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Research Article

An Optimized Transmission Strategy in LoRaWAN-Based IOT Networks Based on Traffic Conditions

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ABSTRACT

Introduction: Intelligent, networked nodes make up the Internet of Things (IoT), which is a dynamic, worldwide infrastructure. Through the autonomous interaction of linked smart objects, IoT provides users with seamless service delivery. The LoRaWAN protocol was developed to provide very low-power signal demodulation, facilitating long-distance, low-data-rate communication among the devices of the Low-power Wide Area Network (LPWAN).

Objectives: This work focuses on enhancing transmission efficiency in the LoRaWAN-IoT network by dynamically regulating traffic under different conditions while reducing power consumption.

Methods: In this paper, we propose a Traffic Aware Data Scheduling Policy (TADSP) for Optimizing Transmission in LoRaWAN-IoT network. Based on various traffic types, traffic priorities are assigned. The gateway nodes apply a data scheduling policy that determines when a certain packet should be forwarded to the network server or discarded. Based on this policy, the gateway node schedules the received data from the end devices and performs time slot scheduling.

Results: The proposed methodology is implemented in LoRaWAN simulator. The simulation results show that the proposed TADSP reduces the energy consumption and packet drop rate and increases the uplink delivery rate.

Conclusions: The proposed policy provides an optimum transmission strategy for LoRaWAN-IoT networks.

Keywords: Internet of Things (IoT), LoRaWAN protocol, Data scheduling policy, Optimized transmission

INTRODUCTION

The IoT makes it possible to link people and objects using any network or service, at anytime, anywhere. More so than user requirements, it's driven by technology improvements. Through the autonomous interaction of linked smart objects, IoT provides users with seamless service delivery [1][2]. Low-power Wide Area Network (LPWAN) standards are contrasted with other standards based on data throughput, range, terminal and connection costs, and energy efficiency. LPWAN technology is appropriate for transferring moderate amounts of data since it connects devices over long distances while preserving battery life [3]. Examples of LPWAN protocols are long-range wide area network (LoRaWAN). The LoRaWAN was developed to provide very low-power signal demodulation, hence facilitating long-distance, low-data-rate communication between devices [4][5]. Many IoT applications rely on battery-powered devices, necessitating compliance with strict energy regulations. The number of devices in the network affects energy consumption; as traffic volume grows, so does the number of collisions [6][7].

LoRaWAN provides multiple transmission parameters: Spreading Factor (SF), Bandwidth (BW), Coding Rate (CR) and Transmission Power (TP) that can be tuned to trade data rate. But each transmission parameter combination (SF, BW, with CR) leads to a different data rate, which results in unfairness among nodes. In many application domains, the traffic on the backhaul network represents an important operational cost to the owners. To reduce the traffic through the backhaul, every gateway should apply a packet filtering policy according to node type, application type and network conditions [8].

A smart long-range sensor node built on LoRa technology was proposed by Jabbar et al. [9] to quickly gather data on air quality and send it to the cloud. To verify the dependability and efficacy of the IoT air quality monitoring system (AQMS) they built, a system called LoRaWAN-IoT-AQMS, which was installed outside. Node-Aware LoRaWAN (NA-LoRaWAN) is an enhancement to the LoRaWAN protocol that was described by Finochietto et al. [10]. It lowers backhaul traffic, which lowers operating costs for IoRT-based systems. By utilizing already-existing hardware and services, Putra et al. [11] incorporated LoRaWAN sensor support into the smart greenhouse. More specifically, the authors created middleware architecture for the LoRaWAN protocol that complies with several best practices.

A LoRa based SH system for AI-based remote monitoring and maintenance of IoT sensors and devices has been presented by Shahjalal et al. [12]. An open-source cross-layer assessment methodology for LPWANs was presented by Callebaut et al. [13]. It expands on the state-of-the-art with energy models, downlink messages, and adaptive data rate characteristics.

OBJECTIVES

Hence the main objective of this work is to optimize the transmission in the LoRaWAN-IoT network by

- Regulating the traffic based on various conditions
- Minimizing the power consumption

METHODS

System Model and Overview

In this paper, we propose a Traffic Aware Data Scheduling Policy for Optimizing Transmission in LoRaWAN-IoT network. The system model consists of the following components.

Edge Device (ED) represents the remotely deployed sensors or actuators that receive and transmit data from/to the gateways. The EDs follow the LoRaWAN protocol for transmission to GW and the GWs follow the backhaul protocol for transmission to NS. **Gateway (GW)** represents the base station that forwards the data from the ED to the network server, and vice versa. The **Network Server (NS)** is responsible for registering the GWs and Eds as well as managing the entire network. The **Application Server (AS)** collects, stores and processes sensor data, delivering services to end-user applications, software agents, and IoT devices.

In each ED, any monitoring application which generates heterogeneous traffic is considered. Then based on these traffic types, various traffic priorities are assigned. The GWs apply a data scheduling policy (DSP), that determines when a certain packet should be forwarded to the NS or discarded. The policy is based on node type, traffic priority and network conditions like SNR. Based on this policy, the GW schedules the received data from the EDs and adjusts the ADR.

Node Type

Each GW maintains a local table of ED addresses (EDAddr) that is processed to determine if a packet should be forwarded to the NS. Each EDAddr has been embedded with a cluster number of group IDs based on their type (camera or sensors). When a LoRaWAN GW receives an incoming packet, it should first check if the EDAddr of the packet is already in its local table. If it is present, then depending on its group ID, the DSP forwards the packet to NS, otherwise it is discarded.

Traffic Types

In each ED, any monitoring application that generates heterogeneous traffic is considered. The traffic has 3 types:

- Emergency traffic (warning messages) with Priority 1
- Discrete heavy traffic (picture, audio sensor data) with Priority 2
- Continuous light traffic (e.g. temperature, humidity sensor data) with Priority 3

Network Condition

To measure the network condition, the GW requires the SNR values from each received uplink data. The SNR margin value M is computed as

$$M = (SNR_{mes} - SNR_{req}) \quad (1)$$

where SNR_{req} and SNR_{mes} represent the required and measured SNR values at each GW. Based on the value of M, the data rate is increased or the transmit power is decreased.

Data Scheduling Policy (DSP)

When a packet is received, a GW first uniquely identifies the sending ED and then applies a DSP to determine when a certain packet should be forwarded or discarded. The policy is based on node type, traffic priority and network condition. Each GW that listens to an ED will not forward its incoming packets until its DSP is activated.

A weighted sum of the policies is derived as follows:

$$OI = \alpha.P_1 + \beta.P_2 + \gamma.P_3 \quad (2)$$

where OI is the operational index, Pi(i=1,2,3) represents the policies corresponding to the node type, traffic priority and network condition. α, β, γ are the weighting constants of the policies. The steps involved in each policy are presented below:

Policy 1 (P_1): Node Type

```
If EDAddrj ∈ LT(GWi), then
For each EDAddrk ∈ LT(GWi) , (k ≠ j)
  If Gidj = Gidk, then
          Assign same slot T1 for (i,j)
             Execute P2
          End if
      End for
      If Gidj ≠ Gidk, ∀k ≠ j , then
         Execute P2
      End if
Else
         Discard the packet
End if
```

In this policy, the EDAddr of the received packet is checked at the GW by looking up its local table. If it is not present, then the packet is discarded immediately. Otherwise, the group id of the EDAddr is checked with group id of other EDAddrs. If multiple entries are found at the same group ID, then it is considered a group transmission hence same slot T_1 is assigned for all the packets of the same group. Then the policy P_2 is executed. On the other hand, if there are no packets from the same group ID, then the transmission is considered as a unicast transmission, and then policy P_2 is executed.

Policy 2 (P_2): Traffic Priority

```
If TP = 1, then
        Forward the packet immediately
End if
If TP =2, then
        If slot T1 is assigned, then
           Assign same slot T1
```

Execute P_3

Else

Assign slot T2

Execute P_3

End if

End if

If TP=3, then

If slot T1 is assigned, then

Assign slot $T_1+\delta$

Execute P_3

Else if slot T2 is assigned, then

Assign slot $T_2+\delta$

Execute P_3

Else

Assign slot T_3

Execute P3

End if

In this policy, if the traffic priority is 1, it is considered as an emergency traffic and then the packet is forwarded to the NS, immediately. If the TP =2, then if its previous slot allocation is checked. If it is already assigned a slot T1, then policy P3 is executed. Otherwise, a new slot T2 is assigned, and then policy P3 is executed. If the TP =3, it is the least-priority traffic. If it is already assigned a slot T1 or T2, then this transmission is delayed by an interval of δ and policy P3 is executed.

Policy 3 (P3): Network condition

If M $\geq$0, then

Transmit the packet in assigned slots

End if

If M < 0, then

If slot T_1 or T_2 is assigned, then

Wait for interval σ

If M $\geq$0 after σ, then

Transmit the packet at $T_1+\sigma$

or $T_2+\sigma$

Else

Discard the packet

End if

End if

End if

RESULTS

The proposed TADSP technique has been simulated using the LoRaWAN simulator. LoRaWAN simulator is implemented in MATLAB which characterizes the behavior of LoRaWAN networks with physical, MAC and network layer features. The traffic generation models for both the uplink (UL) and the downlink (DL) are configured by the user. The performance of the proposed TADSP technique is compared with the Fair Adaptive Data Rate Allocation (FADR) technique [14]. The performance metrics considered in LoRaWAN simulator are uplink delivery rate, total energy consumption and packet drop rate.

Varying the number of EDs

In the first experiment, the number of EDs varied from 50 to 250, with the number of gateways set at 2. Figure 1 shows the uplink delivery rate measured for the two techniques.

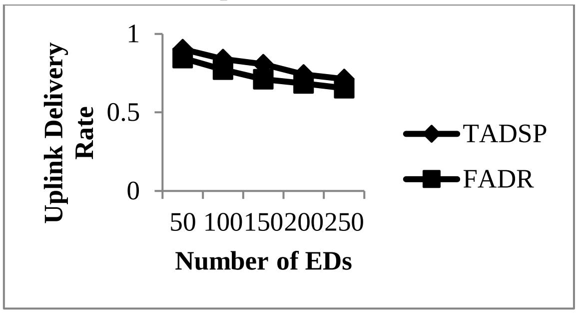

Figure 1 Uplink delivery rate Vs EDs

As seen from Figure 1, the uplink delivery rate of TADSP is 8.4% higher than that of FADR, for an increasing number of EDs.

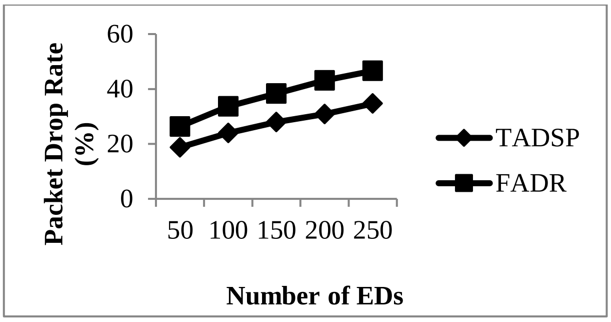

Figure 2 Packet drop rate Vs EDs

As seen from Figure 2, the packet drop rate of TADSP is 27% lesser than that of FADR, for increasing number of EDs.

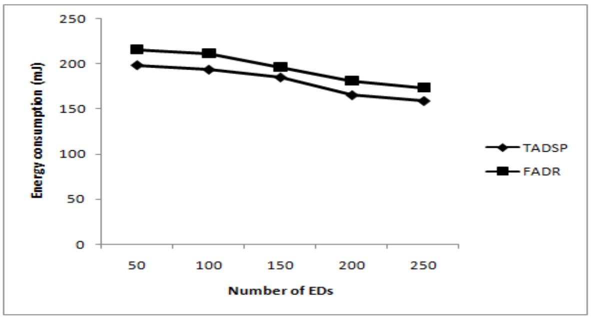

Figure 3 Energy Consumption Vs EDs

As seen in Figure 3, the total energy consumption of TADSP is 8% lesser than that of FADR, for increasing number of EDs.

Varying the Payload size

In the next experiment, the UL payload size has been varied from 10 to 50 bytes. Figure 4 shows the uplink delivery rate measured for the two techniques.

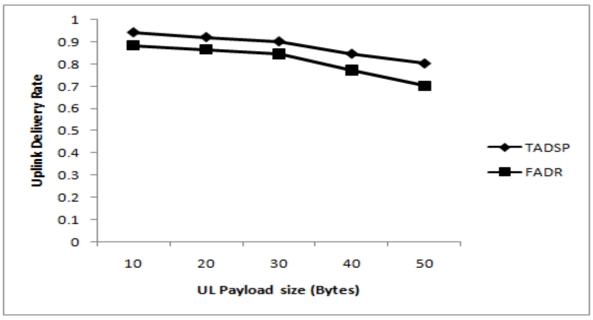

Figure 4 Uplink delivery rate Vs payload size

As seen from Figure 4, the uplink delivery rate of TADSP is 8% higher than that of FADR, for increasing the payload size.

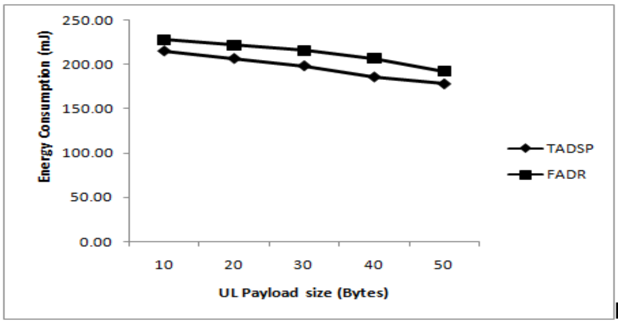

Figure 5 Energy consumption Vs payload size

As seen from Figure 5, the total energy consumption of TADSP is 7.5% less than that of FADR, for increasing the payload size.

DISCUSSION

In this paper, we have proposed a TDSP for optimizing the transmission in LoRaWAN-IoT network. The gateway nodes apply a DSP that determines when a certain packet should be forwarded to the network server or discarded. Based on this policy, the gateway node schedules the received data from the end devices and adjusts the ADR. The proposed methodology has been implemented in LoRaWAN simulator. The performance of the proposed TADSP technique is compared with the FADR technique. The performance metrics considered in LoRaWAN simulator are uplink delivery rate, total energy consumption and packet drop rate. By simulation results, we have shown that the proposed TADSP reduces the energy consumption and packet drop rate and increases the uplink delivery rate.

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