Futuristic Computational Model in the Era of NVRAM

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Introduction

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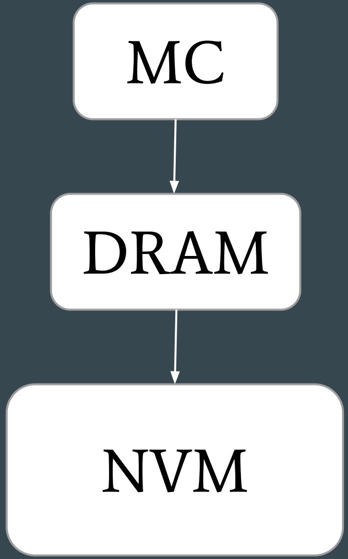
Solution: **Hybrid Memory Systems**

Hybrid Memory Systems (HMS)

- DRAM as a cache for the NVM
    - Capacity Loss



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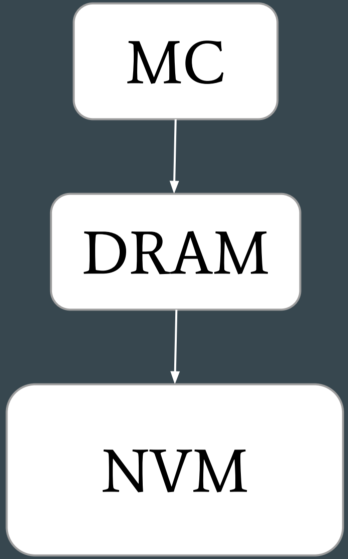

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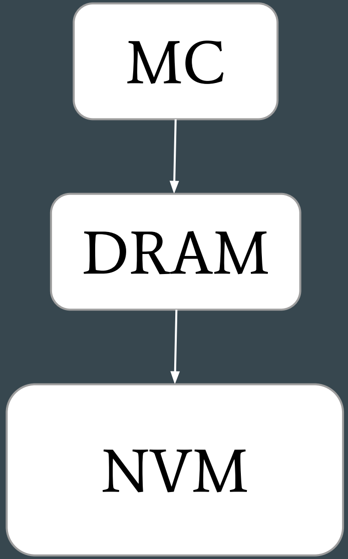

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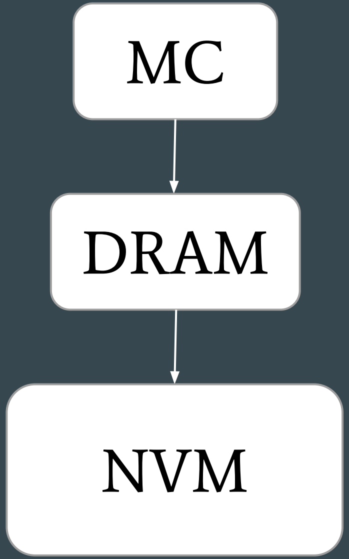

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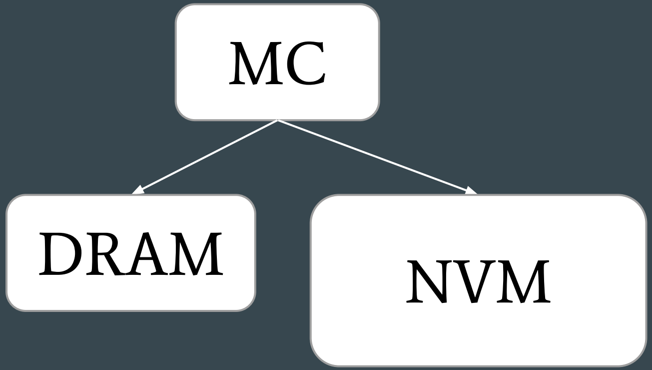

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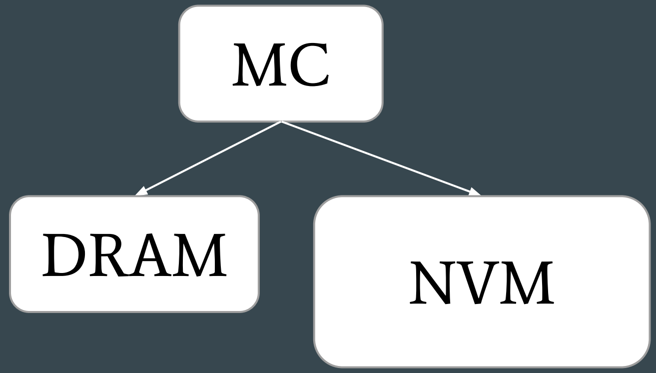

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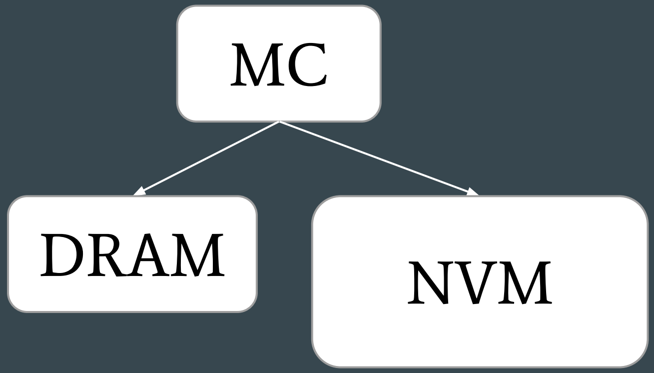

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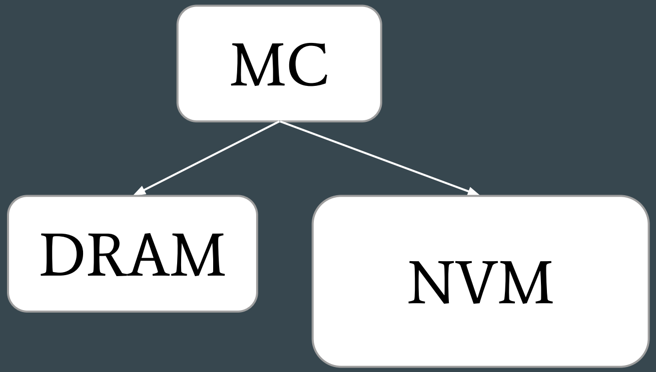
  - **OS support is helpful**



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Surveys show that hardware and software issues needs to be tackled for successful integration of NVMs

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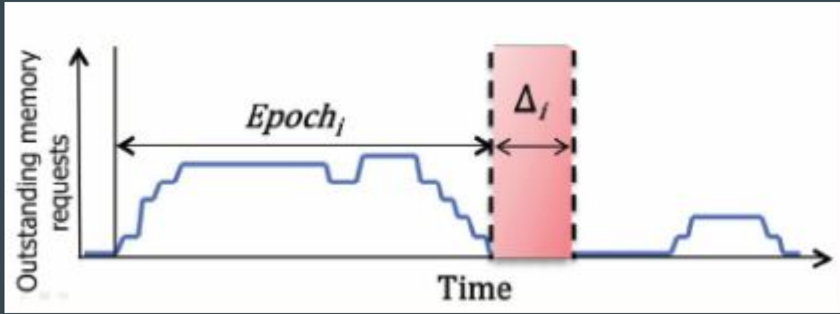
- Operating Systems

Emulation: Quartz



- Latency Model
  - Dynamically injects software created delays

$$\Delta_i = M_i.(NVM_{lat} - DRAM_{lat})$$

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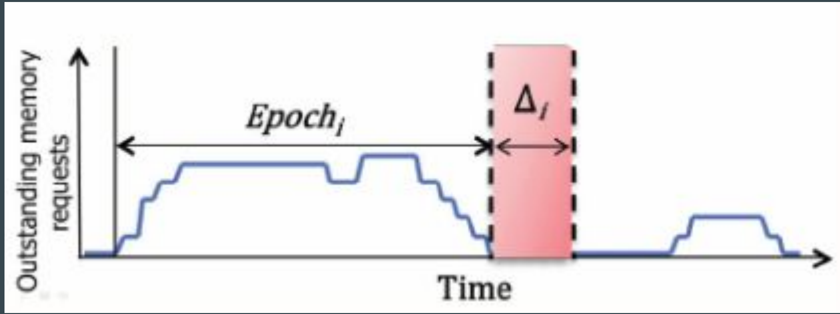

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- Bandwidth Model
  - DRAM thermal control feature

Programming Model: Mnemosyne

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Operating Systems: Twizzler

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- **Lack of Implementation Details and Incomplete**

Object Model

- Abstract binary files to object

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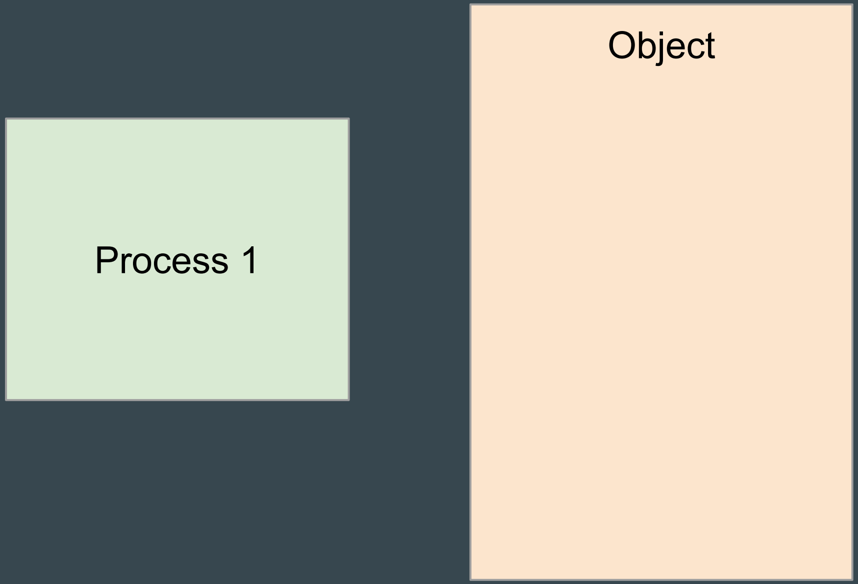
  - Pipeline Processing

High Level View

Process 1

High Level View



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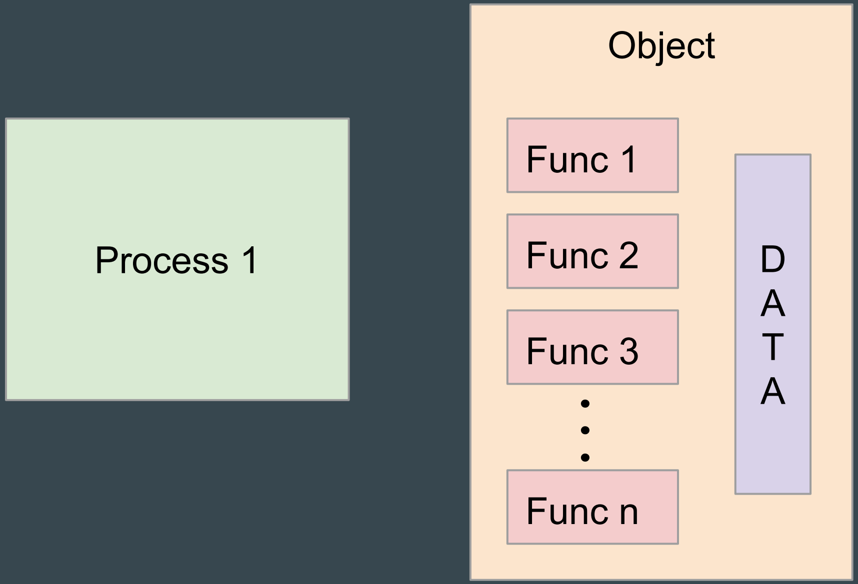

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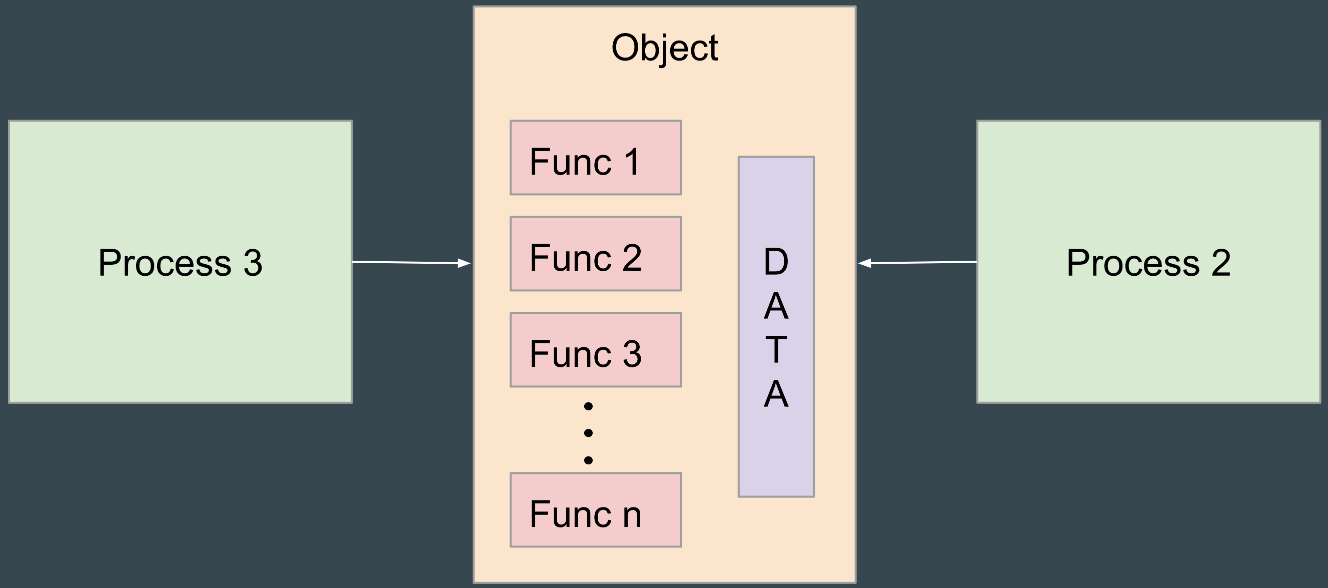

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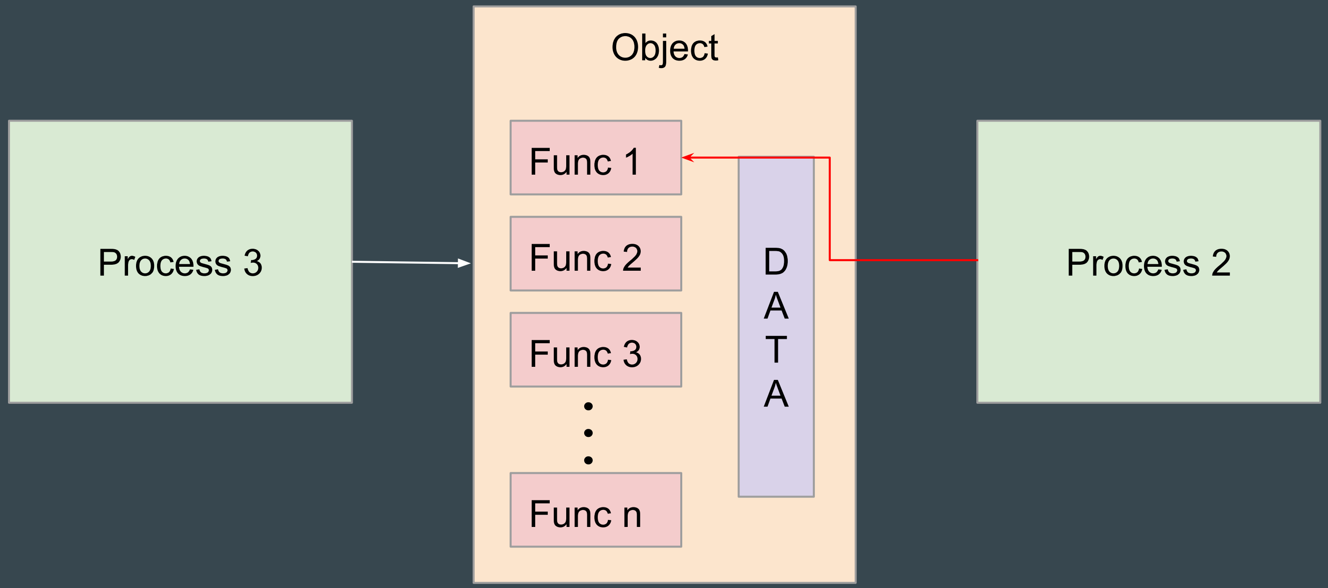

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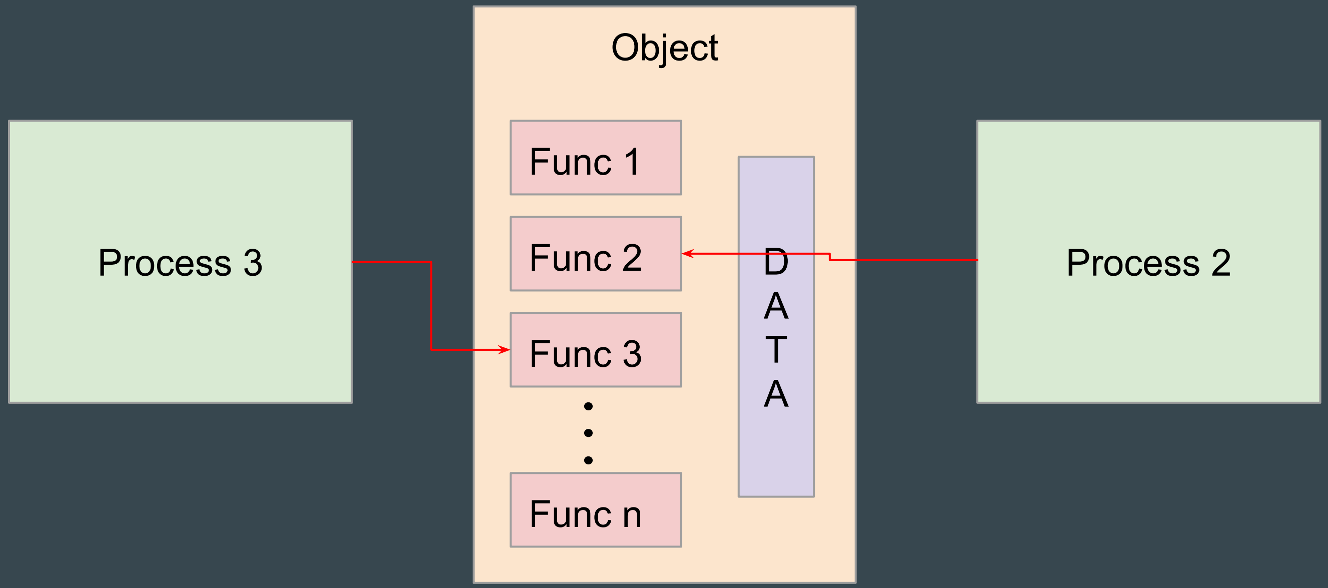

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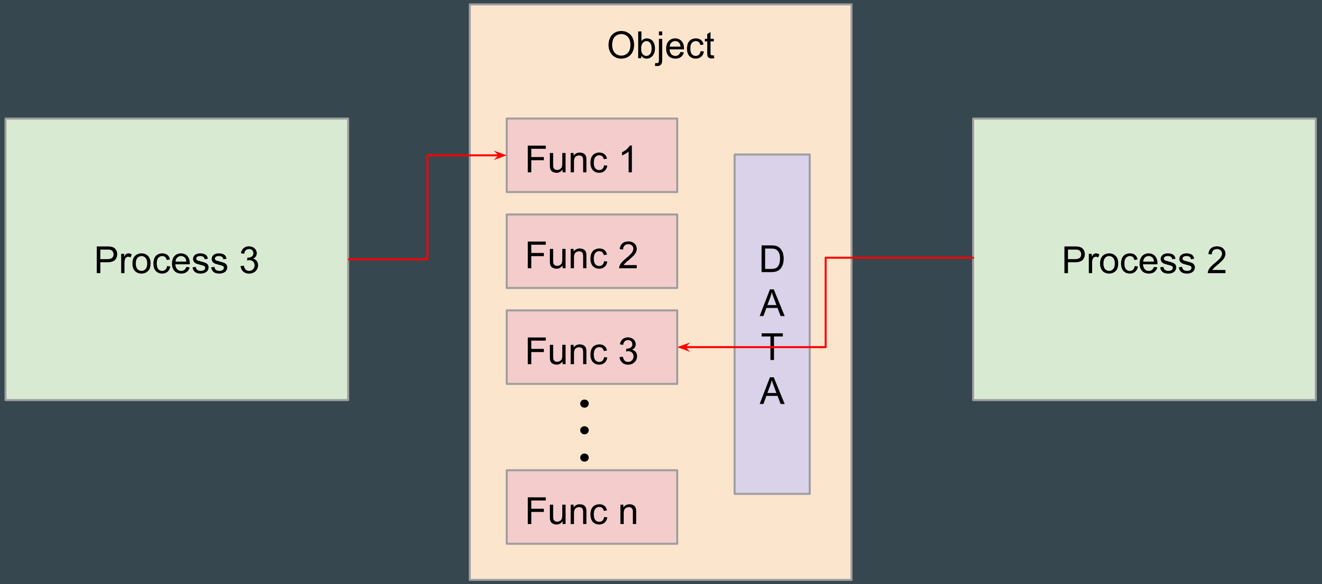

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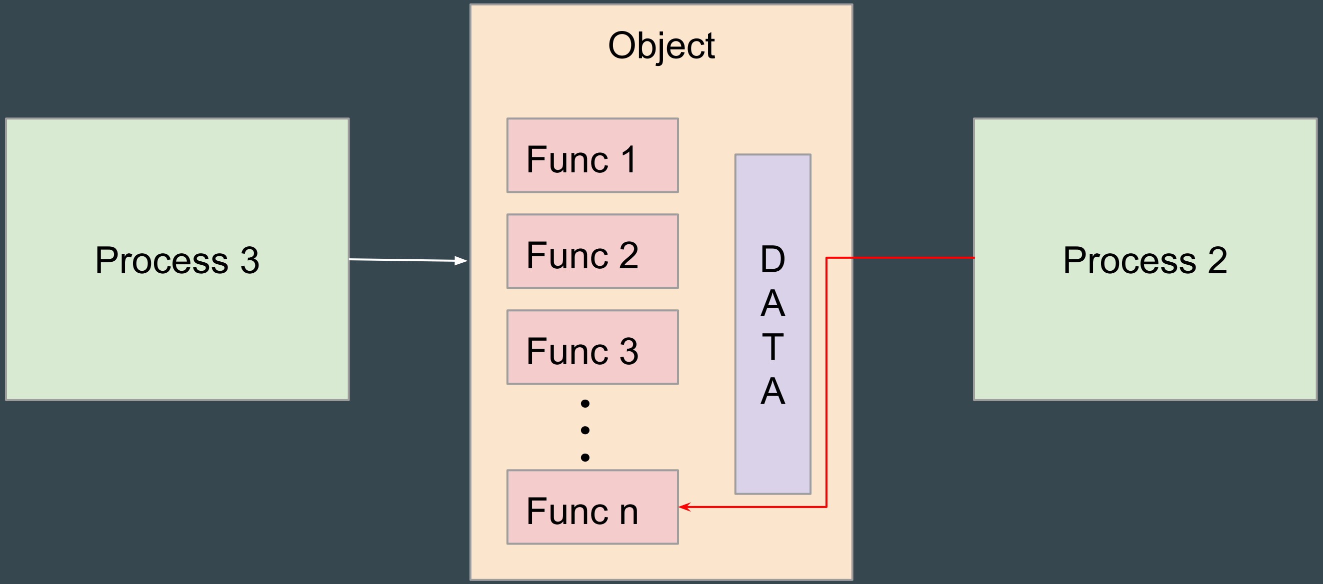
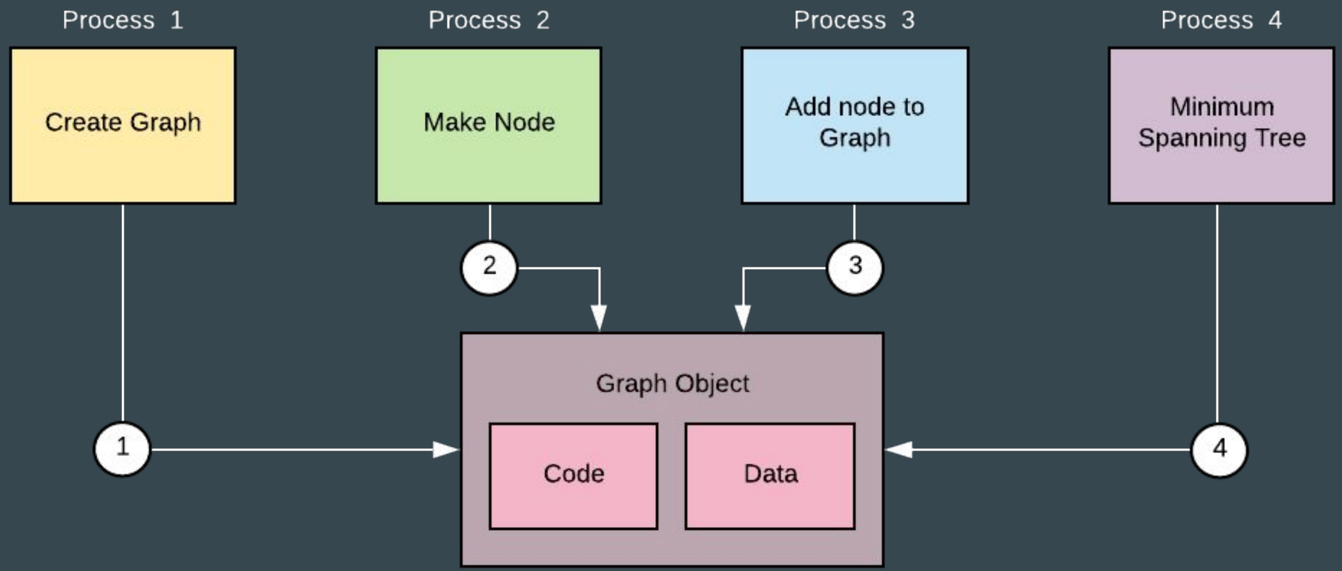


Example: Graph Processing



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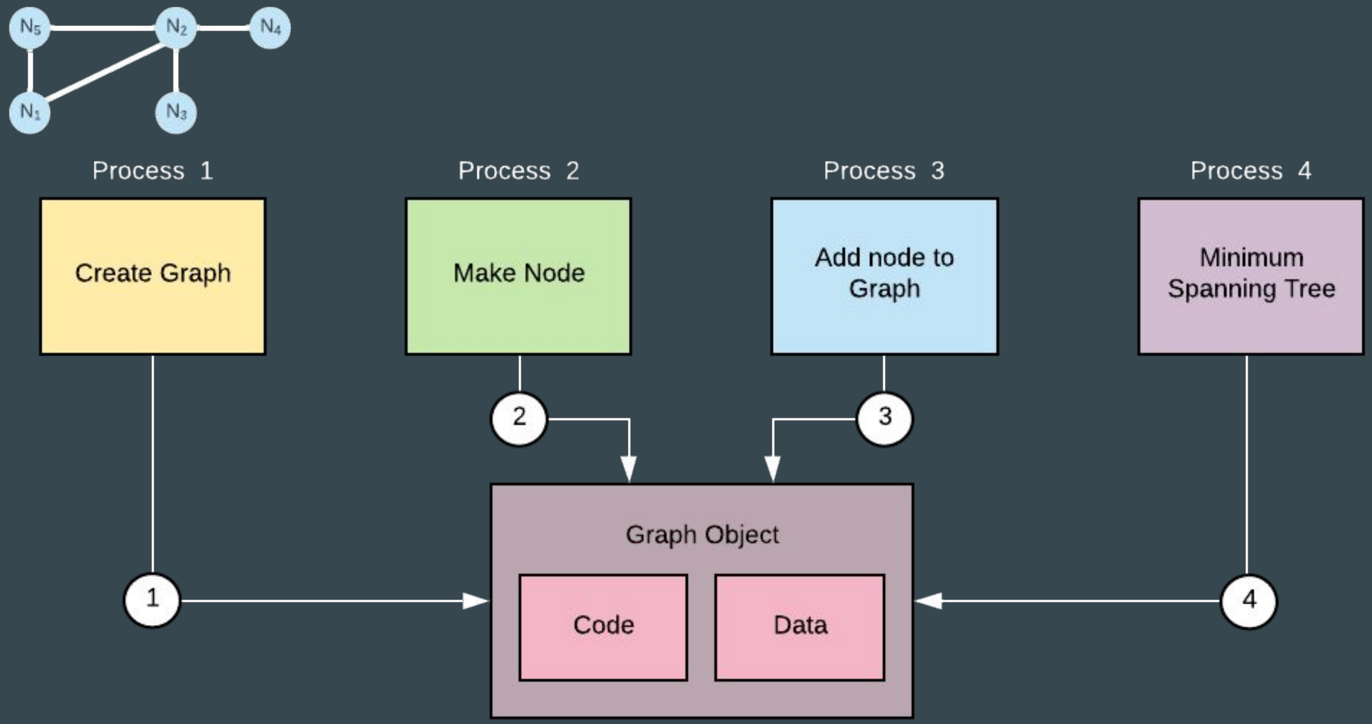

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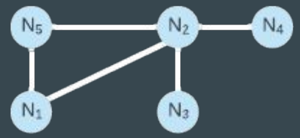
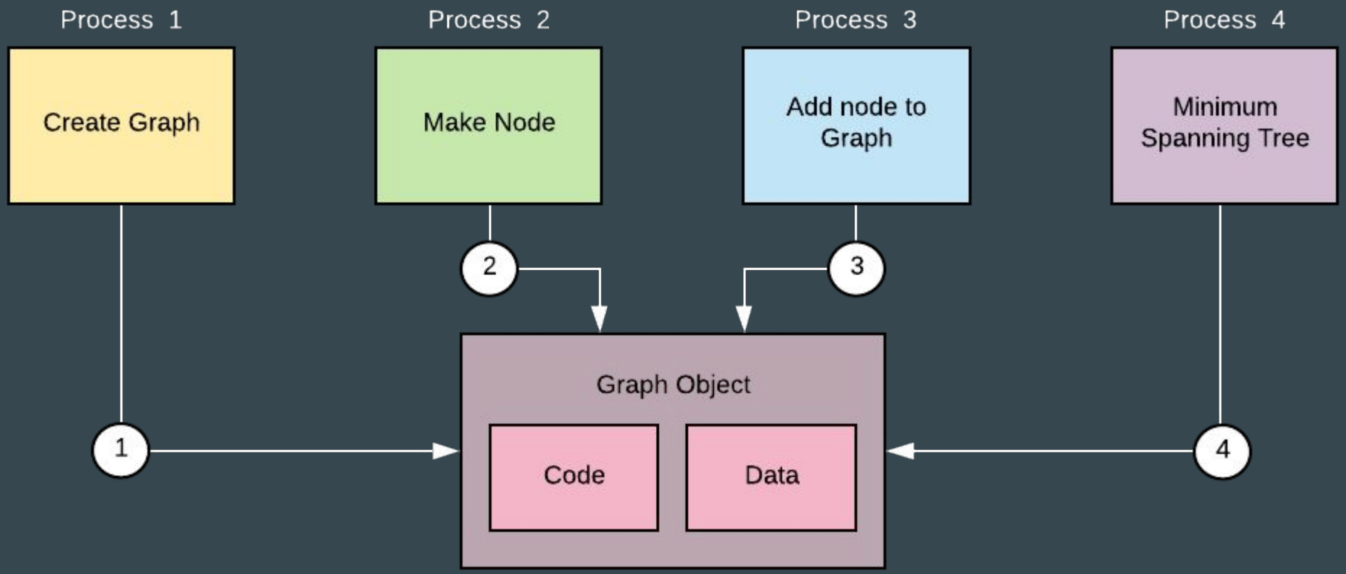


Node	N_1	N_2	N_3	N_4	N_5
Edge	0	0	1	1	0



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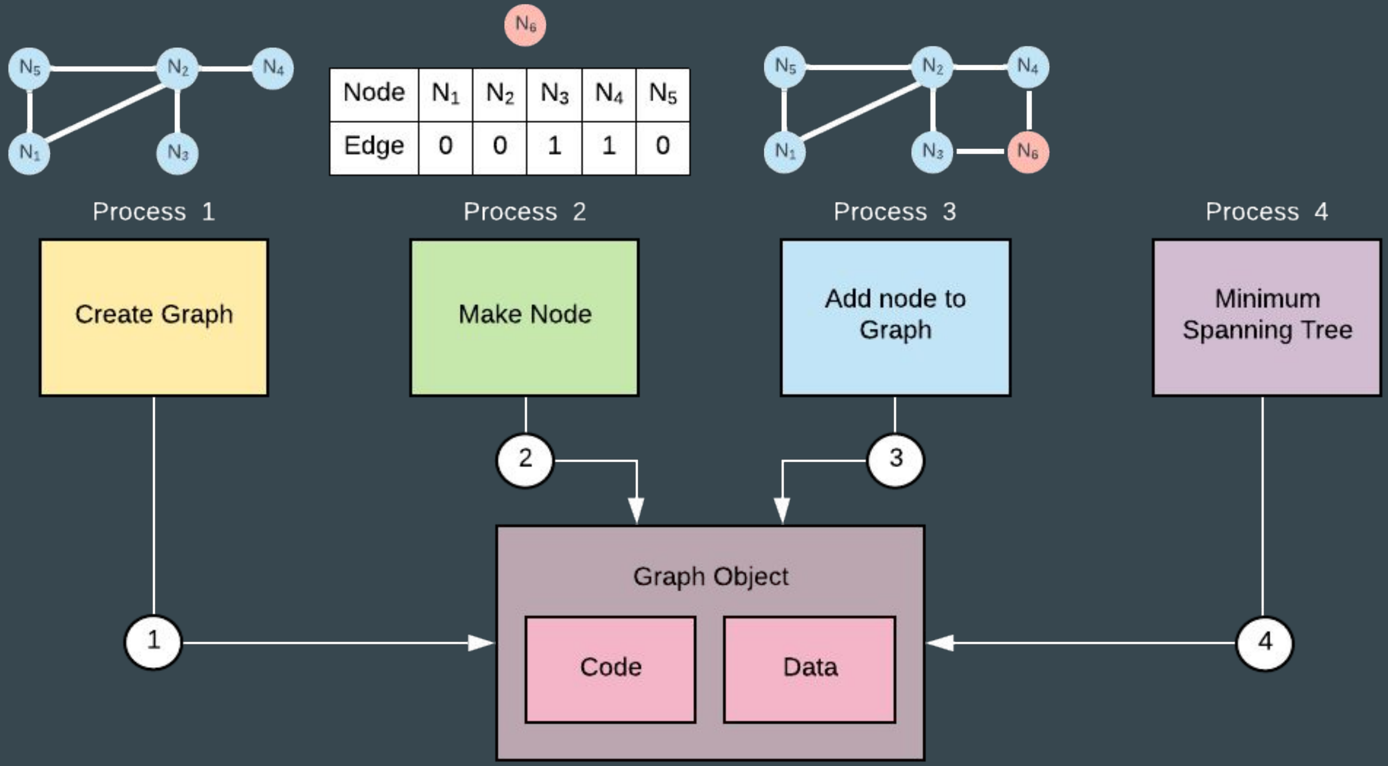

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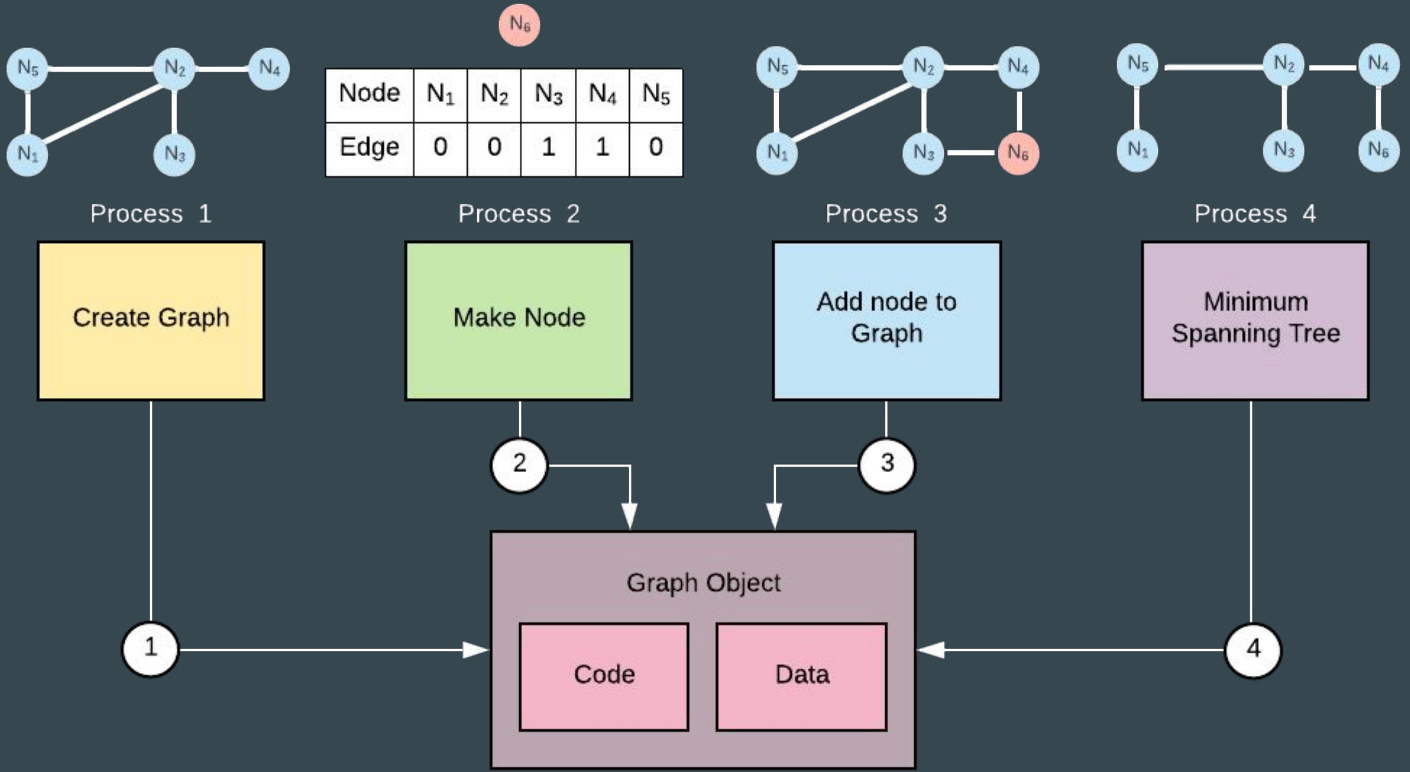

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  - Communication through IOCTL
- A user library, which needs to be linked to process
  - Responsible for making all the calls related to the object framework
  - Obtains metadata of objects and carry out the required functionality

Interface: Library calls

- Init_object (binary):
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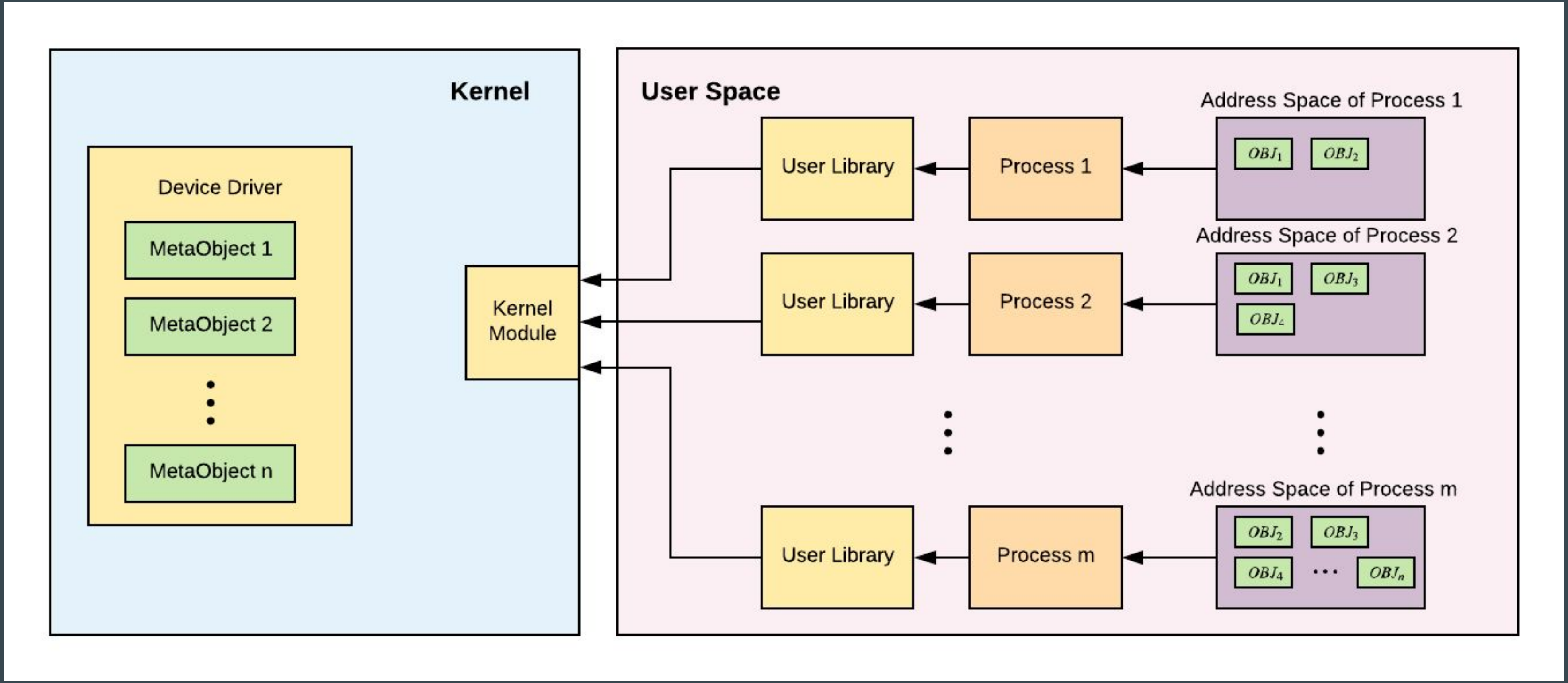
- Append_code (obj_id, binary):
  - Adds the given code in object's memory segment

Implementation: Framework



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- Use Shared Memory Techniques
  - Shm (shmget, shmat, shmdt, shmctl)
  - Mmap

Implementation: Relocations

- Binary (code segment) of object can contain unresolved links (since binary is compiled code)
  - Functions in different library
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Implementation: Relocations

- Binary (code segment) of object can contain unresolved links (since binary is compiled code)
  - Functions in different library
  - Global Variables
- Resolved using elf library
  - Relocation section contains relevant information
  - Target address can be found in symbol table of linked libraries

Applications

Object model is a basic framework which can be used in variety of fields

- Operating System for NVRAM
- Lambda Services
- Distributed Systems

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Applications: Operating System

- Traditional process oriented OS mechanisms don’t have defined behaviour when stopped suddenly
- Objects can be handled in defined manner
- Replace process with Objects
- Make kernel itself an object
    - Requires composition of objects

Applications: Lambda Services

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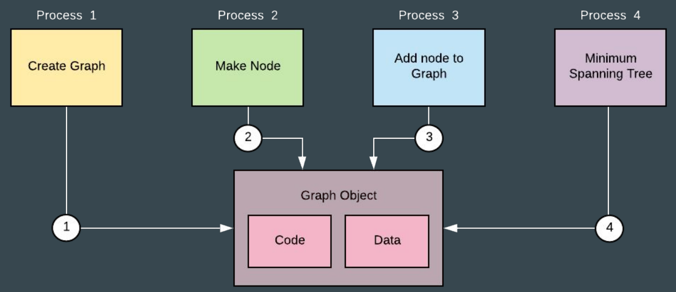
- Modern serverless online computing
- Takes code and data as input and outputs processed data using the code
- Object model fits in perfectly
  - Also provides stateful experience by keeping updated data in the object
  - Requires data input only once

Applications: Distributed Systems

- Make objects the computing entities



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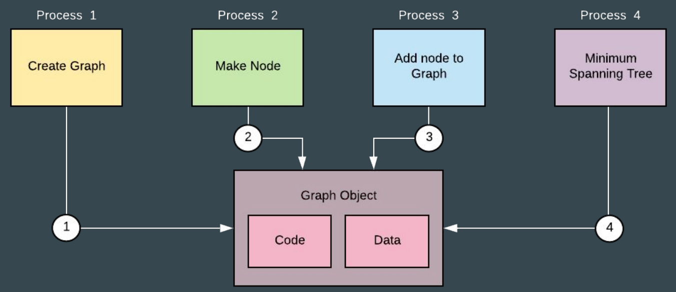

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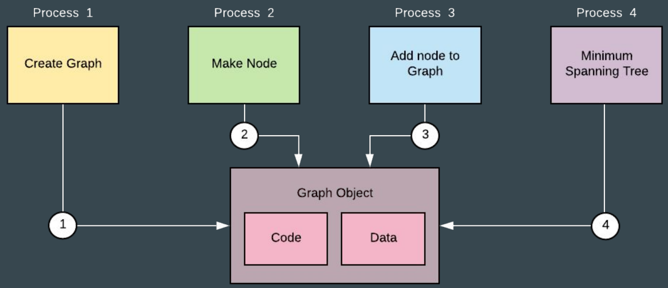
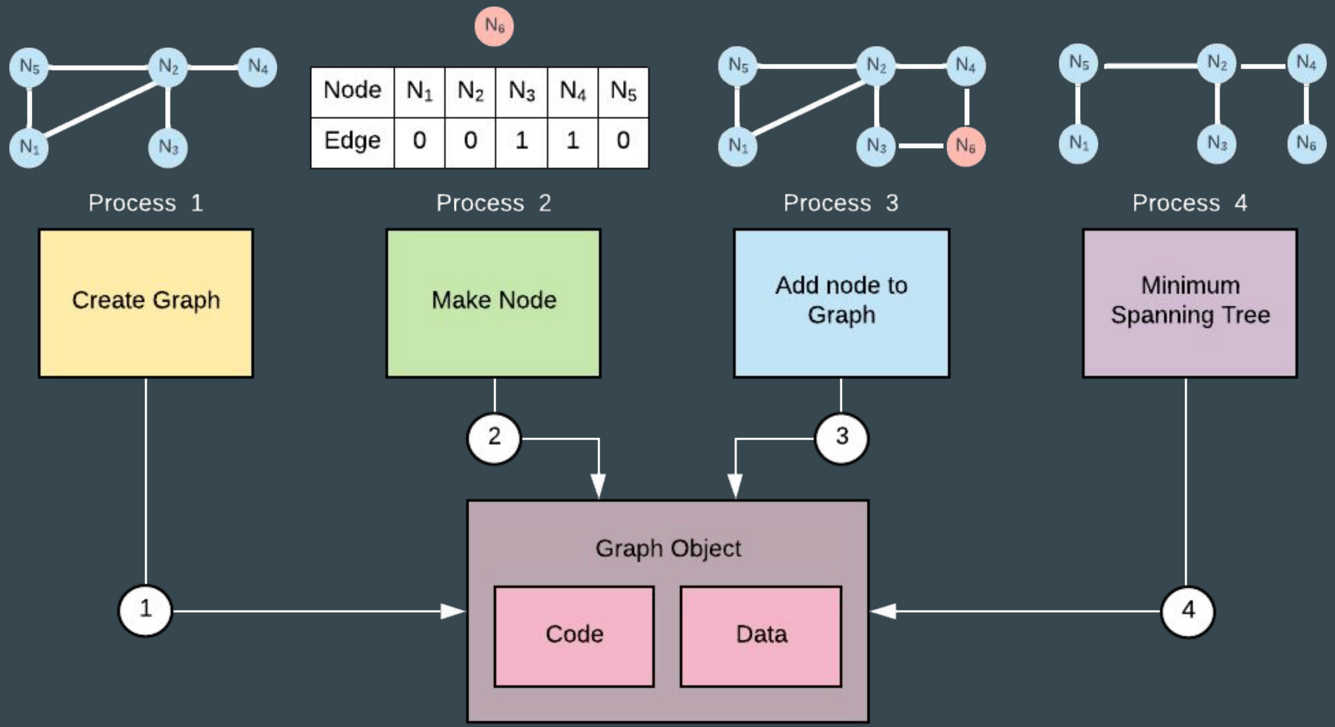
- Signals would automate the computing as well



Evaluation

- Basic Test Cases
  - Consistency Checks
  - Data Integrity
  - Function Calls
  - Add Code (binary)
  - Relocation checks
- Graph Processing

Evaluation: Graph Processing



Future Work

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- Integrate our object model in different applications

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- Object model finds a lot of applications in modern day computing
- This is just a glimpse of the bigger picture that remains to come in future

Thank You !!

Back Up: NVM Characteristics

	SRAM	DRAM	HDD	NAND flash	STT-RAM	ReRAM	PCM	FeRAM
Cell size (F^2)	120–200	60–100	N/A	4–6	6–50	4–10	4–12	6–40
Write Endurance	10^{16}	$>10^{15}$	$>10^{15}$ (pb: mechanical parts)	10^4–10^5	10^{12}–10^{15}	10^8–10^{11}	10^8–10^9	10^{14}–10^{15}
Read Latency	~0.2–2ns	~10ns	3–5ms	15–35μs	2–35ns	~10ns	20–60ns	20–80ns
Write Latency	~0.2–2ns	~10ns	3–5ms	200–500μs	3–50ns	~50ns	20–150ns	50–75ns
Leakage Power	High	Medium	(Mechanical parts)	Low	Low	Low	Low	Low
Dynamic Energy (R/W)	Low	Medium	(Mechanical parts)	Low	Low/High	Low/High	Medium/ High	Low/High
Maturity	Mature	Mature	Mature	Mature	Test chips	Test chips	Test chips	Manufactured