

# Effectively Task Containerization in High Performance Clustering using Artificial Intelligence

आर्टिफिशियल इंटेलिजेंस का उपयोग करके  
उन्नत सक्षम क्लस्टरिंग में प्रभावी ढंग से कार्य कंटेनरकरण



Thesis submitted in partial fulfillment  
for the Award of Degree

*Doctor of Philosophy*

by

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It is further certified that the student has fulfilled all requirements of Comprehensive Examination, Candidacy, and SOTA for the award of Ph.D. Degree.

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Dedicated to my family,

Mrs. Sharda Devi, Mr. Shio Shankar Singh (parents)

Mrs. Neha Singh (wife)

and

Ms. Adwita Singh, Ms. Akshita Singh (Daughters)

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# List of Symbols

Symbol	Description
$\mathcal{N}$	Set of WMs
$N$	Number of WMs
$\tau_n$	Fraction of task
$Z_n$	Number of containers
$\alpha$	Security threshold
$n$	Index of WM
$w_n$	WM $n$
$\alpha_n$	Probability of attack
$\gamma_{n,z}$	Price of WM $n$
$Q_{n,z}$	Quality of data
$\beta$	Deadline threshold
$\mathcal{P}$	Set of participants
$\mathcal{D}_i$	Dataset at participant $p_i$
$\mathcal{C}$	Set of clusters
$M_k$	Model for cluster $C_k$
$Q_i$	Total instances in $\mathcal{D}_i$
$\mathcal{F}_i$	Freshness of data at $p_i$
$W_i$	Weight matrix at $p_i$
$d$	Dropout
$B_i$	Available Bandwidth
$\Delta T_i$	Time elapsed of data collection
$\mathcal{C}$	The set of available containers
$M$	The set of available shared memory locations
$P$	The set of performance metrics
$x$	Binary variable for container selection and placement
$w(p)$	Weight assigned to each performance metric

<b>Symbol</b>	<b>Description</b>
$(p,x)$	Function for system performance calculation
$y$	Variable matrix for container placement
$y_{ij}$	Variable indicating container $c_i$ placement in $m_j$
$c_i$	Size of container $c_i$
$m_j$	Capacity of shared memory $m_j$
$p$	Threshold value for performance metric $p$
$N'$	Number of available containers
$\eta$	Learning rate
$R$	Number of communication rounds
$E$	Number of epochs
$K$	Count of leaf devices
$S$	Shared memory
$t$	Iteration index for communication rounds
$C_j$	Selected container in iteration
$D_i$	Local dataset of party $P_i$
$M$	Global machine learning model
$\Theta_i$	Local model parameters of party $P_i$
$t$	Communication round index
$\Delta\theta_{it}$	Update to local model parameters of party $P_i$
$\Delta\theta_t$	Global model update aggregated from all parties
$\Delta\Theta_t$	Global update communicated to all parties
$T$	Fixed number of communication rounds
$F(w)$	Objective function representing the global loss
$n_k$	Number of data points on client $i$
$x \in D_i$	Data point $x$ belonging to local dataset $D_i$
$f_i(w)$	Local loss function with respect to $\Theta_i$
$F(w)$	Equation for global loss in federated learning
$\{x_{ji}, y_{ji}\}$	Radiology image data and class label
$F_i$	Data freshness at participant $p_i$
$T_i$	Time elapsed since radiology image collection
$Q_i$	Number of images in participant's dataset
$C$	Set of clusters in the system

# Abbreviations

<b>Abbreviation</b>	<b>Description</b>
AI	Artificial Intelligence
ANN	Artificial Neural Network
ML	Machine Learning
MM	Master Machine
WM	Worker Machine
MAR	Maximum Allowable Response time
FL	Federated Learning
KD	Knowledge Distillation
HPC	High Performance Computing
CE	Community Edition
EE	Enterprise Edition
CLI	Command-line Interface
CNCF	Cloud Native Computing Foundation
CRD	Custom Resource Definition
CI/CD	Continuous Integration/Continuous Delivery
CNN	Convolution Neural Network
RNN	Recurrent Neural Network
LSTM	Long Short-Term Memory
IoT	Internet of Things
LN	LoRa Nodes
LG	LoRa Gateway
CR	Coding Rates
SF	Spreading Factors
LoRaWAN	Long Range Wide Area Network
CPU	Central Processing Unit
IoMT	Internet of Medical Things
DDoS	Distributed Denial Of Service

<b>Abbreviation</b>	<b>Description</b>
DNN	Deep Neural Network
GRU	Gated Recurrent Unit
FLOP	Floating Point Operations Per Second
WPM	Weight Parameter Matrix
SGD	Stochastic Gradient Descent
CASAS	Center for Advanced Studies in Adaptive Systems
OS	Operating System
VM	Virtual Machines
TFLOPS	TeraFLOPS
C-DAC	Centre for Development of Advanced Computing
SLURM	Simple Linux Utility for Resource Management
IID	Independently and Identically Distributed
SMPC	Secure Multi-party Computation
PFS	Parallel File System