Fresh Breeze Streams

**Programming Model and Architecture for
Real Time Streaming**

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What is a Program Execution Model?

User Code
- Application Code
- Software Packages
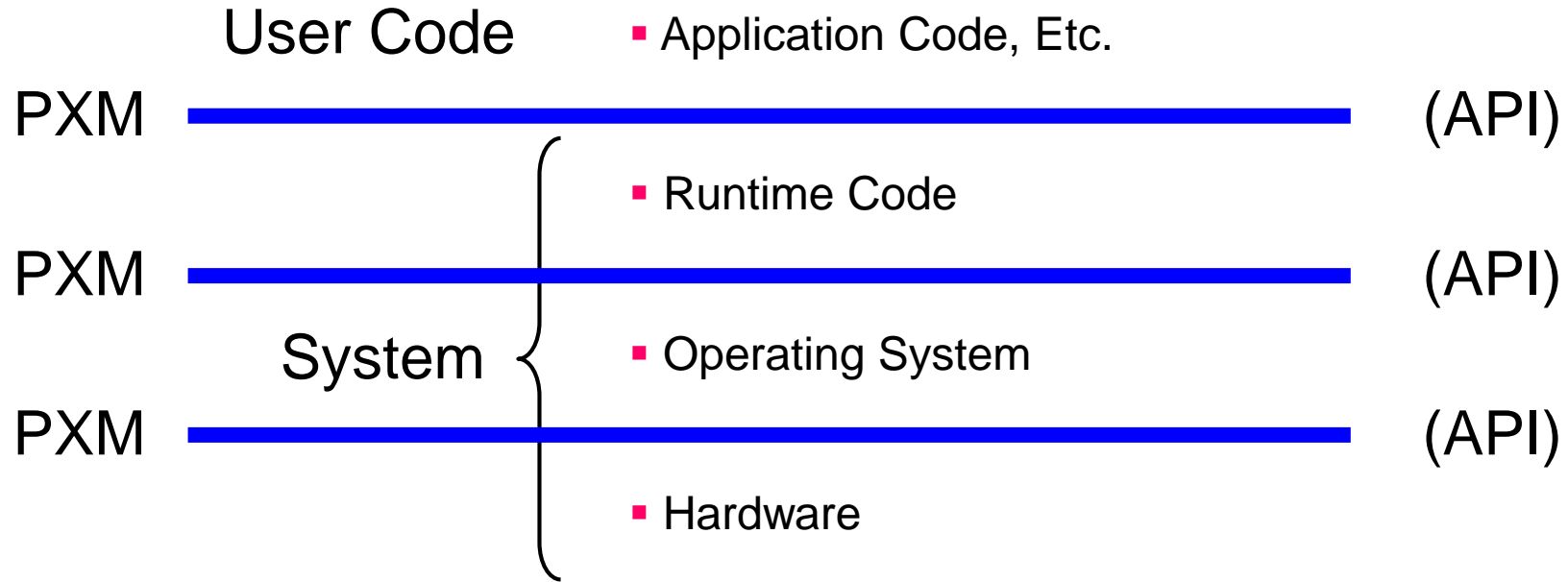- Program Libraries
- Compilers
- Utility Applications

PXM ━━━━━━━━━━━━━━ (API)
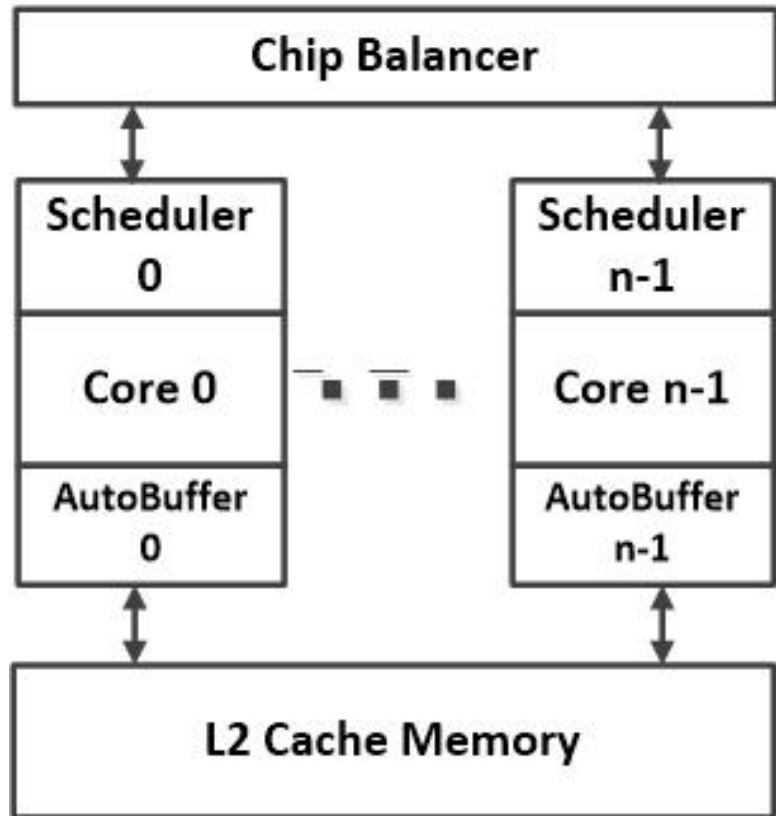
System
- Hardware
- Runtime Code
- Operating System

Today's Conventional Software Stack

User Code   ▪ Application Code, Etc.

PXM ━━━━━━━━━━━━━━━━━━━━━━━━ (API)

       ▪ Runtime Code

PXM ━━━━━━━━━━━━━━━━━━━━━━━━ (API)

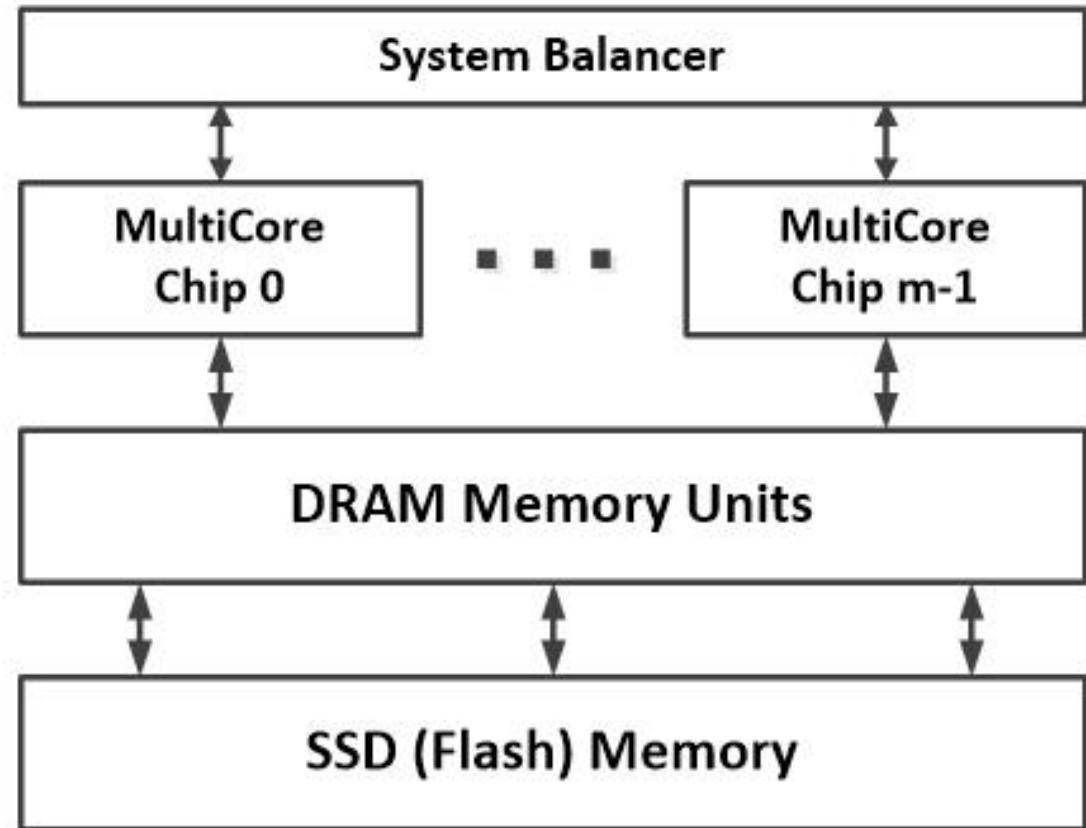System   ▪ Operating System

PXM ━━━━━━━━━━━━━━━━━━━━━━━━ (API)

       ▪ Hardware

Each system layer compensates for inadequacies of the layers below, leading to an inefficient whole.

a) Fresh Breeze Multicore Chip

Chip Balancer

Scheduler 0	· · ·	Scheduler n-1
Core 0		Core n-1
AutoBuffer 0		AutoBuffer n-1

L2 Cache Memory

b) Fresh Breeze System Structure

System Balancer

| MultiCore Chip 0 | · · · | MultiCore Chip m-1 |

DRAM Memory Units

SSD (Flash) Memory

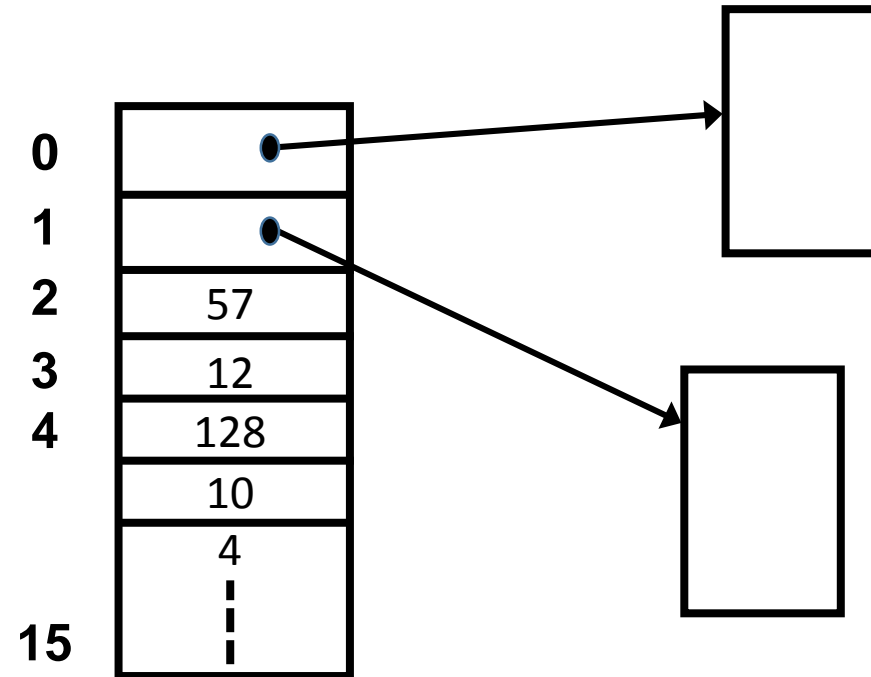# Dynamic Resource Management

Flexibility of resource management requires a unit of exchange for memory and for processing

- Unit of Memory – Fixed Size Memory Chunk

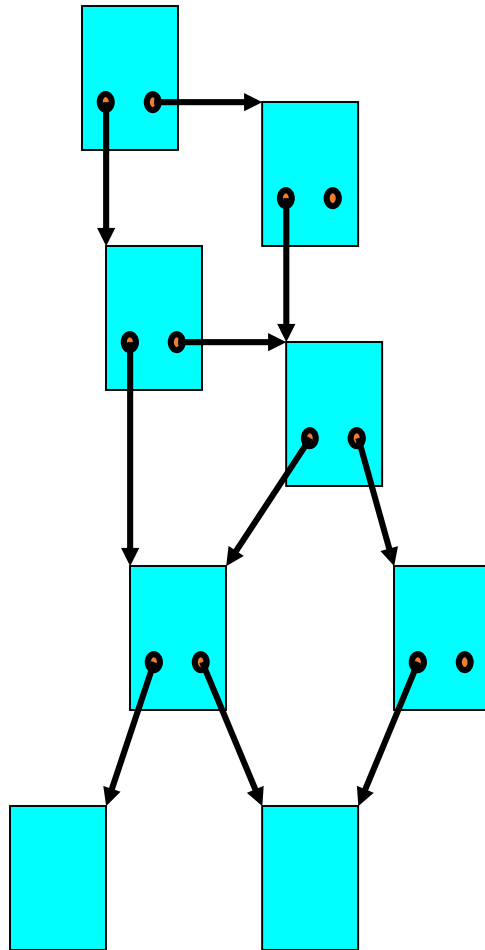- Unit of Processing – Execution of a Codelet
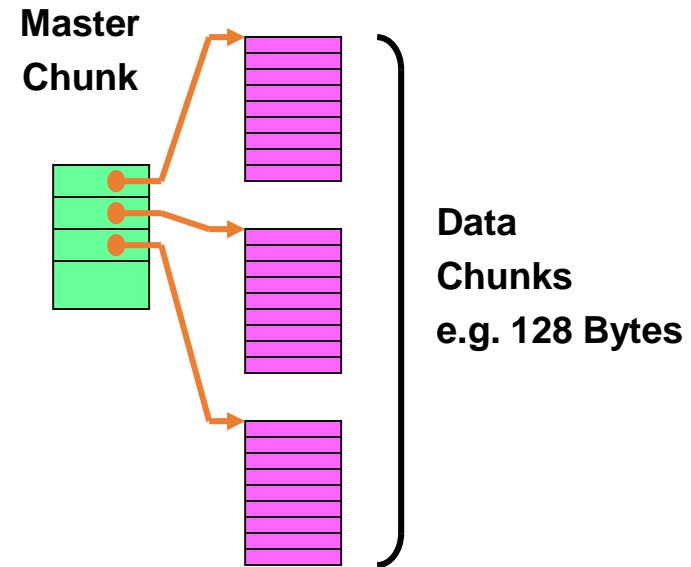
What is a Memory Chunk ?

A chunk holds sixteen data items that may be data values or pointers to (handles of) other memory chunks

Data Structures as Trees of Chunks
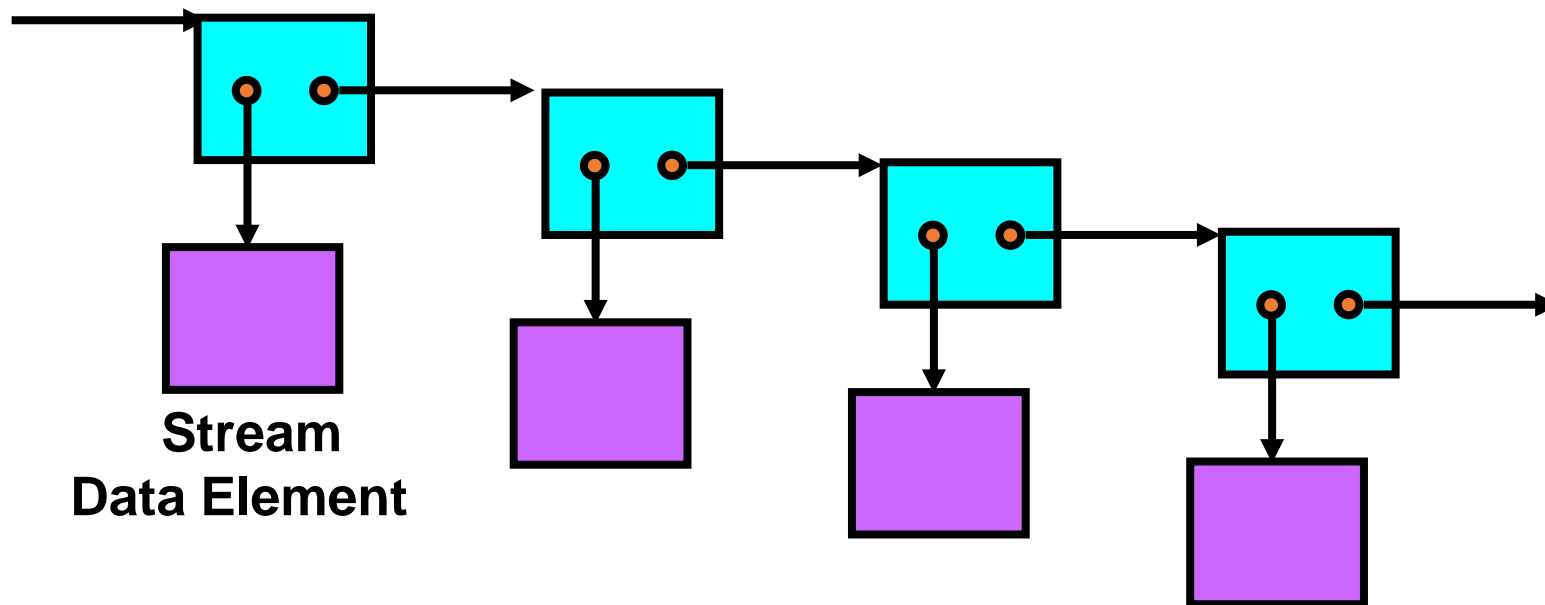
Cycle-Free Heap

Arrays as Trees of Chunks

Master Chunk

Data Chunks e.g. 128 Bytes

- **Fan-out as large as 16**
- **Arrays: Three levels yields 4096 elements (longs or doubles)**
- **Write-Once then Read Only**

A Stream as a Chain of Chunks
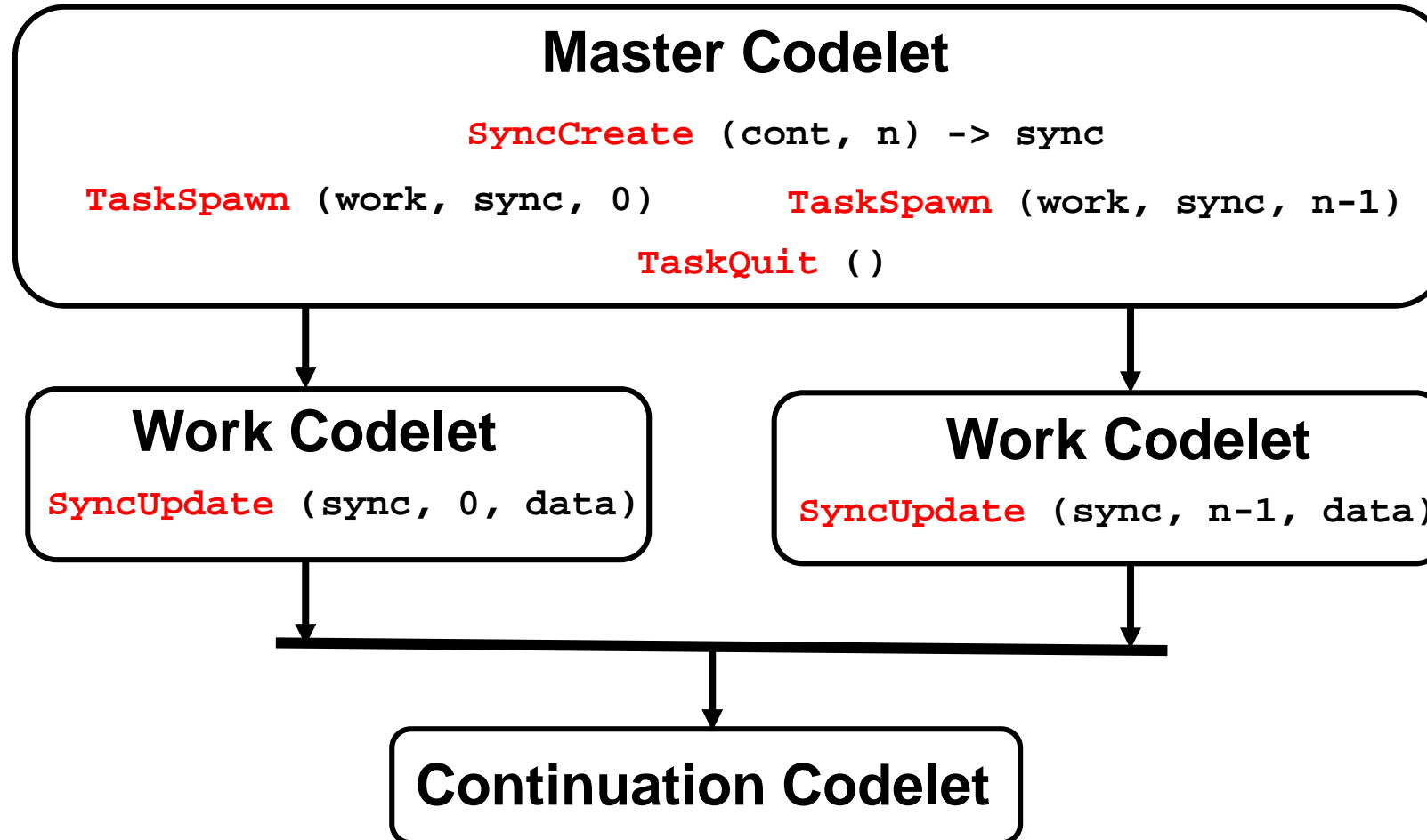

**Stream
Data Element**

- New elements appended at tail of chain
- Elements removed from the head of the chain
- Basic operations implemented by Fresh Breeze machine instructions.
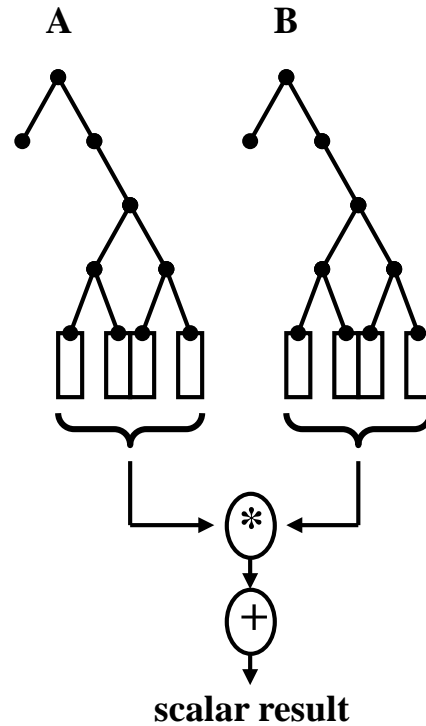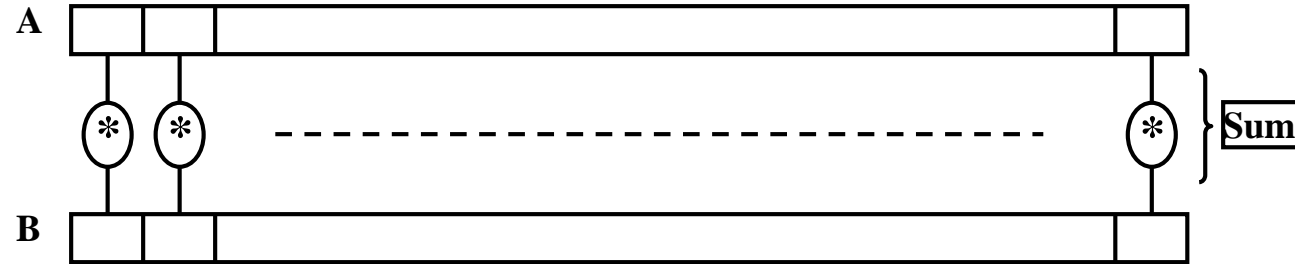
What is a Codelet ?
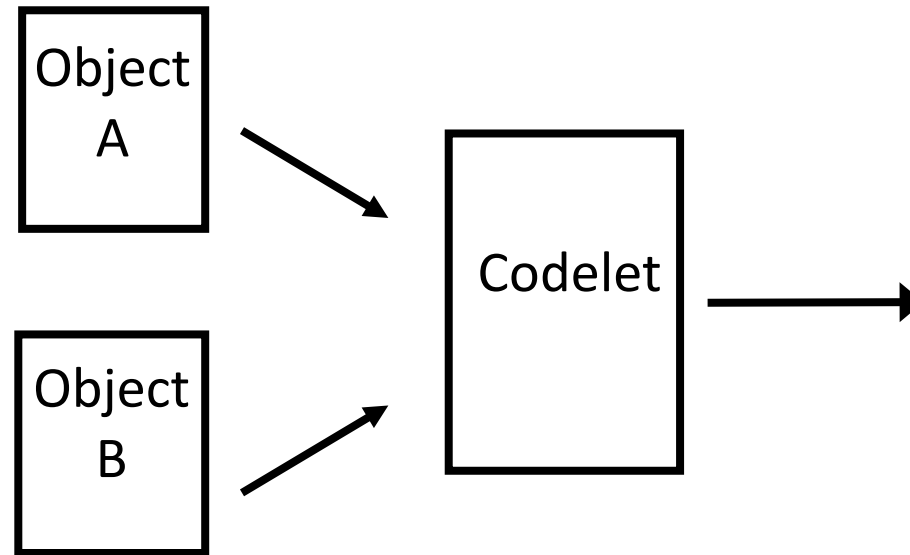
- A block of Instructions scheduled for execution when needed data objects are available.
- Results made available to successor codelets.
- Data objects are trees of chunks.

Work and Continuation Codelets
(Data Parallel Computation)

Master Codelet

SyncCreate (cont, n) -> sync

TaskSpawn (work, sync, 0)   **TaskSpawn** (work, sync, n-1)

TaskQuit ()

Work Codelet

SyncUpdate (sync, 0, data)

Work Codelet

SyncUpdate (sync, n-1, data)
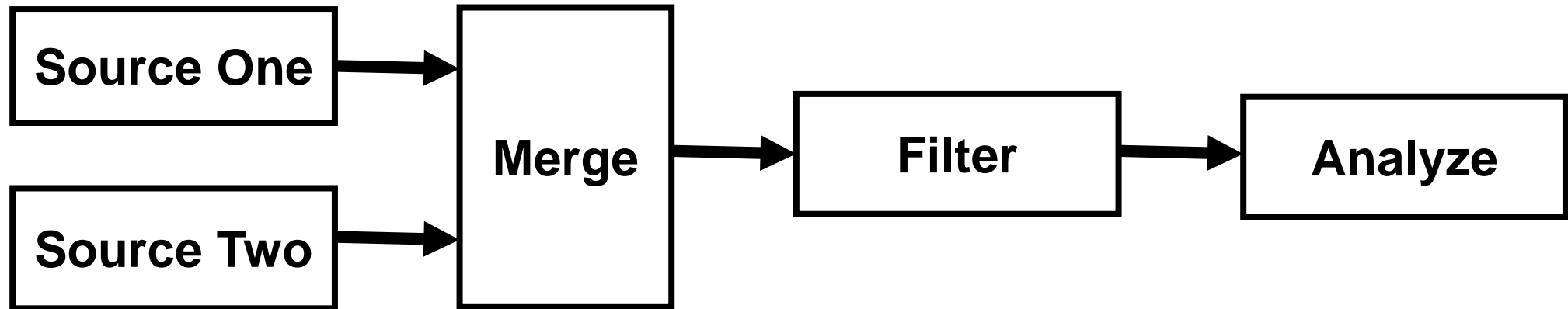
Continuation Codelet

Example: The Dot Product

5 levels:
Vector length =
$16^5 = 1,048,576$

Each of 65536 Leaf Tasks:
  Dot Product of two
  16-element vectors:
  16 multiplies; 15 adds

scalar result

Simple Streaming Example

Stream Data Types and Operations

In **funJava** a stream may be created for any type T:

Stream<T> strm = **new** Stream<T>()

Three methods may be applied to values of type Stream<T>:

The **append** method appends an element of type T to the stream.

The **first** method returns the head element of the stream.

The **rest** method returns a stream equal to the given stream with its head element removed.
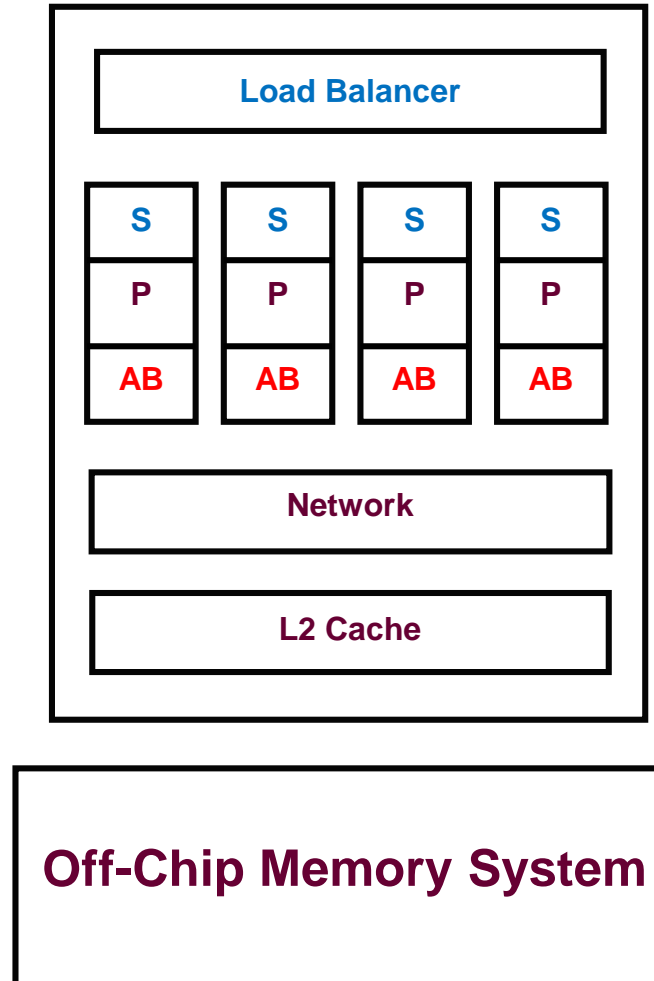
Fresh Breeze Multicore Chip

S - **Scheduler**

P - **Processor Core**
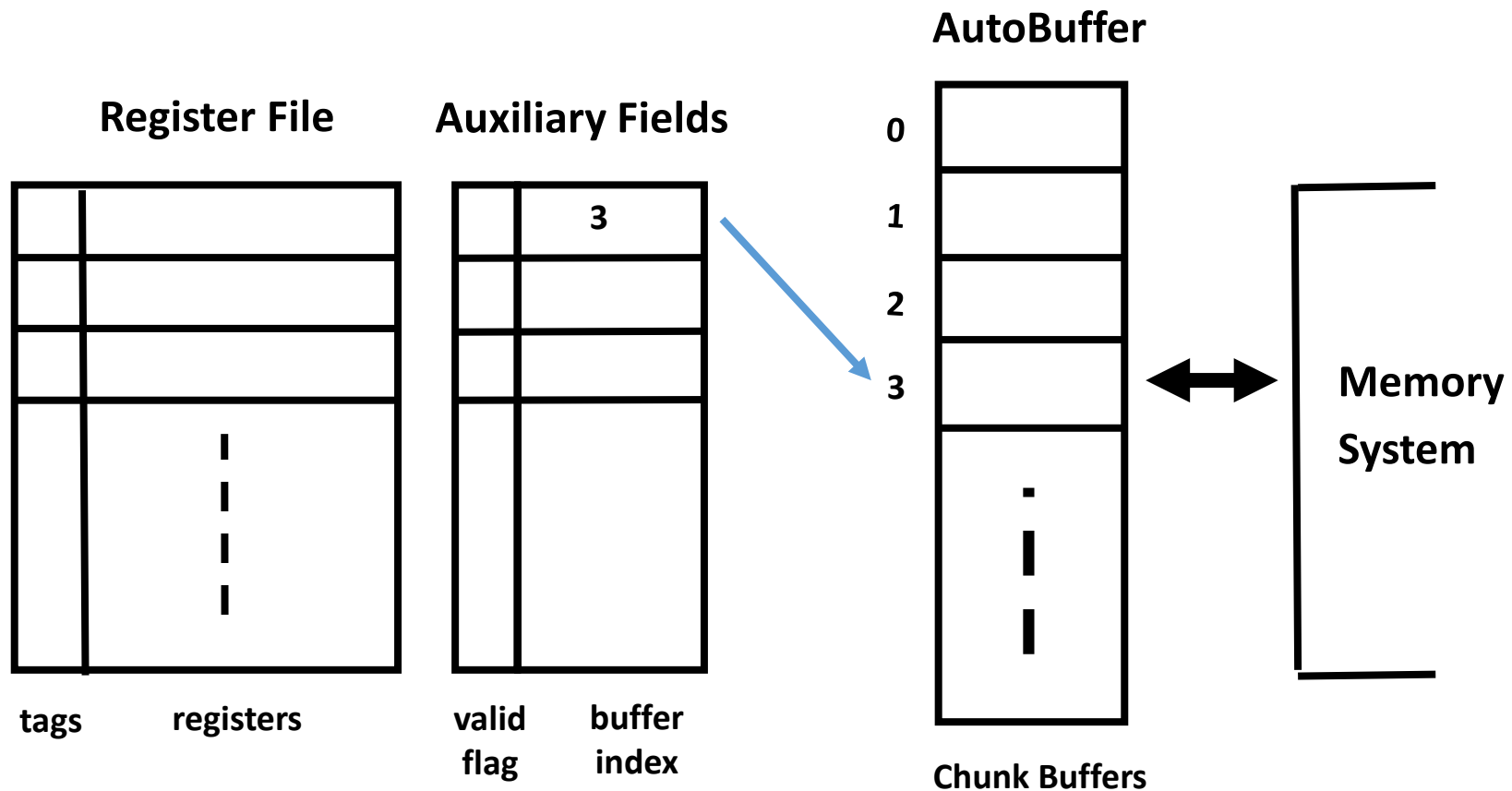
AB - **AutoBuffer**

Innovations:

AutoBuffer - AB

Load Balancer

Load Balancer
S	S	S	S
P	P	P	P
AB	AB	AB	AB

Network

L2 Cache

Off-Chip Memory System

Principle of the Auto Buffer

Register File   **Auxiliary Fields**   **AutoBuffer**

3

tags   registers   valid flag   buffer index

0
1
2
3

Chunk Buffers

Memory System
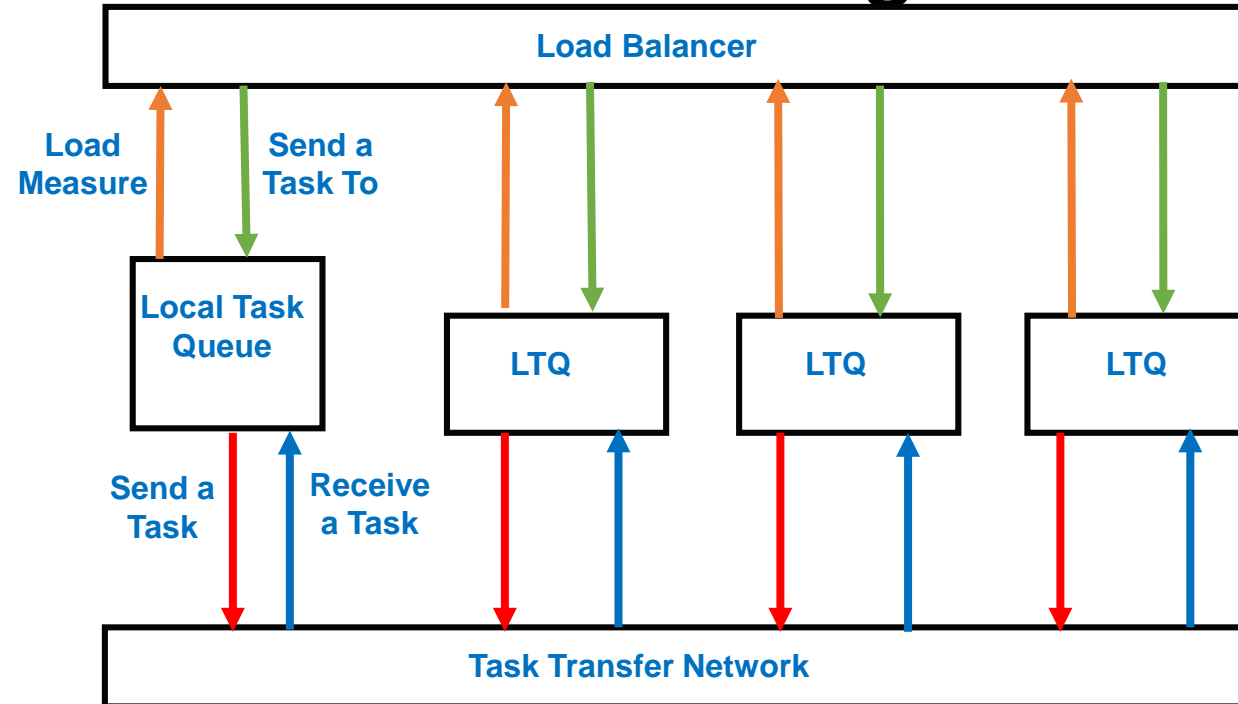
Codelets access chunks using chunk handles held in processor registers. Once a chunk is assigned a buffer, its index is held by the register containing the handle, providing direct access to the chunk.

Dynamic Load Balancing

Load Balancer

Load Measure

Send a Task To

Local Task Queue

LTQ

LTQ

LTQ

Send a Task

Receive a Task

Task Transfer Network

The load Balancer monitors the number of tasks queued at each processor and instructs each local scheduler to send a task from a processor with high load to a processor with low load.

Fresh Breeze Compiler