Interference-Aware Spreading Factor Assignment Scheme for the Massive LoRaWAN Network

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***Abstract*—In LoRaWAN, end devices of class A adapts pure ALOHA for the channel access where interference occurs due to the use of same/different spreading factors (SFs) which leads to high packet loss. In this paper, we propose an Interference-Aware Spreading Factor Assignment (I-ASF) algorithm to counteract against the interference occurred due to the same/different SFs. The I-ASF algorithm considers gateway sensitivity, the interfered SFs, overlaps time of the collided packets, and the interfering energy in order to assign SF to decrease the significance of the interference. Thus, this behavior leads to an optimal assignment of SFs which minimizes the ToA for every end device. As a result, I-ASF reduces the collision and enhances the packet success ratio. Simulation results show that I-ASF algorithm outperforms both the existing distance-based and random-based spreading factor allocation schemes in terms of packet success ratio.**

Keywords— LoRa; LoRaWAN; interference; spreading factor assignment

I. INTRODUCTION

Long Range Wide Area Network (LoRaWAN) describes the MAC protocol, whereas LoRa enables the physical layer for long-range communication by adapting the chirp spreading spectrum modulation [1]. The allocation of spreading factors (SFs) to end devices (EDs) in the LoRaWAN network plays an important role due to different reasons: a higher SF conforms to a long distance within which the data can be received. However, it signifies a low DR and high Time-on-Air (ToA). The ToA greatly depends on the SF and the packet length of an ED and its detail can be found in [2]–[3].

In this paper, we propose “interference-aware spreading factor assignment (I-ASF)” algorithm which adapts the techniques of [5] with the addition of intra-network interference between the same and different SFs in order to enhance the packet success ratio.

The contribution of this paper is two-fold. First, we adapt the additive interference model in order to counteract against the interference. Second, we model the interference caused due to the same and different SFs over the same channel.

The remaining of this paper is organized as follow. Section II presents the network model of our proposed I-ASF assignment algorithm. The simulation results are presented in section III, whereas the last section concludes this paper.

II. NETWORK MODEL

We consider a class A network, where N number of EDs are uniformly positioned in a single cell and managed by a single GW. The transmission is always initiated by an ED in the uplink direction on any available channel among the $\acute{C} = |Ch|$, where $Ch \in \{868.1, 868.3, 868.5\}$. Each channel consists of distinct receive paths (R_p), where $R_p \in \{3,3,1\}$. Therefore, $\acute{C}_1$ and $\acute{C}_2$ has $R_p = 3$, respectively, whereas $\acute{C}_3$ has $R_p = 1$. The rest of this section highlights the I-ASF assignment algorithm.

A. Interference model

Due to massive EDs in the LoRaWAN network, it suffers two types of collisions owing to multiple SFs which are: (1) two or more packets suffer a collision with the same SF or (2) multiple packets collide with different SFs [6]. The multiple Co-SF interferences cause low signal-to-interference-plus-noise-ratio (SINR) which affects the quality of the received signal [7]. Therefore, SINR is the primary concern of our interest in order to measure the interference correctly. We adapt the interference model from [5], [8]. Let denote the power of a packet on channel $\acute{C}$, the SINR anticipated by GW of channel $\acute{C}$, ($\gamma_{\acute{C}}$) is given by;

$$\gamma_{\acute{C}} = \frac{P_{\mathbb{y}}, r}{\sigma^2 + \mathbb{P}_{\mathbb{W}}} \tag{1}$$

In (1), $P_{\mathbb{y}}, r$ represents the power of a packet under observation, σ is the depth of shadowing, and $\mathbb{P}_{\mathbb{W}}$ is the cumulative power computed by (2).

$$\mathbb{P}_{\mathbb{W}} = \sum_{i \epsilon I_j \backslash \{\acute{C}\}} P_{pkt(i)}^{int}, \tag{2}$$

where $P_{pkt(i)}^{int}$ is the interfering power of the i^{th} packet, using $SF = i$, and I_j is a list of interferers using $SF = j$ over a channel, $\acute{C}$.

By substituting (1) with (2), $\gamma_{\acute{C}}$ provides a general picture for finding the SINR over a channel.

$$\gamma_{\acute{C}} = \frac{P_{\mathbb{y}}, r}{\sigma^2 + \sum_{i \epsilon I_j \backslash \{\acute{C}\}} P_{pkt(i)}^{int}} \tag{3}$$

To this end, a packet received by the GW using $SF_{(i,j)}$ is successful, if it satisfies (4).

$$\gamma_{\acute{C}} \geq \beta_{(i,j)}, \tag{4}$$

where $\gamma_{\acute{C}}$ is the SINR defined by (3) and $\beta_{(\text{I,j})}$ (in dB) is a threshold corresponding to an acceptable SINR value for same/different SFs [5].

Collision model of two packets is presented in [4], [5]. Moreover, it is assumed that a packet is always received correctly as long as it is above the sensitivity (i.e., $\gamma_{\acute{C}} \geq \beta_{(i,j)}$) and this packet survived all kind of interference [5].

B. Interference-Aware based spreading factor assignment algorithm and its working

Our proposed I-ASF algorithm adapts the distance-based algorithm [5] during the initial deployment phase, where it computes the received power, P, using function $getRecvPower(ED_{\eta})$ for the transmission from ED_{η} to a GW. When EDs initiate the transmission, the GW triggers the I-ASF algorithm in order to examine the interference for a given SF, $SF_{(k)}$, by checking the list of interferers containing SF, $SF_{(int)}$. If the $SF_{(k)}$ matches to any SF in the list, $SF_{(int)}$; GW assigns a unique SF, $SF_{(U)}$, by using function $getNonInterfererSF(P)$ and the ED proceeds transmission with $SF_{(U)}$. If $SF_{(k)}$ does not match to any SF in the list, $SF_{(int)}$, the ED proceeds transmission with $SF_{(k)}$. The detailed working of the I-ASF algorithm is presented in Algorithm 1.

Algorithm 1. Interference-Aware based spreading factor assignment

INPUT: GW sensitivity
OUTPUT: Assignment of $SF\epsilon\{7-12\}$ to N EDs
for η EDs, where $\eta\epsilon\{1,2,\ldots,N\}$
//check for each ED
  $P = getRecvPower(ED_{\eta})$
  $SF_{(k)} = getCurrentSF(ED_{\eta})$ //device's current SF
if ($P \geq GW$ sensitivity)
  if ($SF_{(k)}$ *is in* $SF_{(int)}$)
    $ED_{\eta} = getNonInterfererSF(P)$ //returns $SF_{(U)}$
  end
end

III. SIMULATION RESULTS

This section presents the performance analysis of our proposed I-ASF algorithm in comparison with distance-based and random-based SF allocation algorithms. The simulation analysis is based on ns3 where N number of EDs communicate with a single GW within 7.5 km range. Each ED transmits a packet of 30 bytes with a transmitting power of 14dBm during the 600 seconds of simulation time.

Fig. 1 shows the packet success ratio of I-ASF, distance-based and random-based spreading factor assignment algorithm for the different number of EDs over 1 and 3 channels. It is clear from Fig. 1 that by increasing the number of EDs the packet success ratio is observed decreasing for all the algorithms. It is due to massive EDs trying to send the packets at the same time without knowing the other EDs are already sending their packets to GW and thus causes collisions and hence decreases the success ratio. The random-based algorithm performs the worse in both cases (i.e., 3 channels and 1 channel) due to the unfair assignment of SF. Which leads to higher ToA in case of a higher SF (10-12) and thus suffers collisions and under sensitivity problems. In the case of the I-ASF algorithm (i.e., 3-channels), the influence of interference is less, resulting in a better success ratio of 96.8% and 74.6% for N=500 and 4000, respectively. Also, for 1 channel, the I-ASF algorithm achieves a high success ratio of 91.8% and 55.7% against N=500 and 4000, respectively when compared to the distance-based algorithm where it achieves a success ratio of 71% and 46.4% against N=500 and 4000 for 1 channel.

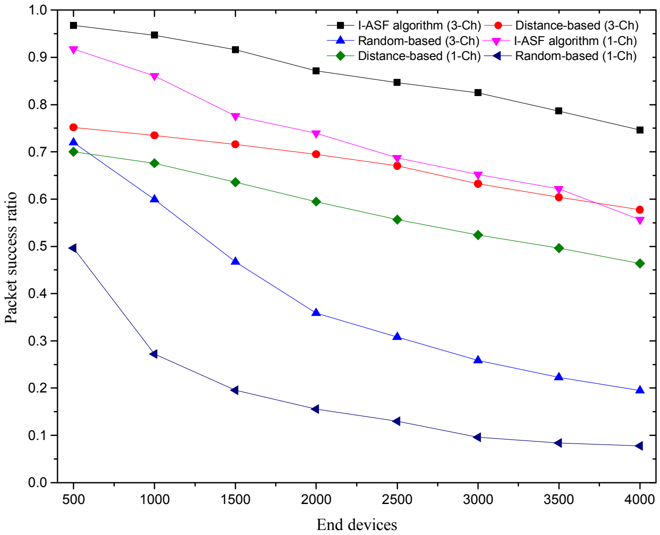

Fig. 1. Packet success ratio

IV. CONCLUSIONS

This paper proposes an algorithm called I-ASF by considering the interference between the same and different SFs. We adapted the additive interference model to counteract against the interference by leveraging the distance-based SF assignment algorithm. The simulation results show that I-ASF algorithm performs better than both the distance-based and random-based algorithm in terms of the packet success ratio.

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