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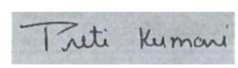

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Dedicated to my parents and my teachers

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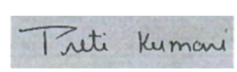

(Preti Kumari)

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List of Symbols

Symbol	Description
N	No. of LNs in network
$\mathcal{N}$	Set of N LNs
n	$n \in \mathcal{N}$, index of LNs
M	No. of LGs in network
$\mathcal{M}$	Set of M LGs
m	$m \in \mathcal{M}$, index of LGs
S	No. of services request from LN
$\mathcal{S}$	Set of S services
s	$s \in \mathcal{S}$, index of services
C	No. of CRs of LN in network
$\mathcal{C}$	Set of C LGs
c	$c \in \mathcal{C}$, index of CRs
F	No. of SFs in network
$\mathcal{F}$	Set of F SFs
f	$f \in \mathcal{F}$, index of SFs
σ^2	Power of white Gaussian noise
t_n^m	Transmission time duration of LN n on LG m
t_n^f	Transmission time duration of LN n using SF f
$t_{n,m}^{s,c}$	Transmission time duration of LN n on LG m for service s on CR c
$\rho_m^{s,c}$	Price paid by LN to the LG m for service s on CR c
R_n^m	Transmission rate between LN n and LG m
R_n^f	Transmission rate of LN n using SF f
$R_{n,m}^{s,c}$	Transmission rate between LN n and NS via LG m for service s on CR c
p_n	Power level used by LN n for data transmission
η, ω	Terminating constant
h_n^m	Channel gain from LN n to LG m
W	Bandwidth between LN to LG

Symbol	**Description**
Q	Maximum number of layers of Compression-Decompression model
Q_n	Number of layers of LN n
d_{Q_n}	Compressed data size at Q_n layer

Abbreviations

Abbreviation	**Description**
AS	Application Server
BG	Bayesian Game
BNE	Bayesian Nash Equilibrium
BW	Band Width
CF	Channel Frequency
CoR	Convergence Rate
CR	Coding Rate
CSS	Chirp Spread Spectrum
EESM	Energy Efficient Smart Metering
ETR	Effective Transmission Rate
EU	End User
IoT	Internet of Thing
ITS	Intelligent Transportation System
LAN	Local Area Network
LG	LoRa Gateway
LN	LoRa Node
LoRa	Long-Range
LoRaWAN	Long-Range Wide Area Network
LPWAN	Low Power Wide Area Network
NE	Nash Equilibrium
NS	Network Server
SE	Stackelberg Equilibrium
SF	Spreading Factor
SG	Stackelberg Game
TILR	Traffic Information acquisition system based on Long Range
TP	Transmission Power
TR	Transmission Rate

Preface

The Internet of Things (IoT) framework can be widely used to remotely monitor and manage everything such as lighting, traffic congestion, road warnings, and early detection of things. One of the energy-efficient wireless communication technology of Low Power Wide Area Network (LPWAN) is Long-Range (LoRa) that supports sustainable IoT due to its capability to offer tradeoffs among power consumption, communication range, and data rate. LoRaWAN open standard is an effective LPWAN protocol that builds on the top of the LoRa modulation scheme. The LoRa architecture consists of end users, nodes, gateways, servers, and applications. Nodes acquire and transfer the data to the gateways by using LoRaWAN protocol. LoRa supports high-density deployment of nodes because of its physical layer which offers degrees of freedom in carrier frequency, bandwidth, coding rate, and spreading factors to orthogonalize transmissions. The spreading factors act as virtual channels. A lower spreading factor provides high data rates but reduces transmission range, whereas, a higher spreading factor provides longer range at the low data rate. Despite the above advantages of LoRa, it suffers from the interference problem. The interference problem occurs when multiple nodes are connected with a gateway using the same spreading factor and thus subject to collisions. The transmissions of data with different SFs are also not completely immune to the adjacent SFs due to the imperfect orthogonality within SFs. Therefore, the performance of the network deteriorates due to the interference problem.

An efficient way of allocation of the resources can reduce the interference problem.

In the thesis, we propose the techniques to allocate the resources for extending the performance of the LoRa network. We first study the allocation of spreading factors based on the needs and requirements of the nodes, which helps to handle the interference problem. We estimate the required time of a node for accessing the spreading factors, such that it satisfies its service requirement and the network maximizes its utility. Unlike earlier work in the literature, we use an end-to-end network to compute the effective transmission rate and time duration for using the allocated SF with the interference problem in the network. We propose centralized and distributed algorithms to implement the solution. Next, we propose an approach for optimal spreading factors allocation and scheduling the nodes that are connected to the gateway. We compute the required transmission time duration of each node for using the spreading factors, such that the requirement of nodes is satisfied and the network maximizes the utility. We use a game theory-based approach for computing the time duration of nodes on suitable spreading factors. The obtain optimal time duration of nodes are then scheduled to minimize the waiting time. Further, we propose an approach for identifying the best gateways within the communication range of the nodes and optimal time duration for data transmission on those gateways. We use a Bayesian game for modeling the LoRa network in which the nodes can have variable transmission power. We also demonstrate an application of the analysis to design a traffic information acquisition system based on the LoRa network. Finally, we propose an energy efficient smart metering approach for transferring information about energy consumption to the operator. The approach uses Compression-Decompression model that incorporates deep learning techniques. The model compresses the multivariate data of the smart meter (from different consumer devices) at the node and transfers it to the gateway. The gateway decompresses the received data using a similar architecture as Compression model. Further, the gateway transfers the decompressed data to the electricity provider, which can be utilized for accurate decision making.