# Study Item Proposal: Network for AI Computing

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# Background

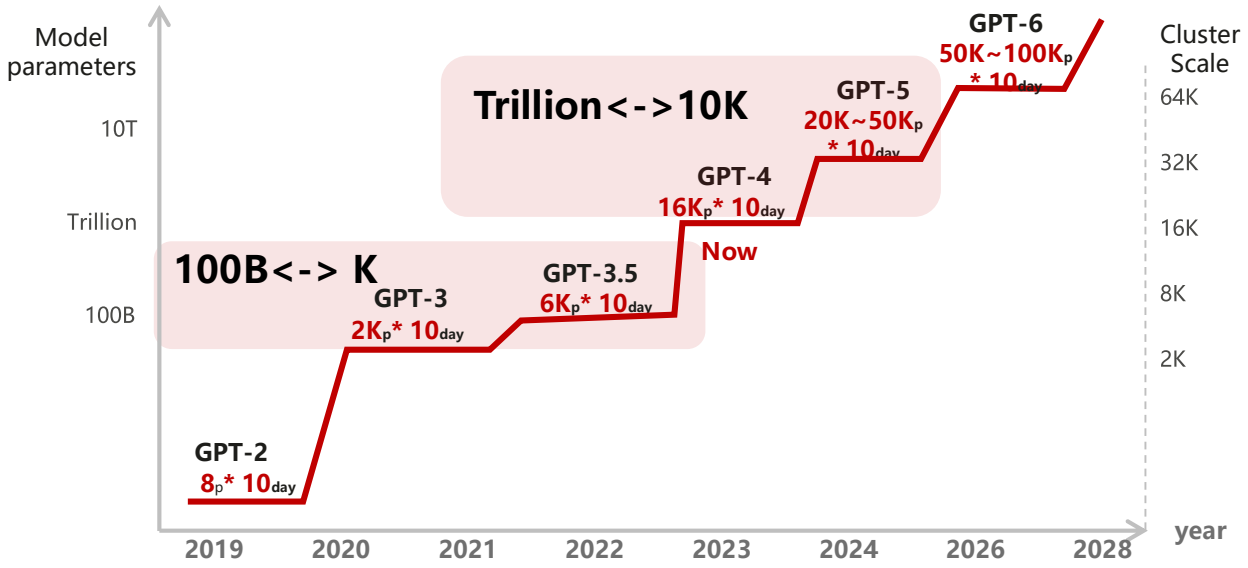
## AI large model – new surge of AI computing

- AI large models show emergent abilities, attracting industry's attention.

Emergent abilities that are not present in smaller-scale models but are present in large-scale models, which are qualitative changes resulted by quantitative changes (training compute, number of model parameters and training dataset size)

--- Google&Standford, 2022

- AI large models evolve very fast, requiring large scale network.




## Network development

### Industry activities:

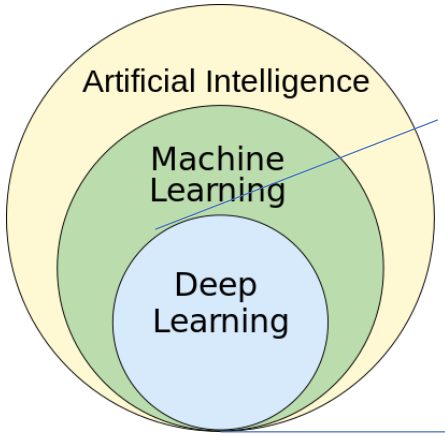
- UEC https://ultraethernet.org/
- IETF AI DC(datacenter) side meetings
  https://github.com/Yingzhen-ietf/AIDC-IETF117
  https://github.com/Yingzhen-ietf/AIDC-IETF118

### Nendica contributions:

- Requirements for AI Fabric
- Congestion Signaling (CSIG)
- Network for AI datacenters
- Load balancing challenges in AI fabric

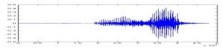
**There's a lot of interest in network improvement in order to support AI large model.**

# Important to Know How AI Works




## Deep Learning ≈ Looking for a Function

- Speech Recognition

$f($  $)=$ "How are you"

- Image Recognition

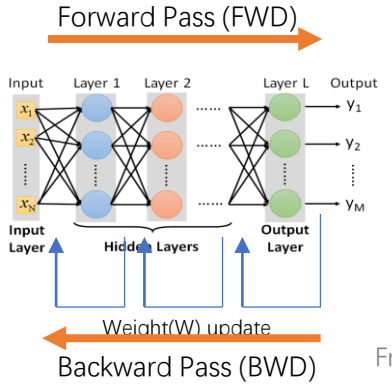
$f($  $)=$ "Cat"

- Dialogue System

$f($ "Hi" $)=$ "Hello"

(what the user said) (system response)

## DNN-based Architecture for deep learning (DNN: Deep Neural Network)

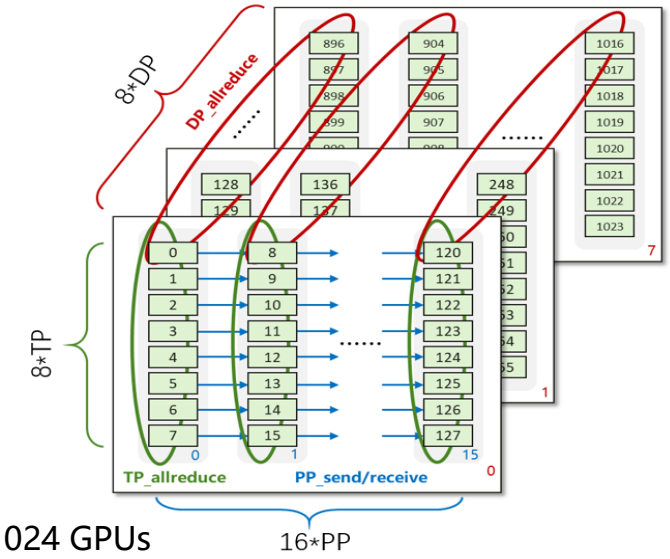



- ✓ Samples
- ✓ Parameters
- ✓ Gradients
- ✓ ……

From Nendica contribution: "Network for AI datacenters"

## Keys to AI Training:

- **Compute** (FLOPS, floating point operations per second) decides how fast to train a model.
  - Days trained * Number of GPUs * single GPU FLOPS ≈ (peta)FLOPS-day of model
- **Memory size** determines if the model can be trained.
  - Memory must be big enough to store model parameters and intermediate values generated during FWD and BWD.
    - Large model cannot fit into a single GPU memory, model parallelism has to be used.
- **Parallelism** enables model training.
  - Model parallelism and data parallelism




Example:

GPT3_175B, 1024 GPUs

DP(data parallelism) =8, TP(tensor parallelism)=8,

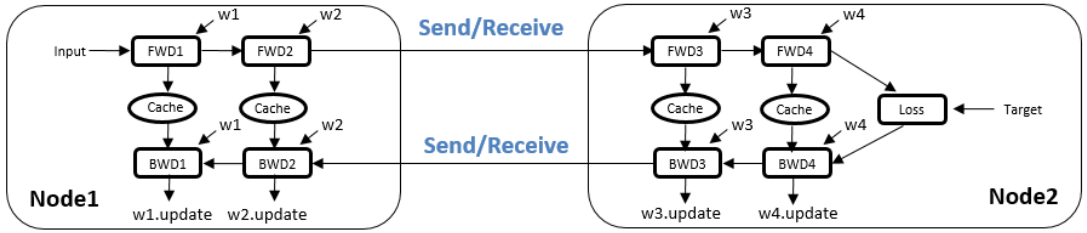
PP(pipeline parallelism)=16

# Important to Understand Communication in AI (1/3)

**Overlap communication and computation as much as possible to optimize training.**

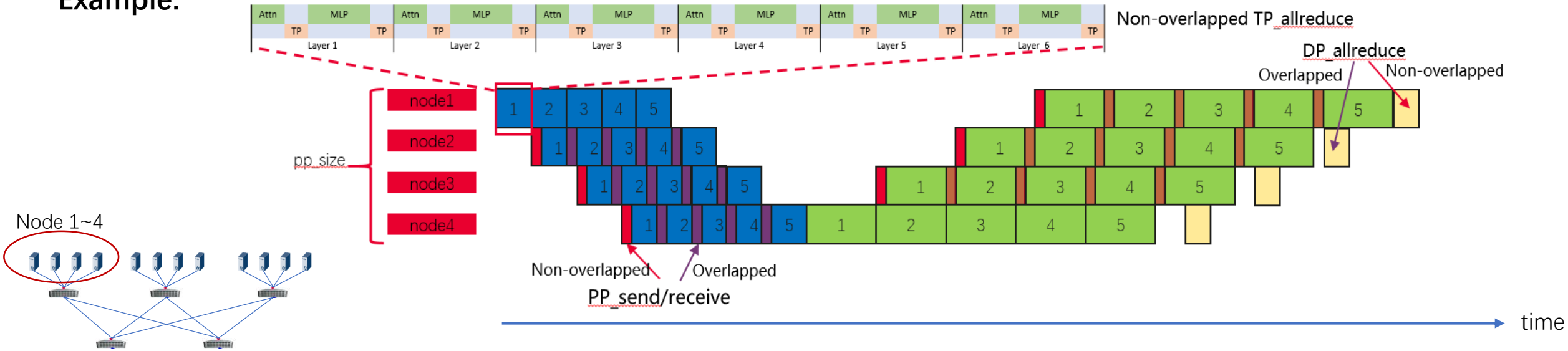
- TP Communication  is hard to be overlapped with computation.
- PP Communication can be overlapped with computation.
- DP Communication can be overlapped with computation.

**TP/PP/DP may have overlap.**




From Nendica contribution: "Network for AI datacenters"

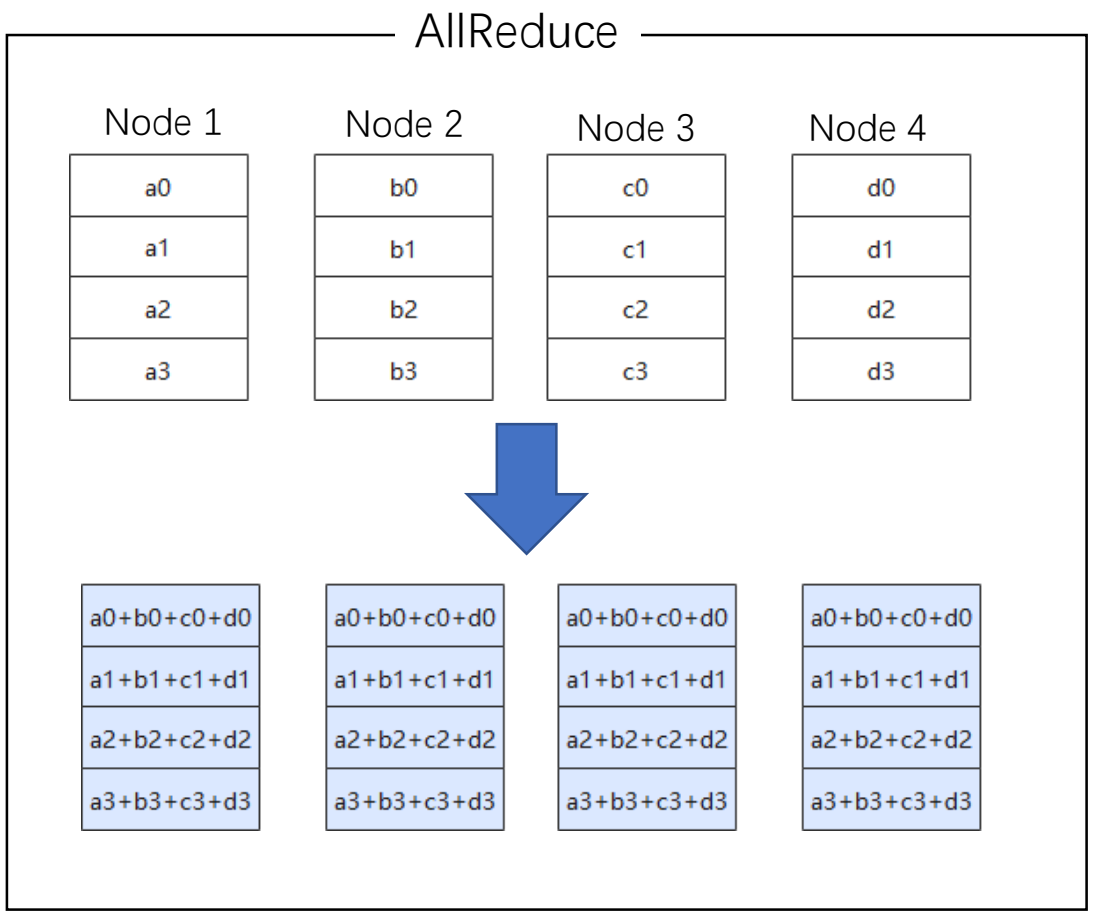
**Example:**

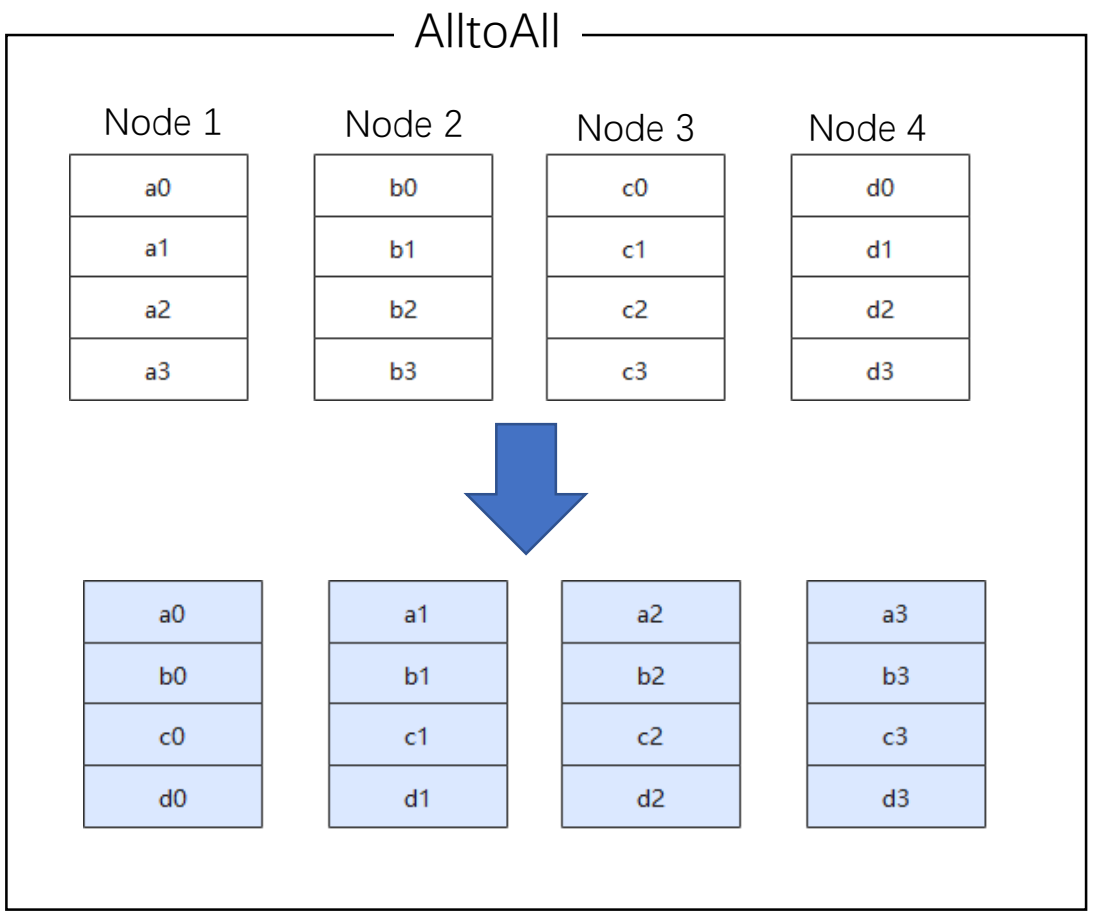



Attn: attention
MPL: multilayer perceptron

# Important to Understand Communication in AI (2/3)

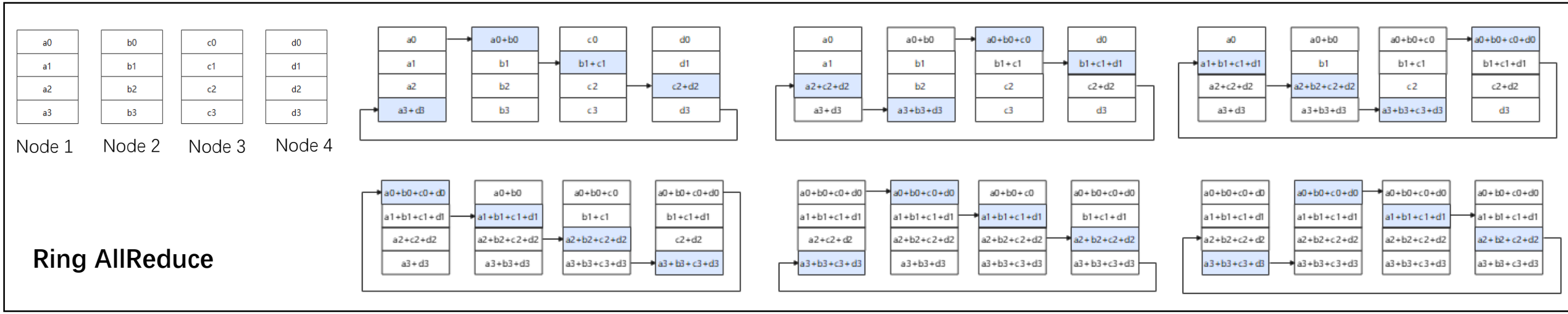
- **AllReduce and AlltoAll are typical collective communication operations in AI training.**

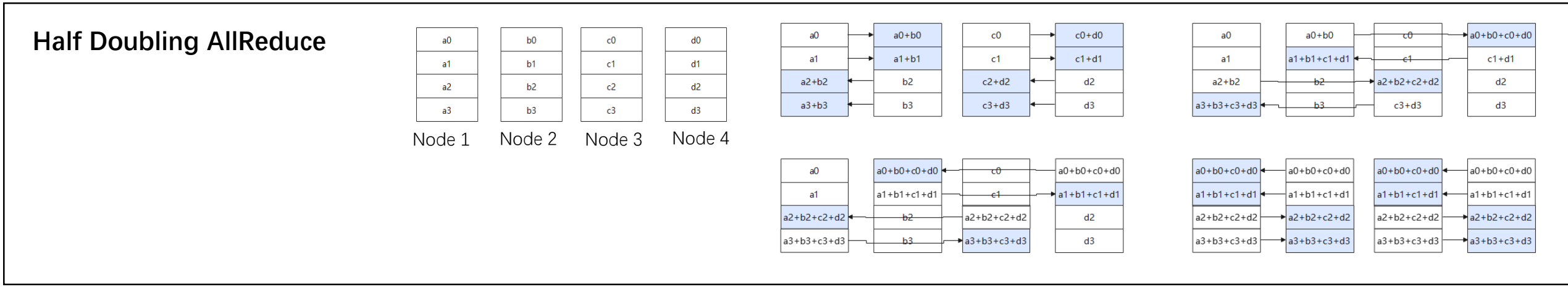


# Important to Understand Communication in AI (3/3)

- **Collective communication can have different implementations.**
  - Needs comprehensive considerations (e.g. network topology, message size) to design proper implementation.

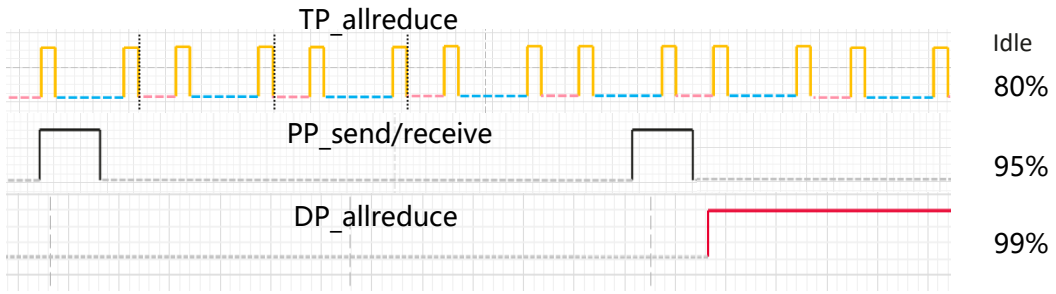


# Need to Notice New Traffic Pattern

**Sparse communication but requiring large bandwidth**

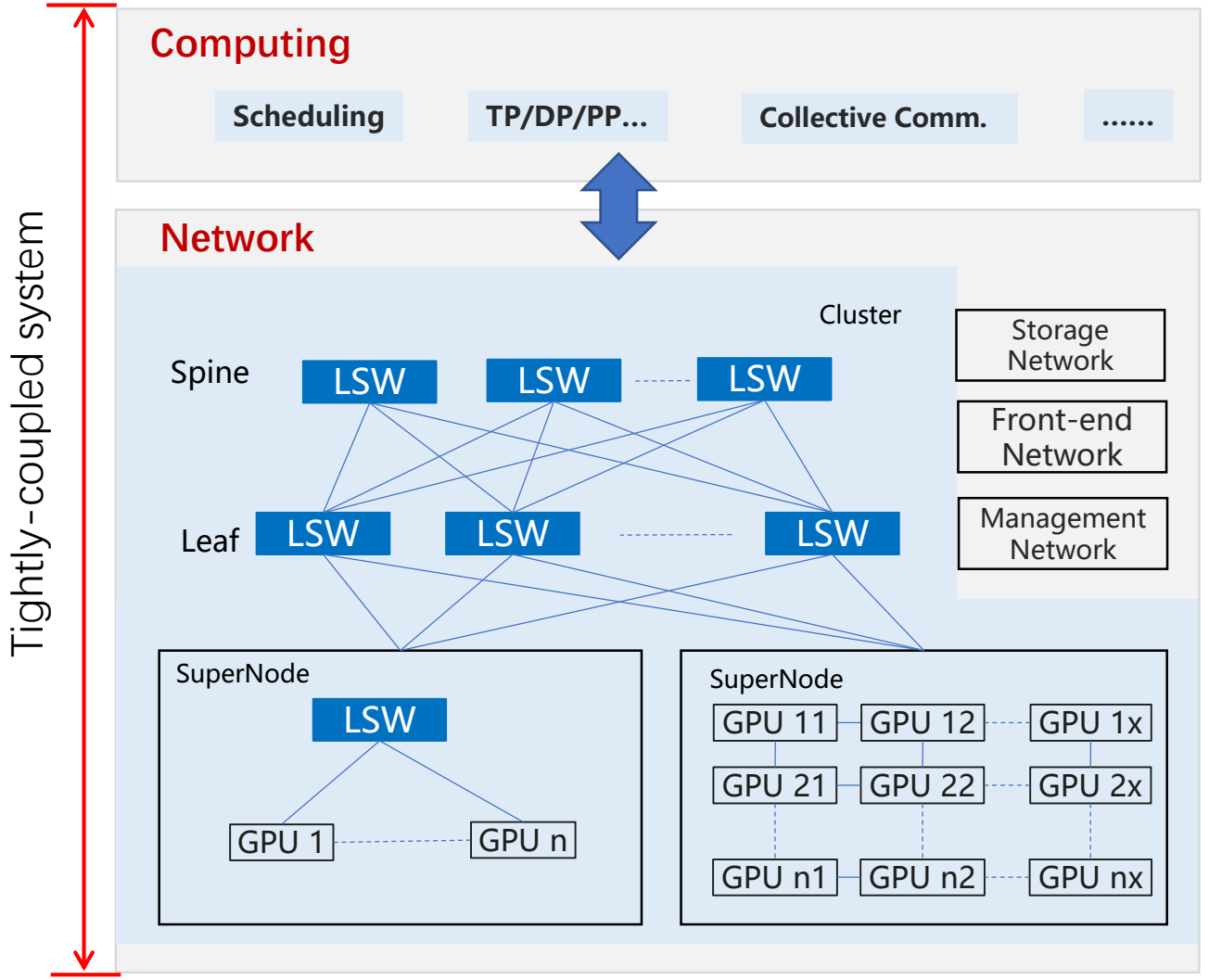
- The distribution of traffic is regular in both space and time dimensions.
  - The flow of traffic is regular.
    - Communication pair is predictable.
    - Maximum number of connections on a GPU is TP-1+DP-1+1 (TP/DP/PP)
  - TP/DP/PP logical planes show periodic bursts of traffic.
    - The burst frequency : TP>PP>DP
    - Link is idle in most of time.




- Single GPU requires large bandwidth for traffic communication

| Parallel Mode | Communication (1 GPU 1 time) |
|---|---|
| TP | 100s GB level |
| PP | 100s MB level |
| DP | GB level |

# Systematic View On AI Computing Network (1/2)




LSW: LAN switch

# Systematic View On AI Computing Network (2/2)

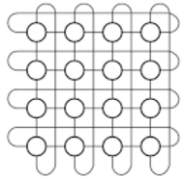
**Total compute = single GPU compute * Scale * Efficiency * Availability**

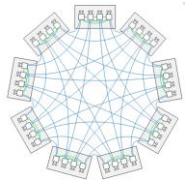
**Challenge:**

- Interconnection of large number of GPUs (K->10K->100K)

**Consideration:**

- Topology optimization for super-node and cluster network
  - Direct topology, e.g. torus, dragonfly



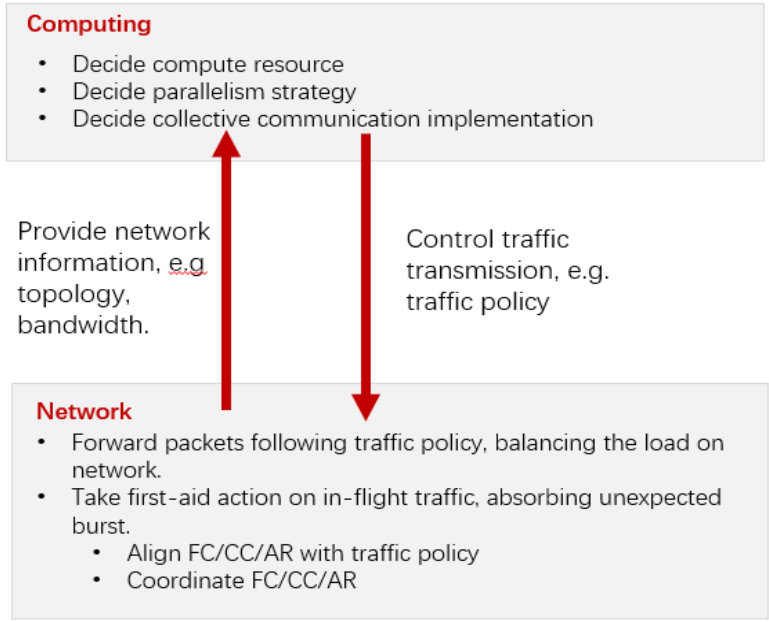


**Challenge:**

- Communication costs hinder linear expansion of computing power

**Consideration:**

- Coordination between computing and network.




FC: flow control
CC: congestion control
AR: adaptive routing

**Challenge:**

- Components in large scale system frequently fail.

**Consideration:**

- Combination of hot swap, automatic path migration , and checkpointing
- Backtracking to the last checkpoint has a high penalty
- Avoid it whenever possible with APM plus load balancing, followed by retransmission of lost packets
- Combine with AR for immediate response after failure detection

Quote from Nendica contribution: "Network for AI datacenters"

# Study Item Proposal

**Study item: AI computing Network**

**Purpose:**

- Understand the requirement of network for AI computing.
- Look for potential standardization opportunity in IEEE802.

**Scope:**

- Study main factors (parallelism, collective communication) in AI training which impact traffic.
- Analyze the major challenges for the network.
- Investigate future network technologies.
- Identify potential standard work.

**Deliverables:**

- Informal report documenting, including
  - AI computing network requirements and challenges
  - Potential technologies
  - Possible standardization needs
  - Work item proposal

**Schedule:**

- Start in Jan 2024
- Propose work item in March 2024

**Leader:**

Lily Lyu (Huawei)

**Supporters:**

José Duato (Royal Spanish Academy of Sciences)

Liang Guo (China Academy of Informational and Communication Technology)

Jesús Escudero (UCLM)

# Thank You!