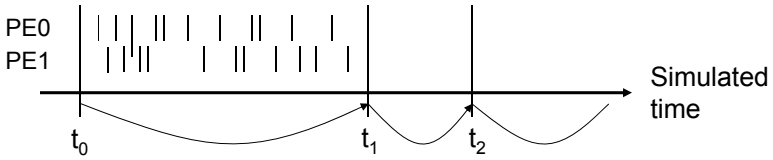


Speed vs. Accuracy

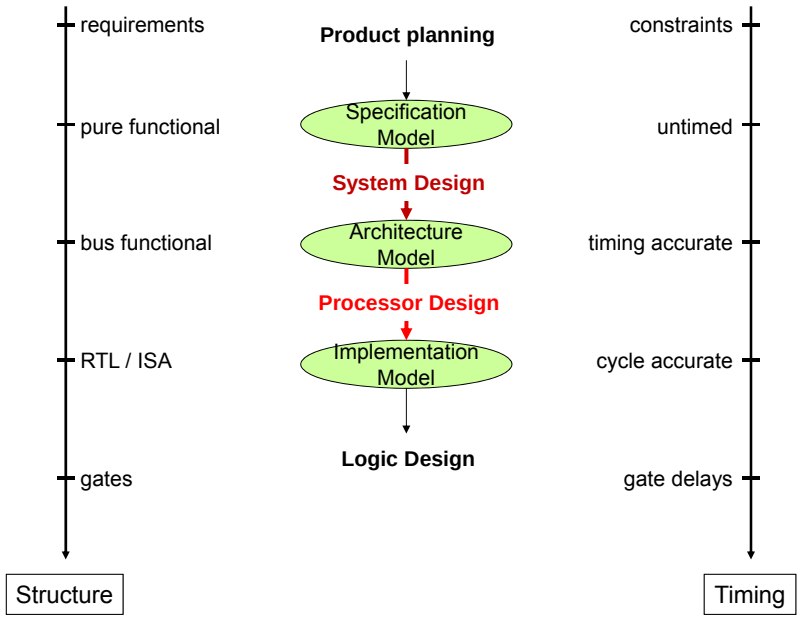
- **Discrete-event simulation speed**
  - Proportional to number of simulated events
  - Proportional to granularity of simulated time/detail
    - "Real-time": simulated vs. simulation time > 1
- **Discrete-event simulation accuracy**
  - Proportional to simulated implementation order
  - Inversely proportional to simulated granularity
    - Where order matters (structural concurrency)



➢ **Fundamental modeling tradeoff**

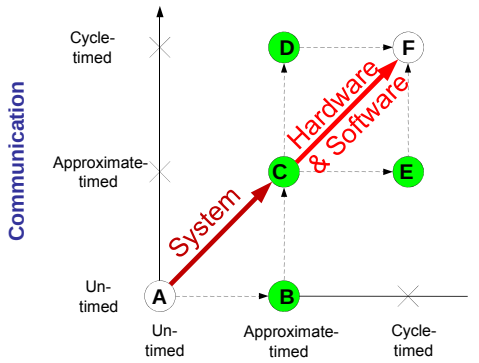


Abstraction Levels



Computation vs. Communication

- **System design flow**
  - Path from model A to model F

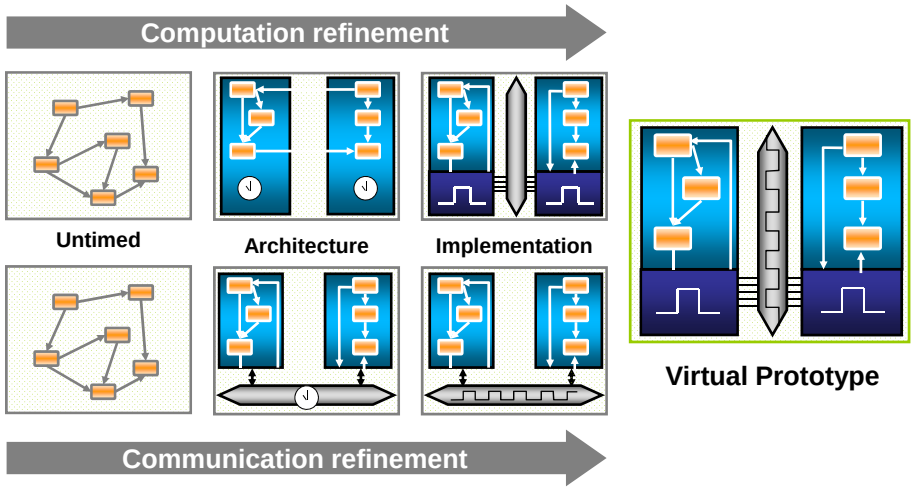


A. System specification model
B. Timed functional model
C. Architecture model
D. Pin-/bus cycle-accurate model (P/BCAM)
E. Computation cycle-accurate model (CCAM)
F. Cycle-accurate implementation model (CAM)

Source: L. Cai, D. Gajski. "Transaction level modeling: An overview", ISSS 2003

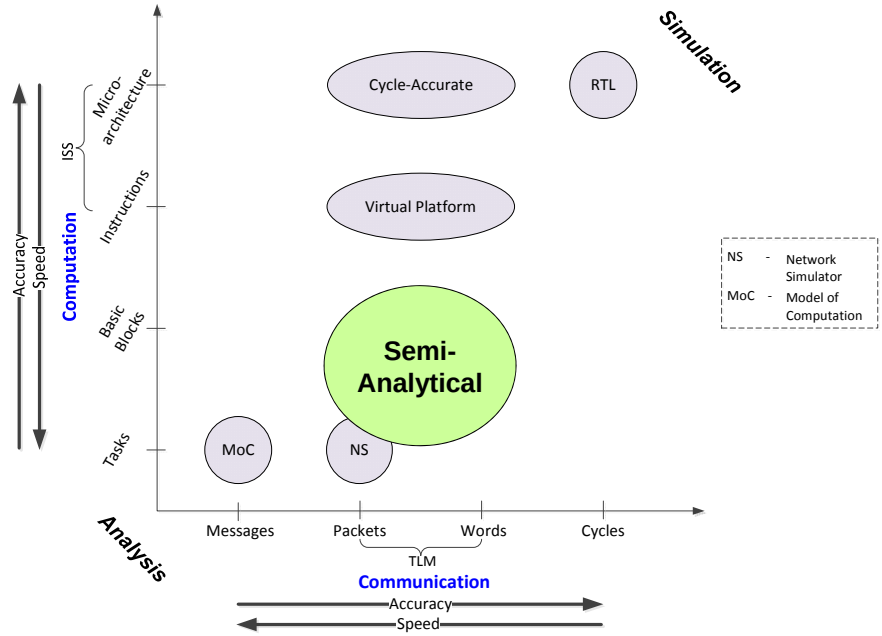
- **Design methodology and modeling flow**
  - Set of models and transformations between models

Virtual Platform Prototyping

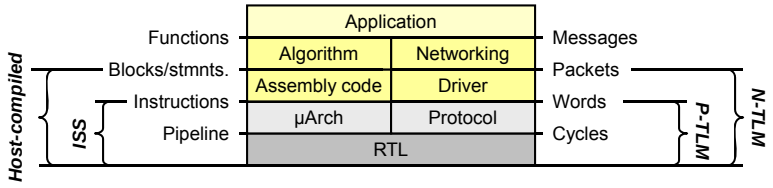


Source: C. Haubelt, Univ. of Rostock

System-Level Modeling Space

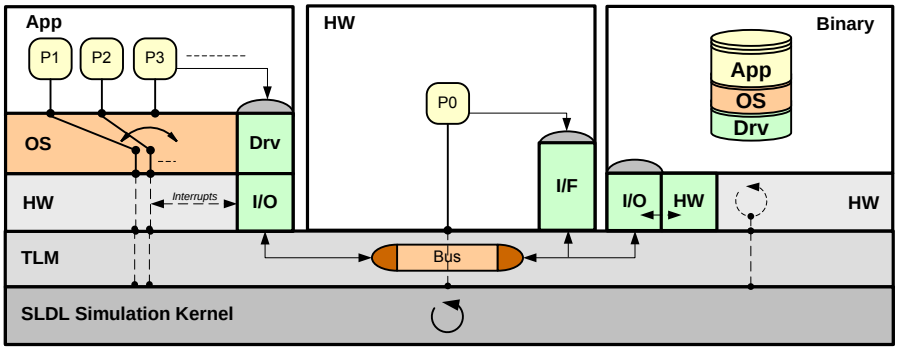


Modeling Levels



- **Host-compiled modeling of computation**
  - Abstract execution above instructions
  - ➢ Native execution of functionality
  - ➢ Back-annotation of timing, energy, …
  - ➢ Models of execution environment (OS & processor)
- **Transaction-level modeling (TLM) of communication**
  - Abstract transactions above pins and wires
  - ➢ Function calls for data transfer functionality
  - ➢ Back-annotation of timing, energy, …
  - ➢ Models of topology and glue logic

Virtual Platform Models



- **CPU model**
  - Source-level timing, energy, .. back-annotation
  - OS & processor models
- **Hardware/IP model**
  - Functional model
  - Timing, energy, … back-annotation
- **ISS model**
  - Cycle-accurate [GEM5]
  - Functional [QEMU] + timing, energy, … back-annotation
- **System-level design language (SLDL) & TLM backplane [SystemC]**

Lecture 7: Summary

- **System-level design flow**
  - Decision making + refinement
- **System refinement**
  - Structure and timing
- **System modeling**
  - Computation and communication