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## Interdisciplinary

Highlights

- Cloud-based Analytics
- Revolutionizing Supply Chains
- Optimal Cooling Systems
- LoRa Backscatter Communication

Discovering Thoughts, Inventing Future

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# Modeling LoRa Backscatter Communication Range

By Siaka Konate, Changli Li, Andri Pranolo & Moriba Traore

*Nanjing University of Information Science and Technology*

*Abstract-* The enhancement of IoT applications for low-power and long-range communication requires developing communication techniques that consume a small amount of power while transmitting at longer distances. LoRa backscatter is a promising solution for such applications. In this work, we will develop a model that helps to estimate the communication range between a LoRa backscatter tag and a receiver. The developed model has been tested by simulation using Python, and the results are validated by comparing the achieved range using our model with state-of-art LoRa backscatter works. We have also extended the model to account for the effect of SNR loss due to direct interference from the transmitter and inter-tag interference from neighbouring tags in concurrent LoRa backscatter systems.

*Keywords:* *LoRa backscatter, low power communication, IoT, backscatter communication, Energy harvesting.*

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MODELINGLORABACKSCATTERCOMMUNICATIONRANGE

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# Modeling LoRa Backscatter Communication Range

Siaka Konate [α], Changli Li [σ], Andri Pranolo [ρ] & Moriba Traore [Ѡ]

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*Table 1:* List of Abbreviations

| Abbreviation | Description |
|---|---|
| AmBack | Ambient Backscatter |
| IoT | Internet of Thing |
| MIoT | Massive IoT |
| LoRa | Long Range |
| LPWAN | Low Power Wide Area Network |
| LoRaWAN | LoRa Wide Area Network |
| NB-IoT | Narrow Band IoT |
| BLE | Bluetooth Low Energy |
| FM | Frequency Modulation |
| RF | Radio Frequency |
| BPSK | Binary Phase Shift Keying |
| OOK | On off Keying |
| FSK | Frequency Shift Keying |
| SF | Spreading Factor |
| AWGN | Additive white Gaussian noise |
| NLOS | Non-line-of-sight |
| LOS | Line-of-sight |
| NF | Noise Figure |
| BW | Bandwidth |
| CSS | Chirp Spread Spectrum |
| SNR | signal-to-noise ratio |
| SINR | signal-to-interference-plus-noise |

*Author α Ѡ: Normal School of Technical and Vocational Education, Kabala, Bamako Mali. e-mails: konatesiaka77@gmail.com, maitydiallo2018@gmail.com*
*Author σ: School of Artificial Intelligence, Nanjing University of Information Science and Technology, 144 Pancheng new Street Pukou District, Nanjing, 210044, China. e-mail: charlee@nuist.edu.cn*
*Author ρ: Informatics Department, Universitas Ahmad Dahlan, Yogyakarta, Indonesia. e-mail: andri.pranolo@tif.uad.ac.id*

## I. Introduction

Today, with the expansion of IoT devices, one of the most significant challenges is developing a communication theory that can reduce the power consumption of the nodes while maintaining a long communication range. In the last decade, different technologies have been proposed for this purpose. Recently, LPWAN technology such as LoRa, SIGFOX, and NB-IoT has been seen as a promising candidate for future IoT applications [1–5]. However, with extremely low power requirements in today's IoT applications, active communication using power hungry devices such as amplifiers, filters, and oscillators is limited. These small objects are sometimes placed in environments where battery replacement or recharging is difficult. Therefore, backscatter communication has been seen as a promising solution to significantly lower power consumption by communicating with nodes using passive devices [6]. Backscatter communication has been widely used for different low-power applications such as environmental monitoring, health monitoring, and localization [7, 8]. One of the advantages of backscatter technology is its ability to rely on available ambient RF signal sources in the environment, such as FM and TV broadcasting, WIFI, or cellular signal [9–12]. This significantly lowers the deployment cost since any dedicated signal source is required as in bi-static backscatter configuration. Several ambient backscatter communication systems have been proposed in the literature. In [12], the ready available FM broadcasting signal is used to backscatter tag data that can be decoded in any FM receiver. In that work, a range of 60 feet (18.2 m) was achieved and consuming only 11.07 W of power. [11] uses Wi-Fi transmission as an excitation signal to backscatter tag information to be decoded by a Wi-Fi access point. They achieve a communication rate of 5Mbps at a range of 1m and 1Mbps at 5m. In work [13], the maximum range for backscatter communication utilizing the ambient FM radio signal was presented. Using a ray-tracing technique and radar equation, and placing the receiver antenna close to the FM transmitter as in monostatic backscatter, a distance of 14.5 km was achieved.

The limited range of technologies mentioned above has motivated the research community to develop a backscatter system that uses LoRa transmission as an excitation signal. The high sensitivity of the LoRa signal due to CSS-type modulation has been used by researchers to develop the LoRa backscatter communication technique for energy-constrained IoT devices communication [14–18]. LoRa backscatter is intended to improve communication range while consuming a small amount of energy. For example, [16] overturns the conventional short-range wisdom of backscatter and presents a LoRa Back system that can transmit up to 475m and consumes only 9.25 $\mu W$ of power while being compatible with commodity LoRa hardware. The error performance of LoRa backscatter has been addressed in the literature. In [19], a closed-form expression was derived for SER on both the AWGN and the Nakagami-m double fading channels. The authors in [20] propose a receiver design based on the square-law detector to theoretically evaluate the error performance of the LoRa backscatter system under the AWGN channel and derive an approximate closed-form expression of the bit error rate using the union bond method. The authors show that LoRa backscatter outperforms active LoRa for SNR values between 2 and 9 dB. The authors in [21] present a comprehensive review of the literature on LoRa backscatter technology with an emphasis on tag design, interference cancellation techniques, receiver design, applications, and future research directions.

Despite the broad literature, the link budget of LoRa backscatter is not adequately addressed yet. We aim to evaluate the communication channel using a path loss channel model to derive the transmission range between the LoRa backscatter tag and the receiver.

In this paper, we propose an analytical model to evaluate the propagation channel and estimate the communication range between the tag and the receiver in different propagation environments. The proposed model can be used to optimize network efficiency.

Our key contributions to this work are summarized as follows.

- We develop an analytical model to estimate the communication range of LoRa backscatter technology. The proposed model can be used to theoretically estimate how far a receiver can be placed from the tag based on the design parameters such as the modulation scheme, the properties of the tag material and the propagation environment.
- Analyze the effect of different parameters that affect the communication range, such as active LoRa parameters, the propagation environment, and antenna polarization.
- We have extended the model to account for the effect of inter-tag interference, time, and frequency synchronization as well as the near-far problem for a concurrent transmission where several tags concurrently transmit to a receiver simultaneously.
- Evaluate the accuracy of our range model by comparing it with the achieved range in state-of-the-art LoRa backscatter systems that use proof-of-concept prototypes.

The remainder of this paper is structured as follows. In Section 2, we present the principles of LoRa backscatter communication. Section 3 develops a theoretical model for estimating the range between the RF tag and the receiver in LoRa backscatter communication with details of each parameter. Section 4 presents the simulation results and discussion. The work was concluded in Section 5.

## II. Overview of LoRa Backscatter

LoRa backscatter technology is an ambient backscatter communication technique that uses an ambient LoRa signal as an excitation signal. Depending on the type of excitation signal, two possible LoRa backscatter designs are possible: first, the excitation is an unmodulated single tone that a backscatter tag uses to synthesize a LoRa compatible packet and transmit information to the receiver [16, 17, 22–24]. However, this requires complex tag operation and hence increases its energy consumption. The second idea consists of using the LoRa-modulated signal to encode the tag data and backscatter to the receiver [14, 15, 18]. This type of tag design is complex because of the cancellation of the interference from the LoRa transmitter, which is complex and unknown to both the tag and the receiver. To address this challenge, the work [18] simply shifts the excitation signal to another channel and therefore creates out-of band interference that limits network performance. [15] shifts the excitation in the same band as the backscatter signal and proposes a method to combine the energy in double sidebands to enhance the SNR. Using an ambient LoRa signal as excitation requires the tag to detect its presence and pick it from unwanted signals. This is achieved using a packet detection circuit. The packet detection circuit in the LoRa backscatter tag is characterized by its power consumption and sensitivity. The higher the sensitivity, the higher the distance from the source to the tag.

## III. Proposed Model

In this section, we present the step-by-step derivation of the proposed model using the path loss channel modeling for different propagation environments. Path loss channel models represent the power reduction of a transmitted signal as it traverses the wireless medium. These channel models are based on the medium through which the signal travels, such as free space, rain, fog, or gas. We will derive a range estimation model for free-space and realistic scenarios of LOS and NLOS.

The flow chart of the proposed model is illustrated in Figure 1. At first, a single node communication is considered, where one transmitter communicates with one receiver. If the propagation channel is the free space environment, the theoretical

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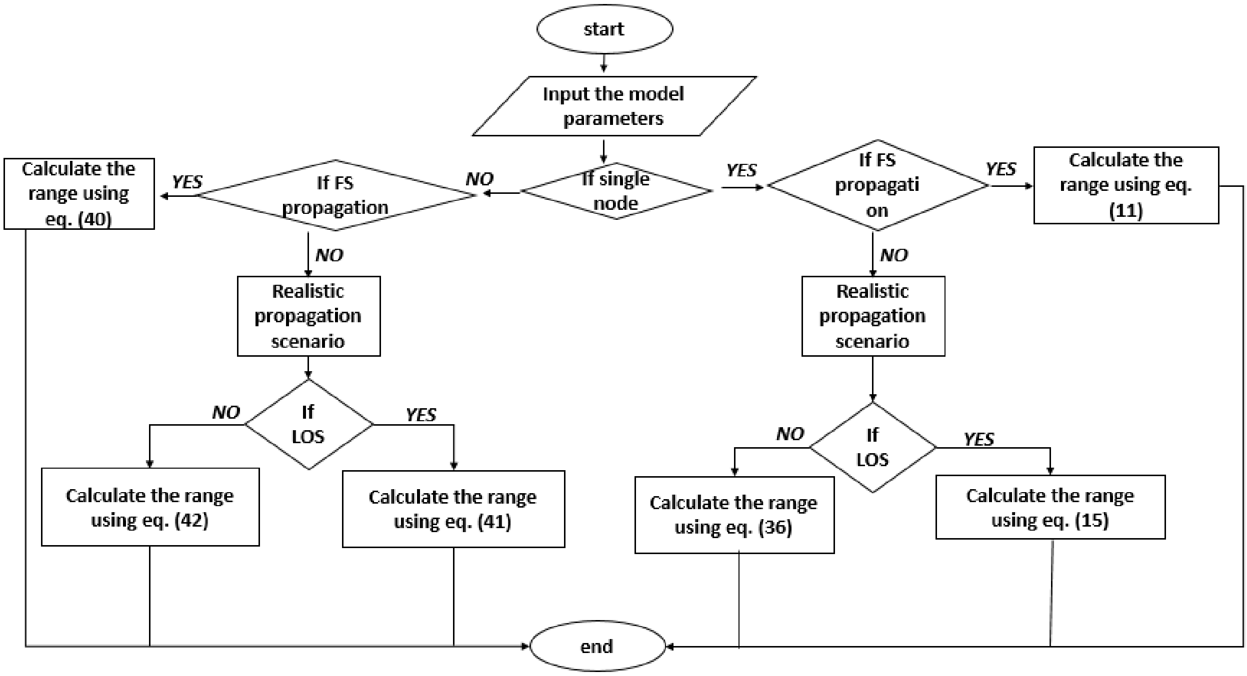



*Figure 1:* Flow Chart of the Proposed Model Derivation

range is calculated using eq. (11). For a realistic scenario, the impacts of different losses are considered. The eq. (15) and eq. (36) are used to calculate the range of the tag and the receiver for the LOS and NLOS scenarios, respectively. When multiple nodes are deployed in the network, communication from different nodes will introduce interference that affects link quality. Similarly, the communication ranges that account for the effect of interference are calculated for free space, LOS, and NLOS using eq. (40), (41), (42), respectively.

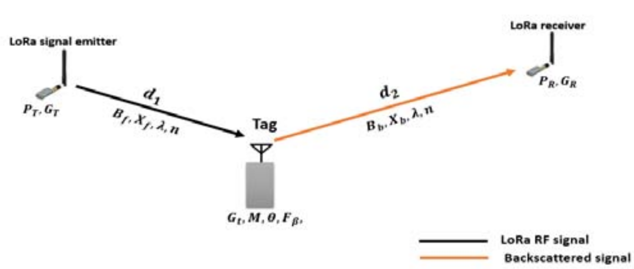



*Figure 2:* System Overview of Ambient Lora Backscatter

*a) Free Space Propagation*

In backscatter communication systems, the link can be divided into two parts, i.e. the forward (unmodulated) and backward (modulated) links, as shown in Figure 2. The link budget for the forward link using the Friis free space equation is given as [25]:

$$P_t = P_T G_T G_t M(\frac{\lambda}{4\pi d_1})^2 \quad (1)$$

$P_t$ is the received power at the tag location, $P_T$ is the transmit power, $G_T$ and $G_t$ are the transmitter and tag antenna gain respectively. $d_1$ is the distance between the transmitter and tag, and λ is the wavelength. M is the modulator factor and will be more detailed in Section 3.3.1

Similarly, the link budget for the backward link is defined as-

$$P_R = P_t G_R G_t M(\frac{\lambda}{4\pi d_2})^2 \quad (2)$$

Where $P_R$ is the received power at the LoRa backscatter receiver, $P_t$ is the received power at the tag, and $G_R$ is the receiver antenna gain. $d_2$ is the distance between the tag and the receiver. We can derive the free space path loss for the forward and the backward link from Eq. (1) and (2) as-

$$P_f^{FS} = \frac{P_T}{P_t} = \frac{(4\pi d_1)^2}{G_T G_t \lambda^2} \quad (3)$$

$$P_b^{FS} = \frac{P_t}{P_R} = \frac{(4\pi d_2)^2}{G_R G_t M \lambda^2} \quad (4)$$

Multiplying Eq. (3) by Eq. (4) results in combined path loss for the free space the backscatter link and is given as-

$$P_c^{FS} = \frac{P_T}{P_R} = \frac{(4\pi)^4 (d_1 d_2)^2}{G_T G_R G_t^2 M \lambda^4} \quad (5)$$

The Eq. (1) and (2) can also be modified to incorporate the effect of different environments. Since the received signal decreases with the $n_{th}$ power of the distance, where the parameter n is the path loss exponent, the value of which depends on the environment. The modified equivalent of Eq. (1) and (2) accounting for the path loss exponent are given as follows.

$$P_t = P_T G_T G_t (\frac{\lambda}{4\pi})^2 \frac{1}{d_1^n} \quad (6)$$

$$P_R = P_t G_R G_t M (\frac{\lambda}{4\pi})^2 \frac{1}{d_2^n} \quad (7)$$

The new combined path loss accounting for the effect of the environment can then be expressed as follows:

$$P_c^{FS} = \frac{P_T}{P_R} = \frac{(4\pi)^4 (d_1 d_2)^n}{G_T G_R G_t^2 M \lambda^4} \quad (8)$$

Assume $P_R$ to be the sensitivity of the LoRa receiver, which is a function of the spreading factor and bandwidth ($P_R$ (SF, BW)) and is defined as the minimum received power required to decode the information. The sensitivity of the LoRa receiver is determined using the following formula [26]

$$P_R(SF, BW) = SNR(SF, BW) * NF * K * T * BW \quad (9)$$

Where, *SNR (SF, B)* is the signal-to-noise ratio and depends on the spreading factor and the bandwidth. *NF* is the noise figure, *K* is the Boltzmann constant, *T* is the temperature in kelvin, and *BW* is the LoRa transmission bandwidth. Applying the processing gain and spreading factor effect, the signal-to-noise ratio can defined as-

$$SNR(SF, BW) = \frac{SNR_0}{2^{SF}} \quad (10)$$

Where $SNR_0$ is the minimum required SNR to decode information. Using Eq. (10) and (9) into Eq. (8), we can defined the RF tag-to-receiver distance as:

$$d_2^{FS} = \left( \frac{P_T.G_T.G_R.G_t^2.M.2^{SF}}{SNR_0.NF.K.T.BW} (\frac{\lambda}{4\pi})^4 \right)^{\frac{1}{n}} \frac{1}{d_1} \quad (11)$$

We can notice from Eq. (11) that the distance between RF tag and the receiver is inversely proportional to the transmitter-to-tag distance. Additionally, an increase in the spreading factor leads to an increase of distance $d_2$.

*b) A General Link Budget*

In practice, different parameters can affect the performance of the system. A complete link budget should account for the effects of these parameters for a better evaluation of the backscatter communication link. As defined for free space propagation, a general link budget equation for the forward and backward account for all the losses introduced in the transmitter-to-tag and tag-to-receiver link can be defined as [27]:

$$P_t = \frac{P_T G_T G_t X_f}{B_f} (\frac{\lambda}{4\pi})^2 \frac{1}{d_1^n} \quad (12)$$

$$P_R = \frac{P_t G_R G_t X_b M}{B_b \theta F_\beta} (\frac{\lambda}{4\pi})^2 \frac{1}{d_2^n} \quad (13)$$

$X_f$ and $X_b$ represent the polarization mismatch of the forward and backward links, respectively. $B_f$ and $B_b$ are the forward and backward lint path blockages, respectively. θ is the RF tag antenna's on-object gain penalty, and $F_\beta$ is the small-scale fading loss for a bistatic dislocated backscatter configuration [27].

Using (12) in (13), the combined link budget is given as-

$$P_R = \frac{P_T G_T G_R G_t^2 X_f X_b M}{B_f B_b \theta F_\beta} (\frac{\lambda}{4\pi})^4 (\frac{1}{d_2 d_1})^n \quad (14)$$

Following the same reasoning as in free space propagation, the tag-to-receiver distance $d_2$ is derived as-

$$d_2^{LOS} = \left( \frac{P_T.G_T.G_R.G_t^2.X_f.X_b.M.2^{SF}}{SNR_0.NF.K.T.BW.B_f.B_b.\theta.F_\beta} (\frac{\lambda}{4\pi})^4 \right)^{\frac{1}{n}} \frac{1}{d_1} \quad (15)$$

The modulation factor M and the unitless loss term $X_f$, $X_b$, $B_f$, $B_b$, θ and $F_\beta$ are well described in Section 3.3.

*c) Parameters Description*

In this subsection, a brief description of each parameter involved in radio propagation between the LoRa transmitter-to tag and tag-to-receiver is presented.

i. *Modulation factor*

The reflected power of the RF tag device depends not only on the antenna properties and the surrounding environment but also on the modulation factor, which also depends on the modulation scheme used. The modulation factor is given as [28]

$$M = \frac{1}{4}|\Gamma_1 - \Gamma_2|^2 = \frac{1}{4}|\Delta\Gamma|^2 \quad (16)$$

There are techniques used to amplify the reflected power from the RF tag. Therefore, the modulation factor can be evaluated in two different ways depending on the tag design: using the convectional tag design without reflection amplifier and using the reflection amplifier.

*Using the conventional tag design without reflection amplifier* A typical tag modulates the information bit by switching between two impedance values $Z_1$ and $Z_2$ resulting in two reflection coefficients $\Gamma_1$ and $\Gamma_2$ representing states 1 and 2, respectively. Where $\Gamma_1$ and $\Gamma_2$ are defined by Eq. (17) and (18) [29]

$$\Gamma_1 = \frac{(Z_1 - Z_a^*)}{(Z_1 + Z_a^*)} \quad (17)$$

$$\Gamma_1 = \frac{(Z_2 - Z_a^*)}{(Z_2 + Z_a^*)} \quad (18)$$

Modulation on the tag will alter the amplitude and/or phase of the signal backscattered by the RF tag [30], [31], resulting in an ASK and/or a PSK signal, respectively. Additionally, switching between two loads multiple times per bit period produces an FSK signal [32]. When using a binary phase shift keying (BPSK), only the phase of the reflected signal will change, and the amplitude will remain the same, resulting in two reflection coefficients, as given in Eq. (19)

$$\Gamma_1 = Ke^{j\phi_1} \quad \Gamma_2 = Ke^{j\phi_2} \quad (19)$$

Where $K$ is a constant whose value varies from 0 to 1, the maximum reflection is achieved for $K = 1$ and $\varphi_1 = -\varphi_2$, resulting in reflection coefficient values $\Gamma_1 = 1$ and $\Gamma_2 = -1$. And using (16), the modulator factor $M$ can be easily derived for the BPSK. For an ASK modulation, only the amplitude of the reflected signal will change; the phase will remain the same, and this is translated in reflection coefficients as in Eq. (20)

$$\Gamma_1 = K_1e^{j\phi} \quad \Gamma_2 = K_2e^{j\phi} \quad (20)$$

Where $K_1$ and $K_2$ are two constants whose values vary from 0 to 1 with $K_1 \leq K_2$. When $K_1 = 0$ and $K_2 = 1$, the reflected signal is an OOK modulated signal, which is represented by a transition between a total absorption (stage 1) and total reflection (state 2) states. Table 2 summarized some modulation factor values calculated using Eq. (16) and by choosing arbitrary values of $K$, $K_1$, and $K_2$.

*Table 2:* Modulation Factor for Different Modulation Scheme

| Modulation type | $K$ | $K_1$ | $K_2$ | $\Gamma_1$ | $\Gamma_1$ | M |
|---|---|---|---|---|---|---|
| BPSK | 1 | - | - | -1 | 1 | 0.5 |
| ASK | - | 0.2 | 0.8 | 0.2 | 0.8 | 0.15 |
| OOK | - | 0 | 1 | 0 | 1 | 0.25 |

*Using RF tag reflection amplifier* in the past decade, researchers have introduced the principles of the reflection amplifier to improve the efficiency of RF tag scattering, which refers to the amount of power a tag can reflect for a given induced power level and therefore to increase the communication range between the tag and the receiver [33], [34], [35]. In [33], an ASK modulation is achieved by switching on and off the amplifier, resulting in two reflection coefficients defined as-

$$\Gamma_1 = Ke^{j\phi_1} \quad \Gamma_2 = \sqrt{G}e^{j\phi_2} \quad (21)$$

Where $K$ and $G$ are the amplitudes of the reflected signal during the on and off state, in their respective phases, respectively. The reflection coefficient difference amplitude is-

$$|\Delta\Gamma| = |Ke^{j\phi_1} - \sqrt{G}e^{j\phi_2}| \quad (22)$$

The maximum reflection is achieved for K=1 and $\varphi_2 = \varphi_1 + \pi$ and is given as-

$$|\Delta\Gamma|_{max} = \sqrt{G} + 1 \quad (23)$$

The minimum reflection is derived for K=1 and $\varphi_2 = \varphi_1$ and is given as-

$$|\Delta\Gamma|_{min} = \sqrt{G} - 1 \quad (24)$$

When K=0, the resulting modulation is an OOK, then the difference in the reflection coefficient will be-

$$|\Delta\Gamma|_{min} = \sqrt{G} \quad (25)$$

In [35], an antipodal modulation of type BPSK is achieved by performing a 0 or 180 phase shift on the backscattered signal. The reflection coefficients for the two states are defined as follows.

$$\Gamma_1 = \sqrt{G}e^{j\phi} \quad \Gamma_2 = \sqrt{G}e^{-j\phi} \quad (26)$$

Resulting in a reflection coefficient difference of-

$$|\Delta\Gamma|_{min} = 2\sqrt{G} \quad (27)$$

The value of the reflection gain depends on the input power at the tag. Table 3 gives different values of M calculated from (16) using the tag reflection amplifier gain G of 10.2dB for various modulation schemes.

*Table 3:* Modulation Factor for Different Modulation Schemes using a Reflection Amplifier at Rf Tag

| Modulation Type | Reflection Amplifier gain G in dB | Modulation Factor |
|---|---|---|
| BPSK | 10.2 | 6.48 |
| ASK | 10.2 | 2.24 - 4.24 |
| ASK | 10.2 | 3.24 |

ii. *Polarization Mismatch*

The polarization of an EM wave is a term that describes the direction of the radiated electric field from the antenna. We distinguish three types of polarization, depending on the shape traced by the electric field vector: linear, circular, or elliptical. Signal reception is damaged if the polarization of the antennas does not match, which is also known as polarization mismatch. It represents the electromagnetic (EM) power lost due to polarization mismatch between transmitting and receiving antennas and is characterized by a factor X that varies from 0 (perfect mismatch or no power is transferred between the antennas) to 1 (matched or no power lost) on linear scale. The polarization mismatch loss for any angular alignment θ between the principal axes can be calculated as in [36].

$$X(dB) = 10log\left[\frac{1+\rho_T^2\rho_R^2+2\rho_T\rho_R cos2\theta}{(1+\rho_T^2)(1+\rho_R^2)}\right] \quad (28)$$

where $\rho_T = (AR_T+1)(AR_T-1)$ is the circular polarization ratio of the transmitted wave and $\rho_R = (AR_R+1)(AR_R-1)$ is the circular polarization ratio of the receiving antenna. $AR_T$ and $AR_R$ are the axial ratio of the transmitted wave and the axial ratio of the receiving antenna (in linear scale), respectively. θ is the angle between the polarization vectors.

We can notice from Eq. (28) that two arbitrary polarizations are orthogonal (X=0 in linear scale) only if

$$\rho_R = \frac{1}{\rho_T} \quad \text{and} \quad \theta = 90^\circ \quad (29)$$

Moreover, The maximum and minimum polarization mismatch occurs when θ equals 0° and 90°, respectively. A homograph showing maximum and minimum losses is presented in Figure 3 and can be used to calculate the value of the polarization mismatch between the transmitting and receiving antennas [37].

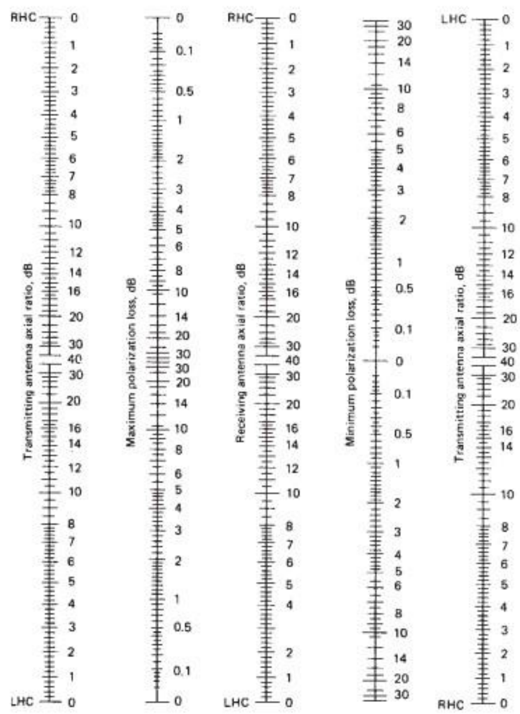



*Figure 3:* Maximum and Minimum Polarization Loss given the Axial Ratio [37]

A linear polarized wave is an elliptically polarized wave with an infinite axial ratio of infinity. For a linear polarization, the Eq. (28) is simplified to-

$$X(dB) = 10log(cos^2(\theta \quad (30)$$

In backscatter communication systems, we can define two polarization mismatches $X_f$ and $X_b$ that represent the forward and backward links, respectively.

Polarization mismatch calculation $X_f$ and $X_b$ Let us consider three cases of antenna polarization for forward and backward links:

- *Case 1:* LoRa transmitter, the tag and LoRa receiver antennas are all linearly polarized.
- *Case 2:* LoRa transmitter and LoRa receiver antennas are right-hand circularly polarized, and the tag antenna is linearly polarized.
- *Case 3:* LoRa transmitter, tag, and LoRa receiver antenna are all left-hand circularly polarized.

Table 4 presents some values of the forward and backward polarization mismatch $X_f$ and $X_b$ given θ values computed using the assumption in case 1.

In case 2, a linearly polarized tag antenna is trying to receive a circularly polarized wave from the LoRa transmitter which can be seen as two orthogonal linearly polarized waves with one in phase; therefore, the linearly polarized tag antenna will simply pick up the in-phase component of the circularly polarized wave from the LoRa transmitter, resulting in a forward polarization mismatch value $X_f = 0.5$. Similarly, the linearly polarized

*Table 4:* Polarization Mismatch $X_f$ and $X_b$ Values Given $\theta$ for Case 1

| Scenario | $\theta_f$ | $\theta_b$ | $X_f$ | $X_b$ |
|---|---|---|---|---|
| Scenario 1 | 0° | 0° | 1 | 1 |
| Scenario 2 | 90° | 90° | 0 | 0 |
| Scenario 3 | 24° | 81° | 0,83 | 0,02 |
| Scenario 4 | 36° | 59° | 0,65 | 0,26 |
| Scenario 5 | 63° | 15° | 0,20 | 0,93 |
| Scenario 6 | 6° | 11° | 0,99 | 0,96 |

receiver antenna will pick up the in-phase component of the circularly polarized wave from the tag, resulting in a backward polarization mismatch $X_b$ of 0.5.

In case 3, we assume that all antennas are right-hand circularly polarized (RHCP). Similarly, Table 5 presents some values of the polarization mismatch for forward and backward links using the monograph in Figure 3, given the axial ratio in dB.

*Table 5:* Polarization Mismatch $X_f$ And $X_b$ Values Calculated from Monograph in Figure 3 Given Axial Ratio Values for Case 3

| Scenarios | $AR_{TX}$ dB | $AR_{tag}$ dB | $AR_{RX}$ dB | $X_f$ dB | $X_b$ dB |
|---|---|---|---|---|---|
| Scenario 1 | 0 | 0 | 0 | 0 | 0 |
| Scenario 2 | 2.4 | 1.5 | 3 | 0.02 | 0 |
| Scenario 3 | 5 | 2 | 0.8 | 0.1 | 0,02 |
| Scenario 4 | 10 | 0.1 | 4 | 1 | 0,26 |
| Scenario 5 | 7 | 2 | 5 | 0,3 | 0,93 |

iii. *Path Blockage*

Path blockage B represents the loss in the link budget that occurs when an obstruction, such as buildings, trees, ridges, bridges, vegetation, cliffs, etc., blocks the signal propagation path. The obstruction causes a non-line-of-sight (NLOS) between the transmitting and the receiving antennas. In [38], a frequency-dependent NLOS equation is defined to characterize the NLOS path loss as given as below.

$$PL^{NLOS} = 36.85 + 30\, log_{10}(d) + 18.9\, log_{10}(F_C) + \chi_a, \tag{31}$$

where $F_C$ is in GHz, $d$ is the distance between transmitter and receiver in meters, and $\chi_a$ is the shadowing component modelled according to a lognormal random variable with standard deviation $\sigma = 4dB$ [39]

We calculate the values of the forward and backward path blockages $B_f$ and $B_b$ using Eq. (31). Since the carrier frequency is the same for the forward and backward links, and assuming the same value of the standard deviation $\sigma = 4dB$ for both links, the blockage loss values $B_f$ and $B_b$ will only depend on the transmitter-to-tag and tag-to-receiver distance and are given as:

$$B_f = 36.85 + 30\, log_{10}(d_1) + 18.9\, log_{10}(F_C) + \chi_a, \tag{32}$$

The Table 6 presents some values of path blockage computed at distances $d$ in the 915 MHz ISM band.

*Table 6:* Path Blokage for Given Distances at 915 MHz ISM BAND

| Distance in (m) | Path blockage in (dB) |
|---|---|
| 1 | 40.12 |
| 10 | 70.12 |
| 50 | 91.09 |
| 100 | 100.12 |
| 1000 | 130.12 |
| 10000 | 160.12 |

The tag-to-receiver distance defined in Eq. (15) can be modified to account for the effect of path blockage on forward and backward links. First, let us express the Eq. (32) and (33) in linear form as follows.

$$B_f = 6487\, \chi_a\, d_1^3 \tag{34}$$

$$B_b = 6487\, \chi_a\, d_2^3 \tag{35}$$

Replacing Eq. (34) and (35) in (15) will result in a tag-to receiver distance $d_2$ as-

$$d_2^{NLOS} = \left(\frac{P_T.G_T.G_R.G_t^2.M.X_f.X_b.M.2^{SF}}{42.10^6.SNR_0.NF.K.T.BW.\chi_a^2.\theta.F_\beta}(\frac{\lambda}{4\pi})^4\right)^{\frac{1}{3n}} \frac{1}{d_1} \tag{36}$$

iv. *Fade Margin*

The fade margin results in interference from scattered waves that are caused by objects surrounding the environment of the tag. It is a function of the position of the RF tag, even in line-of sight [27] and results in a variation of the backscattered signal and is known as small-scale fading [27]. Its value is calculated using the outage probability. The fade margin is defined as [27]:

$$F = 10\, log_{10}\left\{\frac{F_R^{-1}(outage\ probability)^2}{P_{av}}\right\} \tag{37}$$

Where, $P_{av}$ is the average channel power, and $F_R{}^{-1}$ is the cumulative distribution function of the received envelope. In this thesis, we assume a deployment in an agriculture application where there are few objects that can produce interference; therefore, the outage probability can be chosen as small. From [27], for an outage probability of 0.005 and a gain of 3dB, the calculated fade margin for a dislocated backscatter link was 26 dB.

v. *Tag on object gain*

The on-object antenna gain accounts for the losses when the RF tag is close to or attached to an object [27]. The value of θ depends on the properties of the material, the geometry of the object, the frequency, and the type of antenna. In [40], the values of θ for different materials have been measured using simulation. Table 7 shows some values of θ for various materials measured at 915MHZ [27, 40]. In this work, we assume the tag to be attached to a cardboard sheet.

*Table 7:* On-Objet Antenna Gain Penalties for Various Material Measured at 915 mhz in Db [40]

| Material | θ (in dB) |
|---|---|
| Aluminum | 10.4 |
| De-Ionized water | 5.8 |
| Acrylic Slab | 1.1 |
| Cardboard Sheet | 0.9 |

d) *Concurrent transmission in LoRa backscatter and interference effects*

It has been shown that different tag signals can be decoded at the receiver, enabling concurrent transmission using the LoRa signal as excitation. Such receiver designs are commonly used in Internet of Things (IoT) applications where different sensors need to be deployed to cover the entire monitoring area. In [41] a LoRa backscatter configuration based on concurrent transmission was proposed for automatic irrigation monitoring where all sensor nodes transmit their data to a LoRa backscatter receiver. However, in such an implementation, some key challenges have to be addressed. Note that interfering signals contribute to the receiver noise power and hence reduce the SNR which affects the receiver performance and decreases the range. The key challenge while designing such receiver consists in removing the effect of interferences generated by the excitation signal (strong in-band interference) and the one from neighboring tags (inter-tag interference). These challenges have been addressed in [15, 42]. In [15], the inter-tag interference is addressed by using a hamming window that smoothly reduces signal amplitude toward zero from the centre to the edges. [15] also adds additional empty bins between two allocated bins to deal with the frequency and time offset caused by the difference in ToF (Time of Flight) between the tag and receiver. A similar technique is used in [42] to combat the time synchronization effect. Additionally, [42] uses a power-aware cyclic shift technique where lower SNR devices use a much different cyclic shift than higher SNR devices.

On the basis of these observations, we extend our model to account for the effect of interference. Let us denote I as the combined power of interfering signals that represents the total signal loss due to the interference. The value of I depends on the receiver interference removal capability and on the combined received signal power from neighboring tags and transmitter (direct path) at the receiver location. Figure 4 illustrates a concurrent LoRa backscatter link. $d_{i11}$ and $d_{i12}$ are the forward and backward links separation distance for interfering tag 1, $d_{i21}$ and $d_{i22}$ are the forward and backward links separation distance for interfering tag 2, and $d_r$ is the distance between the LoRa transmitter and receiver. $P^d_r$ is the power received through the direct path (between the transmitter and the receiver). It is better for the receiver to eliminate interference and lower the value of I. Note that the interferences are non-coherent, i. e. they are not all at the same frequency and locked in phase. Therefore, the total interference power can be written as:

$$I = P_r^d + \sum_{i=1}^{N} P_{ri}^{tag} \tag{38}$$

Where, $P^d_r$, $P^{tag}_{ri}$ are the received powers from the direct path ( from the transmitter to the receiver) and the received power from the N neighboring tag (i.e. the interfering tags), respectively.

Now, we define the signal-to-interference-plus-noise (SINR) as:

$$SINR = \frac{P_r}{P_n + I} \tag{39}$$

Where $P_n$ is the noise power.

Note that the receiver sensitivity is inversely proportional to the level of interference. Using Eq. (9), the extended model accounting for the effect of interference of the achieved tagto-receiver distance for free space, LOS realistic, and NLOS realistic scenarios are given in Eq. (40), (41), and (42), respectively, as:

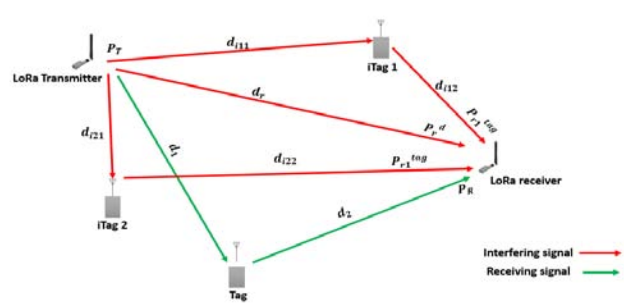



*Figure 4:* Concurrent Transmission Link Illustration

$$d_2^{FS} = \left( \frac{P_T.G_T.G_R.G_t^2.M.2^{SF}}{SNR_0.(NF.K.T.BW + P_r^d + \sum_{i=1}^{N} P_{ri}^{tag})} (\frac{\lambda}{4\pi})^4 \right)^{\frac{1}{n}} \frac{1}{d_1} \quad (40)$$

$$d_2^{LOS} = \left( \frac{P_T.G_T.G_R.G_t^2.X_f.X_b.M.2^{SF}}{SNR_0.(NF.K.T.BW + P_r^d + \sum_{i=1}^{N} P_{ri}^{tag}).\theta.F_\beta.} (\frac{\lambda}{4\pi})^4 \right) \quad (41)$$

The received power from the direct path $P_r^d$ and neighboring tags $P_{ri}^{tag}$ can be measured or computed using Eq. (43) and [44], respectively.

$$P_d = P_T G_T G_R \frac{\lambda^2}{4\pi} \frac{1}{d^n} \quad (42)$$

$$P_{ri}^{tag} = \frac{P_T G_T G_R G_{tag_i}^2 X_f X_b M}{B_f B_b \theta F_\beta} (\frac{\lambda}{4\pi})^4 (\frac{1}{id_{i1} id_{i2}})^n \quad (43)$$

## IV. Results and Discussion

In this section, we evaluate our derived models in different scenarios. First, we evaluate the communication range of LoRa backscatter technology between a tag node and a receiver in free space propagation. We examine the effect of LoRa transmission parameters on the tag-to-receiver distance. In this paper, for a better illustration, we consider an application scenario in which the LoRa backscatter system is deployed to monitor an irrigation field as presented in Figure 13a. However, the model can be adapted for other types of application in both outdoor and indoor environments simply by changing some parameter values. We assume that the LoRa signal source will be generated by the LoRa radio chip SX1272. LoRa chip SX1272 uses a spreading factor that varies from 6 to 12 and operates in the frequency range of 860 to 1020 MHZ [43]. We set the transmission frequency at 915 MHz and the transmit power at 20 dBm, which is the maximum allowed value in most regions. The LoRa provides three main transmission bandwidths: 125 KHZ, 250 KHZ, and 500 KHZ. We use the SX1308P915G LoRa gateway as the receiver which operates in the 915 MHZ band [44]. We fix the receiver noise figure at 6 dB and the minimum signal-to-noise ratio ($SNR_0$) at 15 dB.

Second, we evaluate the tag-to-receiver distance in a realistic scenario where additional losses are considered in the link budget in both the LOS and the NLOS scenarios. The modulation factor M is equal to 0.5 for the BPSK, as given in Table 2. We also assumed a linear polarization for the transmitter, tag, and receiver antennas with an angle between the polarization vector of 36° and 59°, resulting in a forward and backward polarization mismatch of 0.65 and 0.26 dB, respectively. We consider a tag attached to a cardboard Sheet which correspond to an tag-on-object gain penalty of 0.9dB. The fade margin is chosen to be 26dB as mentioned above. The path blockage effect is taken into account in the NLOS scenario and computed by Eq. (36). Moreover, the impacts of the above-mentioned parameters on the tag-to-receiver distance are also analyzed.

Third, we extend our model to account for both in-band strong interference and that generated by concurrent tag transmission. In concurrent transmission, a single receiver receives several tags signal, increasing the interference noise power and the receiver complexity, as detailed in Section 3.4. The effect of the interfering tag is also analyzed in this section.

The simulation parameters are summarized in Table 8 un-less otherwise stated.

*a) In Free Space Propagation*

We place the signal source at a fixed location, move the tag to different locations from the transmitter, and calculate the distance between the tag and the receiver. Figure 5 shows the com-

$$d_2^{NLOS} = \left( \frac{P_T.G_T.G_R.G_t^2.X_f.X_b.M.2^{SF}}{42.10^6.SNR_0.(NF.K.T.BW + P_r^d + \sum_{i=1}^{N} P_{ri}^{tag}).\chi_a^2.\theta.F_\beta.} (\frac{\lambda}{4\pi})^4 \right)^{\frac{1}{3n}} \frac{1}{d_1} \quad (42)$$

*Table 8:* Simulation Parameters

| Parameters | Values |
|---|---|
| $F_c$( MHz) | 915 |
| $P_T$ (dBm) | 20 |
| $G_T, G_R$ (dBi) | 2.4 |
| $G_t$ (dBi) | 2.1 |
| $BW$ (KHz) | 125 |
| $SNR_0$ (dB) | 15 |
| SF | 7 |
| Path loss exponent *n* | 3 for realistic case for free space case |
| $M$ | 0.5 |
| $F_\beta$ (dB) | 26 |
| $X_f$ | 0.26 |
| $X_b$ | 0.65 |
| $\theta$ (dB) | 0.9 |
| NF (dB) | 6 |

Global Journal of Computer Science and Technology ( G ) XXV Issue I Version I Year 2025 9

munication range achieved between the RF tag and the LoRa receiver (distance d2) in free-space propagation using Eq. (11). When the Rf tag is in the vicinity of the transmitter (distance less than 1m), the receiver can be placed as far as 6.8 km. This distance decreases as the transmitter-to-tag distance increases. For example, when the tag is placed 10m from the signal source, the receiver can be placed as far as 700m. At 60m from the transmitter, this distance drops to only about 114m. The midpoint between the LoRa transmitter and the receiver is measured at a distance d1=d2= 88m, which translates to a total distance of 176m between the RF source and the receiver. Note that the maximum communication range of LoRa backscatter technology depends also on tag sensitivity; i.e. the maximum distance at which an RF tag can detect the transmitted signal, limiting its applications range. The higher sensitivity circuit can be used on the tag to increase the detection range to hundreds of meters [15, 45].

i. *Effect of LoRa Parameters*

In this subsection, we analyze the effect of LoRa parameters, such as the spreading factor, bandwidth, and transmit power, on the LoRa backscatter range. LoRa uses different spreading factors. Now, we will increase the value of SF from 7 to 12 and visualize its impact on the communication range. As shown in Figure 6, the communication range increases with increasing SF value. For example, for a distance d1 of 20m, the receiver can be placed as far as 7.7 km, 2.7 km, and 1.3 km using SF values of 12, 9, and 7, respectively. By changing the spreading factor from 7 to 12 for a tag-to-source distance of 20m, we can improve the communication range by 6.4 km. However, for the LoRa communication system, higher throughput is achieved for small values of the spreading fac-

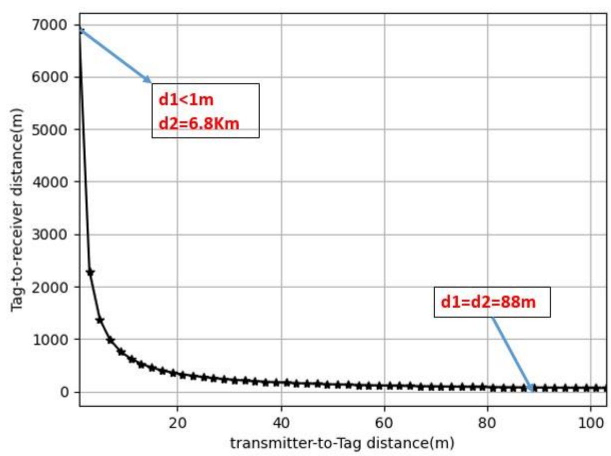



*Figure 5:* Tag-To-Receiver Distance for Free Space Model as a Function of Transmitter-to-tag Distance (D1)

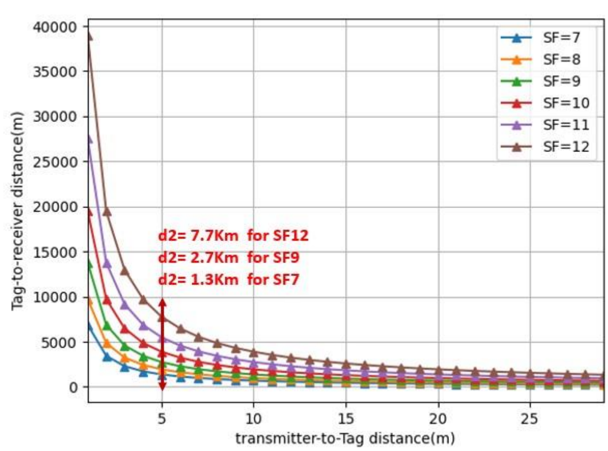



*Figure 6:* Tag-to-Receiver Distance for Free Space Model as a Function of Transmitter-to-Tag Distance (D1) for Different SF

tor [18]. Hence, there is a trade-off between throughput and range. For low data-rate applications such as automatic irrigation [41, 46], animal tracking [47], and forest fire detection, small values throughput can be tolerable; since the sensor node needs to transmit only a few bits of data.

Similarly, we vary the transmit power from 7 dBm to 30 dBm and evaluate its impact on the tag-to-receiver distance. In Figure 7, it can be seen that the communication range varies with transmit power. Higher transmit power leads to a longer communication range. For example, when we move the RF tag 5m away from the transmitter, the receiver can be placed as far as 0.3 Km, 0.7 Km, 1.3 Km, and 4.3 Km for transmit power of 7 dBm, 14 dBm, 20 dBm, and 30 dB, respectively. In other words, an increase of 6dB in transmit power improves the communication range by 47%. Note that a higher transmit power trans-

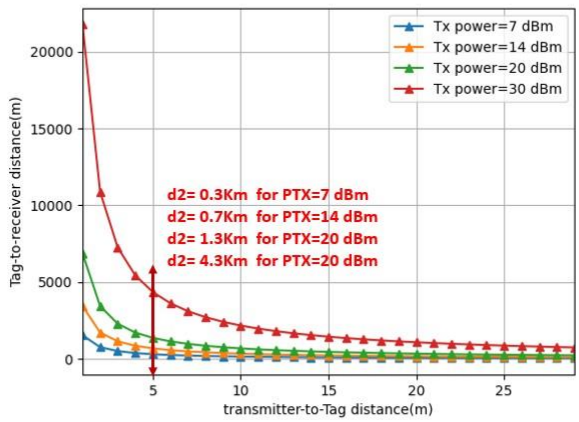



*Figure 7:* Tag-to-Receiver Transmission Range for Free Space Model as a Function of Transmitter-to-Tag Distance (D1)

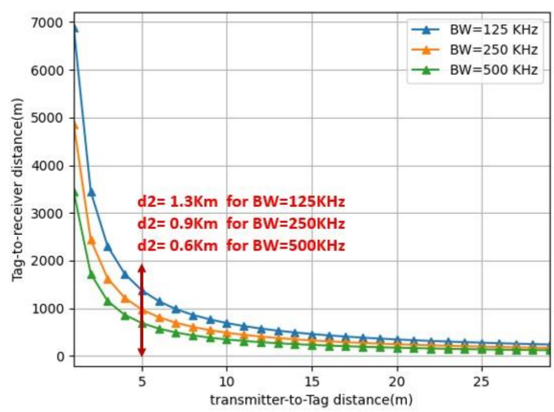



*Figure 8:* Tag-To-Receiver Transmission Range in Free Space Model as a Function of Transmitter-to-Tag Distance (D1) for Different Lora Transmission Bandwidths

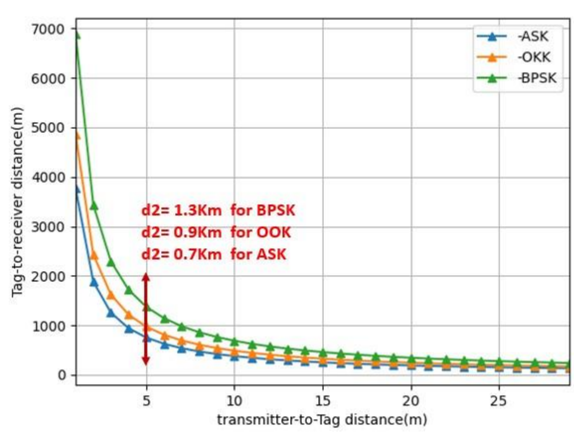



*Figure 9:* Tag-To-Receiver Ranges in Free Space Model for Different Modulation Schemes

lates into higher energy consumption. In addition, in backscatter communication systems, the direct signal received from the transmitter creates interference, which limits the detection of the weak backscatter signal from the tag at the receiver. In the literature, direct interference cancellation techniques have been

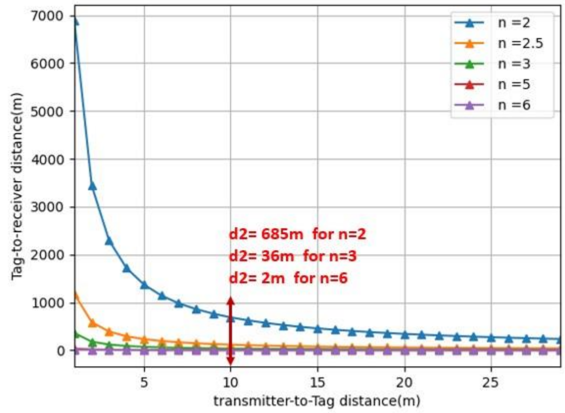



*Figure 10:* Tag-to-Receiver Transmission Range as a Function of Transmitter-to Tag Distance (D1) Different Path Loss Exponent

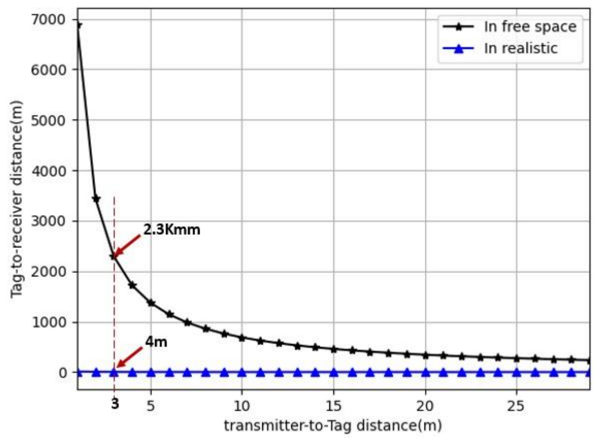



*Figure 11:* Tag-To-Receiver Distance Comparison Between Free Space and Realistic Model Corrected Version Under Same Antenna Gain ($G_T = G_R = G_t = 1$)

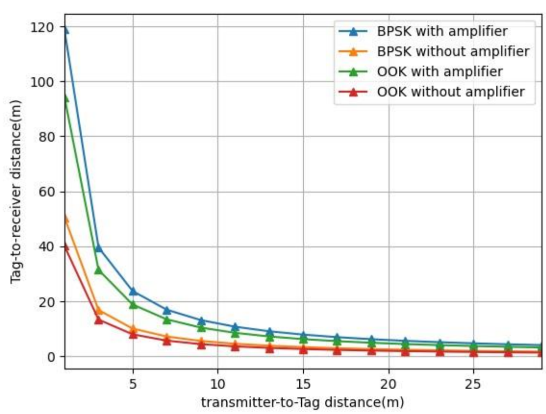
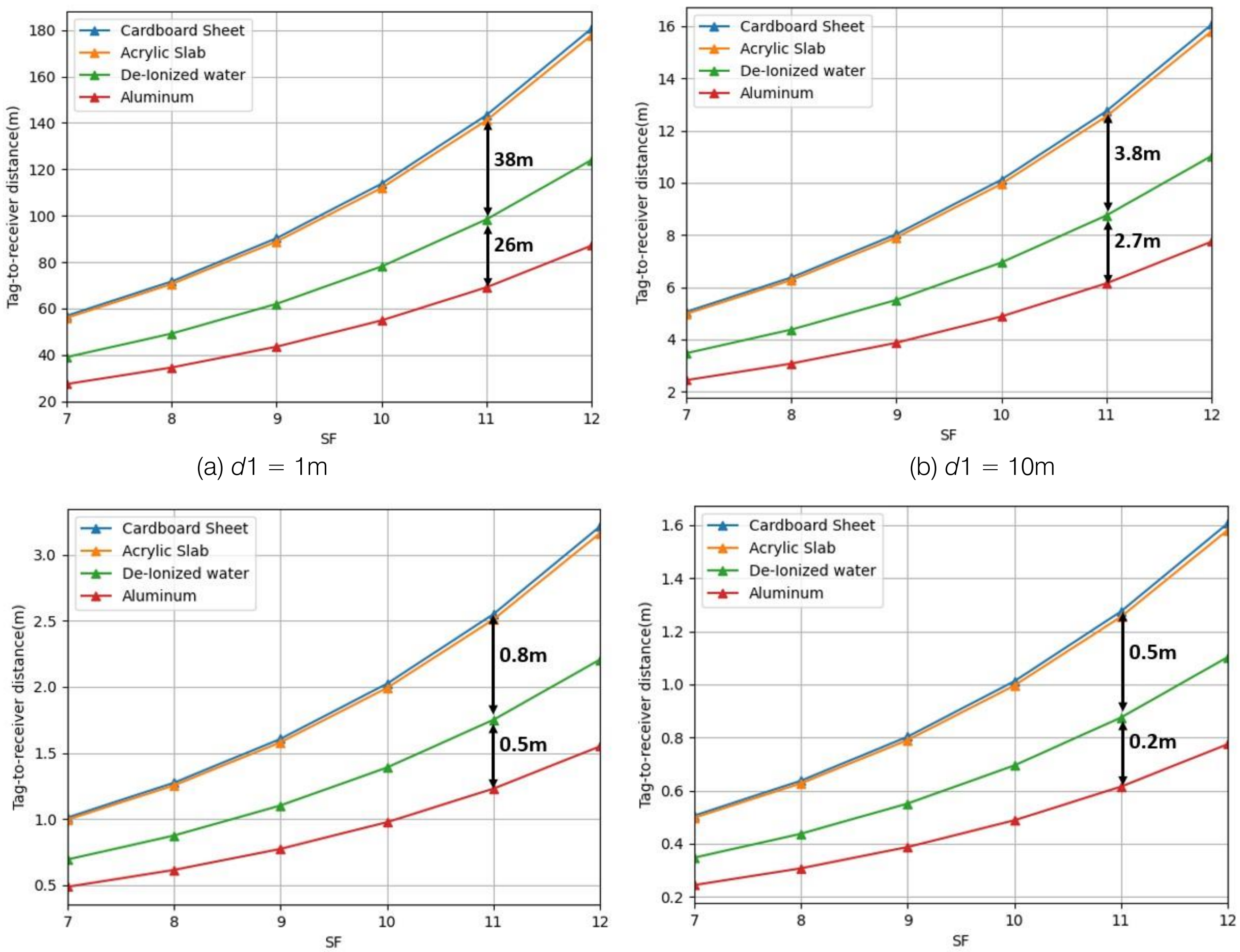



*Figure 12:* Reflection Amplifier Effect on tag-to-Receiver Range for BPSK and OOK Modulation Scheme

proposed to mitigate the strong interference effect and improve the SNR [16, 17, 23]. The variation in bandwidth as a function of distance is shown in Figure 8. We observe that the distance




(a) $d1 = 1$m (b) $d1 = 10$m

(c) $d1 = 50$m (d) $d1 = 100$m

*Figure 13:* Tag-to-Receiver Distance as a Function of SF for Different on Object Gain Penalty and Fixed Distance D1

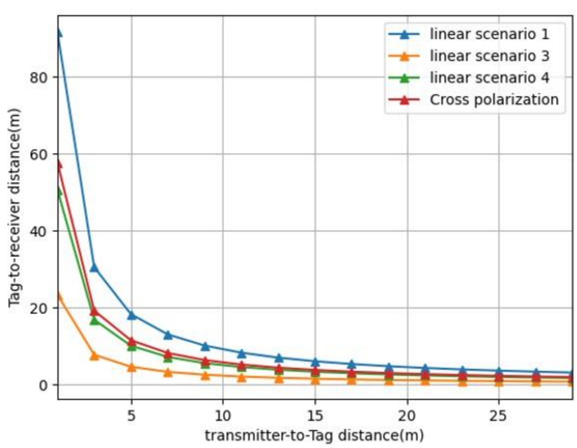



*Figure 14:* Tag-to-Receiver Range in Free Space Model for Different Transmitter, Tag, and Receiver Antennas Polarization

decreases with increasing LoRa bandwidth. For example, the communication range drops from 1.3Km to 0.6Km by increasing the bandwidth from 125KHz to 500KHz.

The communication range of LoRa backscatter systems can also vary parameters, such as the modulator factor and the path loss exponent.

ii. *Effects of Environment on Lora Backscatter Range*

The path loss exponent describes the nature of the propagation environment. Figure 10 shows its impacts on the communication range. For a source-to-tag distance of 10m, the communication range is up to 685m using a path loss value of 2, which corresponds to the case of free space propagation. As the path loss exponent increases, the range decreases, as shown in the figure. For the rest of this work, we assume a path loss value of 3, which is the worst case in the outdoor environment.

iii. *Effects of Modulation Factor on LoRa Backscatter Range*

In backscatter communication systems, the communication range is depends on tag scattering efficiency, which is also referred to as the modulator factor M. The tag modulation factor M depends on the modulation scheme used to backscatter the tag data to the receiver, as discussed in Section 3.3.1. We vary the value of M according to different modulation schemes as shown in Table 2 and compute the communication range for each value of M. In Figure 9, it can be seen that the BPSK achieves the highest communication range compared to ASK and OOK. However, the ASK scheme is more simple to implement than the BPSK. When the tag is placed at 5m, the BPSK scheme can reach the 1.3 km communication range while only 0.7 km is possible using ASK.

*b) Realistic Scenario*

In this subsection, we will evaluate the LoRa backscatter range in a realistic scenario in both LOS and NLOS. In a realistic scenario, different parameters affect the communication range between the RF tag and the LoRa receiver, as detailed in Section 3.2.

i. *In Line-of-Sight*

We compare the communication range of the free space model and the realistic scenario model in LOS (path blockage ignored) using Eq. (11) and (15). In Figure 11, it can be seen that the achieved range in the realistic case is much lower than that of the free space case. For example, for a source-to-tag distance of 3m, a communication range of 2.3 km is achieved, compared to only 4m for the realistic LOS scenario using unit antenna gain for both transmitter, the tag, and receiver. This difference becomes important as the tag is brought close to the transmitter.

To further improve the LoRa backscatter communication range, a reflection amplifier can be used [35]. To evaluate the effect of the reflection amplifier on the communication distance, we compare the range with and without the reflection amplifier in the realistic LOS scenario, as shown in Figure 12. We can observe an increase in the range when a reflection amplifier is used. Next, we evaluate the effect of tag-on-object gain in the communication range. As discussed in Section 3.3.5, different materials have different impacts on the performance of tag communication. Figure 13 shows the communication range as a function of the spreading factor for a tag attached to various materials. The cardboard sheet has the best performance, which is close to one obtained using an Acrylic slab. For a source-to tag distance of 1m, the communication range of 180m for an SF value of 12 is achieved for a cardboard sheet compared to only 83m with aluminum. Note also that the impact of the material becomes important as the SF values increase. However, as we increase the source-to-tag distance, the effect of the attached material becomes negligible as shown in Figure 13d. There was only a decrease of 0.7 between the cardboard sheet and the aluminum.

Antenna polarization is another cause of signal attenuation and hence limits the communication range. Figure 14 shows the communication range achieved in different polarizations. It can be noticed that the linear polarization in Scenarios 1 has a better communication range (about 97m) compared to linear scenarios 3 and 4. This is due to the fact that, in the linear polarisation of Scenario 1, the polarization mismatches $X_f$ and $X_f b$ are maximal ($X_f = X_f b = 1$).

*c) In NON Line-of-Sight (NLOS)*

In some applications, the LOS cannot be guaranteed, hence we must account for the effect of path blockage between the transmitter and tag antenna, and between tag and receiver antenna. We compare the maximum theoretical communication range of LoRa backscatter technology in both LOS and NLOS as shown in Figure 15. We set the value of M at 6.48 which is the maximum value in Table 3, and the transmit power at 30dBm. As can be seen from the figure, for a source-to-tag distance of 1m and an SF of 12, the receiver can be as far as 820m for LOS while only a range of 2m is possible in NLOS scenario. As the tag is moved away from the source, this distance drops to only 8.12m and 0.02m for LOS and NLOS, respectively. This compromises the long-range wisdom of LoRa backscatter and

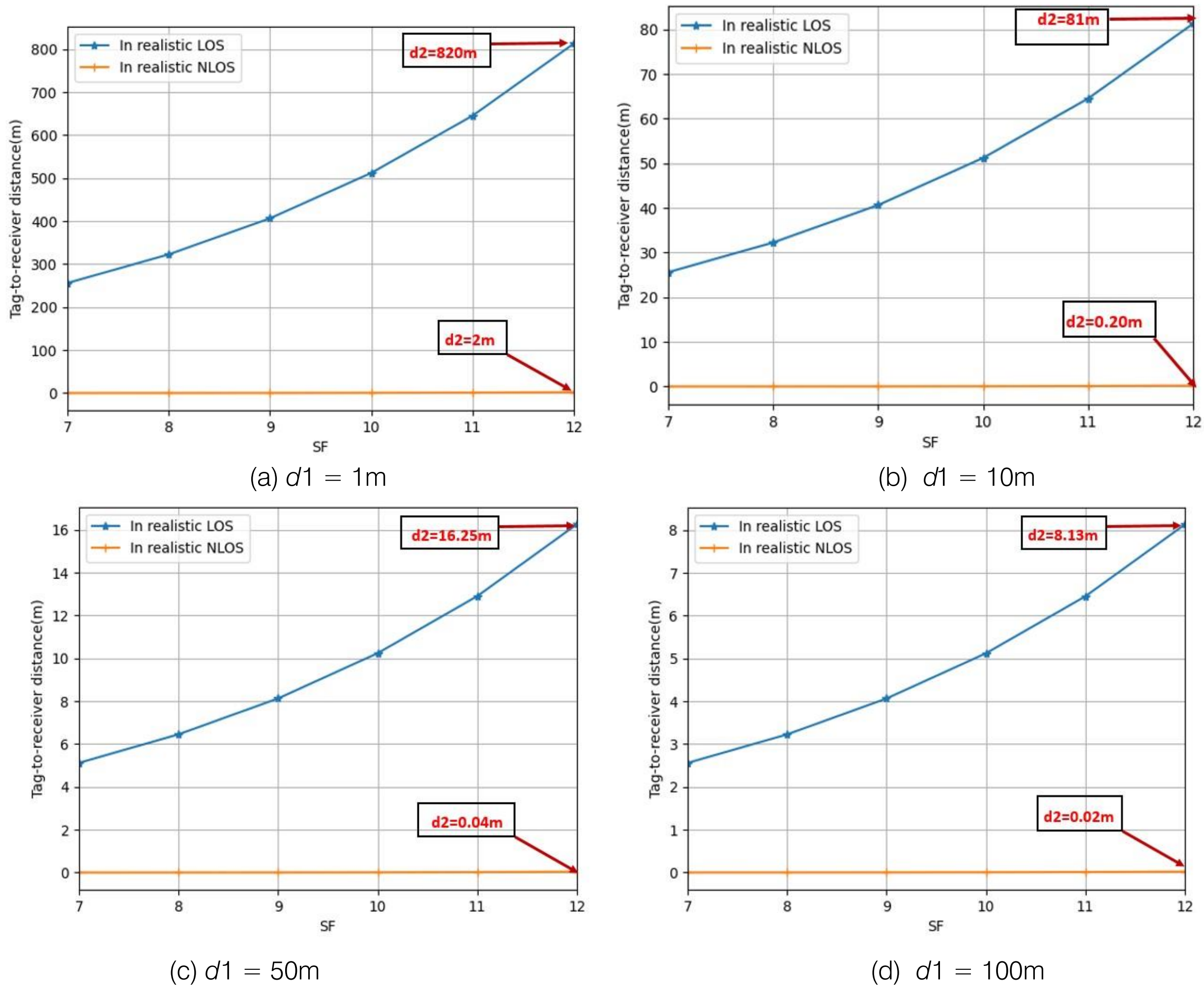



*Figure 15:* Maximum Tag-to-Receiver Range Comparison between LOS and NLOS Model for Fixed Distance D1 with A Maximum Transmit Power $P_T = 30\ dbm$

hence limits the range of its application deployment where there is no LOS between transmitter, tag, and receiver antennas.

### d) *Concurrent Transmission and Interference Effect*

The performance of LoRa backscatter system degrades in the presence of strong interference from the transmitter and the inter-tag interference from the neighboring tags in concurrent transmission as discussed in Section 3.4. The effect of interference on the receiving distance depends on the signal level of the interfering signal at the receiver location, which also depends on the separation distance between the transmitter and the tag. First, we consider a LoRa backscatter system in which only one tag can transmit data to the receiver at a given instant t. Therefore, interferences from neighboring tags are ignored. We vary the values of direct interference power $P^d_r$ from -140 dBm to -30 dBm. Figure 16 shows the distance achieved between the tag and the receiver for different values of direct interference power in the LOS scenario.

It can be noticed that when the level of interference signal power is low, for example -140dBm, the receiver can decode the backscatter signal at a distance of about 160m from the tag for a source-to-tag distance of 1m and a SF value of 12. As the level of interference signal increases, the receiver sensitivity decreases, and the distance achieved drops to 140m, 20m, and 2m for interference power of -120 dBm, -90 dBm, -60 dBm, respectively. For interference signal levels higher than -30dBm, the receiver cannot work anymore. One way to mitigate the interference effect is to increase the transmit power. Several other interference cancellations for LoRa backscatter systems have been proposed in the literature [15, 16, 23].

Another source of interference in LoRa backscatter systems is the inter-tag-interference. The signal received from the neighboring tags is very weak. However, the LoRa receiver has a high sensitivity, hence a receiver can receive both the desired tag signal and interference from neighboring tags. We fix the value of direct interference power to -120 dBm. We assume that all tags have received power at the receiver location of -

140 dBm and evaluate the effect of the number of neighboring tags on the tag-to-receiver distance. The range decreases as the number of interfering tags increases, as shown in Figure 17. Note that in practice, the received powers from both the neighboring tag and the transmitter are randomly distributed and vary depending on the channel condition.

*e) Evaluation of Our Model*

To evaluate the accuracy of our model, we will run different simulations using the same experiment setup and under the same scenario as the state-of-the-art LoRa backscatter systems. The simulation parameters are shown in Table 9.

It can be seen that the range achieved in our model is close to that obtained in practice for works PloRa [18], *P²LoRa* [15], Aloba [14]. PLoRa uses frequency shift keying to encode tag information. The range achieved using our model is significantly higher than the one obtained in PLoRa (about 55%). This is due to the poor interference cancellation in PLoRa. Additionally, the PLoRa tag uses packet detection with a limited range

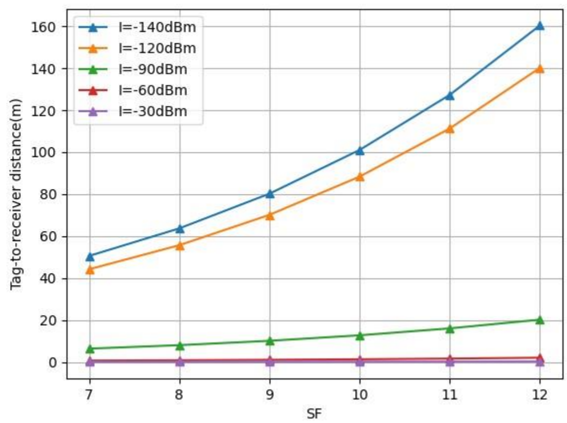



*Figure 16:* Direct Interference Effect on Lora Backscatter Communication Range

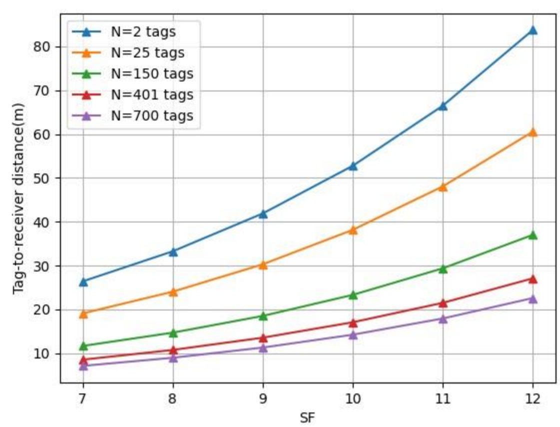



*Figure 17:* Number of Interfering Tag Effects on Lora Backscatter Communication Range for Identical Neighboring Tag Power of -120 dbm and a Fixed Direct Interference Power of -110 dbm

*Table 9:* Comparison of Our Range Model with Existing Lora Backscatter Prototypes Achieved Range in The Literature. Note That the Reported Ranges are Measured in A Line-Of-Sight (LOS) Scenario

| Parameters | PLoRa | $P^2LoRa$ | ALOBA | LoRa backscatter |
|---|---|---|---|---|
| Modulation type | FSK | FSK | OOK | CSS |
| Tx power | 21dBm | 30 dBm | 20dBm | 30dBm |
| Tx gain | 2dBi | 4dBi | 3 dBi | 6 dBi |
| Rx gain | 2dBi | 4dBi | 3 dBi | 6 dBi |
| tag gain | 2dBi | 4 dBi | 3 dBi | 2 dBi |
| SF | 8 | 12 | 12 | 12 |
| BW | 500KHz | 31.25 kHz | 125KHz | 31.25 kHz |

| Parameters | PLoRa | $P^2LoRa$ | ALOBA | LoRa backscatter |
|---|---|---|---|---|
| $F_c$ | 915 MHz | 433 MHz | 902.5MHz | 915 MHz |
| d1 | 20 cm | 1m | 1m | 5 m |
| Range | 1.1Km | 2.2Km | 250 m | 2.8Km |
| **Our model** | **2Km** | **2.5Km** | **206m** | **188m** |

of 50m which limits the overall range of the system. Moreover, the frequency-shifting operation in backscatter communication introduces mirror copies of the backscatter signal and spreads the energy in double sidebands which significantly degrades the SNR, hence limiting the communication range. Aloba[14] range is similar to one obtained using our model. The short range of Aloba is due to the OOK modulation which sacrifices the range for better throughput. Additionally, Aloba checks the amplitude and phase characteristics of the signal in the time domain, which results in a limited accumulated energy and hence a limited range. For *P²LoRa*[15], the theoretical range computed using our model is slightly higher than the one obtained during their experiment about 12%, and this may be due to the effect of the environment and losses due to the surrounding materials. Notice that *P²LoRa* achieved better communication range over both PLoRa and Aloba, this can be explained by the fact that they combine the energy in double sidebands to enhance the SNR. On the other hand, for LoRa backscatter [16] the achieved range during their experiment is about 2.8Km while using our method, this range is only 188m. To understand this, note that [16] synthesizes the LoRa compatible packet at the tag, while the state-of-the-art work mentioned above simply backscatters the ambient LoRa signal. This means that our model is not compatible with the LoRa backscatter system, where the tag generates a LoRa signal. Therefore, a more extensive model is required to cover all possible LoRa backscatter systems, and this is left for future research work.

## V. Conclusion

In this work, we have developed a model to estimate the transmission range in LoRa backscatter communication. The developed model is based on both free space and a realistic LOS and NLOS propagation scenario. Throughout the simulation in Python, we analyzed the effect of different parameters that can affect transmission performance and discussed techniques to enhance link quality. We have also extended our model to account for the effect of interference from both the direct signal and the neighboring tags in concurrent transmission. We have also evaluated the accuracy of our model by comparing the range achieved using our model with state-of-the-art LoRa backscatter works. The developed model model is a useful tool for estimating coverage and deployment cost in real wireless sensor network applications.

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# Revolutionizing Supply Chains: Cloud-based Analytics, Block chain and Security Solutions for Innovation

By Natapong Sornprom

*Abstract-* The rapid evolution in technology advancements have resulted in massive transformation in the global supply chains industry. These technologies bring in much needed innovative solutions that enhance efficiency, transparency, and security. Cloud-based analytics, blockchain technology and enterprise-level advanced security solutions are in the forefront of this evolving transformation. Cloud-based analytics help supply chain stakeholders to make quick decisions based on data insight, which are driven by real-time data processing, with on-demand infrastructure. Blockchain technology extends a decentralized and immutable ledger, for better transparency, traceability, and security. Using blockchain, businesses can grow with decreasing fraud and enhancing trust between participants. At the same time, strong security measures safeguard valuable information and reduce the threat of cyberattacks, maintaining the terms of data and confidentiality.

This paper explores the integration of these technologies to revolutionize how supply chains are designed and operated and displays a framework showcasing the proposed innovations to address contemporary challenges like inefficiencies, frauds, and cybersecurity issues and create sustainable yet adaptive supply chains of the future.

*Keywords: cloud-based analytics, blockchain techno-logy, supply chain innovation, data security, predictive insights, cybersecurity solutions.*

*GJCST-G Classification:* *LCC Code: HF5415.7*

REVOLUTIONIZINGSUPPLYCHAINSCLOUDBASEDANALYTICSBLOCKCHAINANDSECURITYSOLUTIONSFORINNOVATION

*Strictly as per the compliance and regulations of:*

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## I. Introduction

Supply chains are becoming increasingly essential in the current pace of change in the global economy as it helps in the faster transfer of goods & services. On the contrary, most conventional supply chain models stumble with inefficiency, transparency issues, and susceptibility to fraud and cyber attacks. In order to solve these problems, organizations have begun adopting advanced technologies such as cloud-based analytics, blockchain and security solutions to transform supply chain management. Cloud-enabled analytics enable real-time data processing, predictive insight and scalable solutions that take decision-making and operational efficiency to a new level. By allowing every member of the supply chain to see relevant information on a centralized ledger, blockchain technology can reduce fraud and errors. Since it is a distributed ledger that allows for transparency, traceability, and build trust among supply chain participants. At the same time, the security solutions are also critical to ensure sensitive data security, defend against cyberattacks, and preserve data integrity across the supply chain. By integrating emerging technologies, businesses can navigate through existing challenges and foster innovation. In-turn the approach will help them to build supply chains that can help organizations become more agile and resilient. This transformation is paving the way for a new age of supply chain management, one that is more interconnected, is compliant and adaptable to fluctuations in the global market.

Traditional supply chain methods, relying on static models and manual processes, lack the adaptability needed for modern complexities (Longo and Ören, 2008). The integration of digital technologies, such as the Internet of Things (IoT), artificial intelligence (AI), and blockchain, has transformed the way supply chains operate. These technologies enable real-time data collection and analysis, providing greater visibility and insight into supply chain operations (Wu et al., 2022), [1-3].

## II. Cloud based Analytics - Supply Chain

Cloud based analytics have become an inevitable part of Supply chain management. Organizations can leverage on big data to realize operational efficiency using cloud based analytics, which leads to faster and data driven decision making. Traditionally, supply chain processes have been fragmented, with data dispersed across different systems. Which makes it difficult to have operational visibility in real-time. This challenge, however, has been taken up by the cloud. It has provided a centralized system to collect and organize data from multiple sources so that enterprises can enjoy real-time access and analysis of it. This includes suppliers, logistics providers, warehouses and customers working together in a single virtual space that is the cloud. Smart and agile supply chains result from this kind of connectivity, which in turn enables data-based decision-taking.

*Author: e-mail: nsornpro@alumni.depaul.edu*

*a) Scenarios of Cloud based Analytics in Supply Chain Management*

*Demand Forecasting and Inventory Optimization*, Cloud Analytics plays a significant role in improving demand forecasting and inventory optimization. Being able to analyze vast amounts of data, which includes sales data, seasonal trends, and transactions, a business can forecast the demand better. It gives the company a way to find the right stock rate, preventing overstock or a stockout, and getting inventory where it is needed and when it is needed. Should demand suddenly surge outside of normal ranges, the cloud system can issue warnings that allow businesses to quickly change production or sourcing plans.

*Visible Supply Chain and Risk Management,* A cloud-based analytics system, for example, could help a global electronics manufacturer gain real-time visibility into its entire supply chain from raw material sourcing to product delivery. By tracking, for example, delivery times, vendor quality, and vendor performance, the company can identify potential bottlenecks or disruptions before they develop into larger issues. Cloud systems will give real-time alerts so that, if a critical supplier is affected by a natural disaster or geopolitical instability and is delayed, the company can reroute orders or source substitute suppliers or reschedule production. Participants are able to minimize disruption, and derive far greater resilience in their supply chains, by proactively identifying and addressing potential risks.

*Logistics and Route Optimization,* The logistics business relies heavily on cloud-based analytics technology. Thus, for example a logistics service provider could use cloud-based solutions to analyse traffic data, weather and historical delivery records in order to decide the best path and time for a delivery in real time. These will save fuel consumption costs, cut down delivery time periods and increase client satisfaction.

*Evaluation of Supplier Performance,* By giving companies exact means, cloud-based analytics can help them better monitor supplier performance. Companies can track lead times, product quality and price differences at the level of individual suppliers through cloud systems. For instance, an automotive manufacturer would view a dashboard from the cloud that demonstrated quality control metrics of all its suppliers and their delivery times.

Accurate demand forecasting is crucial for maintaining optimal inventory levels and ensuring customer satisfaction. Traditional forecasting methods, such as moving averages and exponential smoothing, often struggle to account for the complex interplay of factors influencing demand (Hyndman & Athanasopoulos, 2018). Buffa and Frank et al, combining demand forecasting models, presented a goal programming problem to determine safety stock in a multi-product environment. [4-5]. Nowadays companies are faced with an increasing risk exposure. This is mainly caused by a greater dependence of supply chain partners on each other, e.g., due to the close integration of their business processes aiming at the reduction of channel inventory, [6]. The modeling of logistics systems is performed to seek the best possible system configuration to minimize costs or maximize operational performance, in order to meet or exceed customer expectations. Classically, analytic system analysis of this type has been performed using optimization, simulation, or heuristics, [7]. Development of partnership with suppliers is widely recognised today as a potent tool for supply chain improvement. To develop an effective partnership, it is necessary to have a small supply base and an effort to reduce the supply base to a manageable level, [8]. Integration of such technologies is a force multiplier, and this will enable industry-specific ChatGPT-like solutions that will revolutionize many industries including but not limited to supply chain, cybersecurity, environment, and entertainment, [9].

## III. Blockchain in Supply Chain

Traditional supply chain was often riddled with problems related to fraud, visibility and inefficiencies of checking the genuineness of a product. Blockchain solves these problems with a distributed, immutable record of every transaction and movement of goods being tracked in a transparent, secure manner. Blockchain can therefore improve stakeholder trust, allow for better accountability and reduce fraud and mistakes in the supply chain.

*a) Scenarios of Blockchain in Supply Chain Management*

*Transparency and Traceability of Products:* Can help businesses track assets end-to-end, from the source of raw materials to when the product reaches a customer. For instance, a food company can use blockchain to track food products from farm level to the retailer level. Each phase of the supply chain process like harvesting, packaging, shipping, storage is recorded on the blockchain. And it creates an immutable log accessible to all participants in the supply chain. Businesses can benefit immensely from this transparency, as consumers and regulatory agencies can verify the authenticity and safety of the product. With a successful implementation of blockchain technology, in terms of a contamination or a recall the source of the problem can be traced within an hour which reduces the risks and increases the associated trust with consumers.

*Smart Contracts for Facilitation of Business Transactions,* is a class of blockchain based agreement that can auto-execute between a buyer and a supplier without a need for third parties (e.g., transactions). For example, a manufacturer and a supplier may create a smart contract that will automatically execute as soon as the goods are received and verified. This reduces administrative costs and speeds up the transaction with automated processes. This has a big implication on international trade with so many different parties involved, they can leverage on blockchain to gain trust in knowing that payment will only go through if the conditions of a contract are properly fulfilled.

*Minimizing Fraud and Forgery,* Counterfeit products turn a severe element within the domains of pharmaceuticals, luxury goods, and electronics. Blockchain helps out with this issue, as having a tamper proof ledger of all transactions and the journey of goods can provide a level of accountability. *For example:* blockchain can be used by luxury goods companies to log each and every sale and transfer of ownership of a good to verifiably prove the provenance of the good. That code is on the product, and anyone interested can scan the product and see all its history, thus verifying it. Such a high level of transparency reduces fraud risk and makes consumers confident in this brand.

*Supply Chain Financing,* Blockchain simplifies and avoids breakage to enable efficient supply chain financing by creating a secure and transparent ledger both for transactions as well as the inventory. For example, it could happen that a small supplier is unable to secure financing from the banks, not necessarily because of the size of the organization but rather due to distrust or lack of visibility on their operations. Now, if the supplier needs a loan against its inventory, the supplier can show real-time verifiable data on the authenticity of their transactions and inventory to lenders and lenders can check the same on the Blockchain as well.

*Enhancing sustainability and ethical sourcing,* one such highlight among many use cases of Blockchain is that of sustainable as well as ethical sourcing material and supply chains sustainability. For example, a clothing brand can use blockchain to prove that the raw materials (cotton, wool, etc.) is sustainably and ethically sourced. Use of blockchain can track the entire chain of events from harvesting to manufacturing, allowing consumers to trace whether a product they purchase is sustainable. This type of transparency empowers companies to demonstrate that they are operating in an ethical and sustainable way.

It has been shown that trust is also a significant predictor of supply chain's performance and fosters cost reductions, higher flexibility and better relational governance (Kim and Chai, 2017, Lee et al., 2010, Singh and Teng, 2016). As can be observed in Viet, Behdani, and Bloemhof (2018), when it comes to analyzing trust and information sharing in the supply chain, studies commonly focus on demand and inventory data. Access to accurate enterprise data and information in a supply chain is only possible when a high level of trust between the parties already exists (Ebrahim-Khanjari, Hopp, & Iravani, 2012). [10-14]

## IV. Security Solutions in Supply Chain

The integration of all these technologies also leads to the need for maintaining security in supply chain management, which is becoming increasingly vulnerable to cyberattacks, data breaches, fraud, as well as theft. The modern landscape sees more and more digitisation and interconnecting of supply chains, which, while more efficient, also increases the frequency and complexity of security challenges that arise. Security solutions are pervasive in their roles from protecting sensitive data and ensuring the integrity of transactions to protecting both physical and digital assets throughout the supply chain to the processes themselves. Strong security solutions are about more than compliance or regulatory obligation, they are about ensuring organizations can operate with confidence while both protecting their own intellectual property and minimizing financial and reputational risk.

### a) *Key Scenarios of Security Solutions in Supply Chain Management*

*Data Protection Cybersecurity,* Protection of data and security of all varieties need to be heightened in today's rapidly digitalising economy. As companies increasingly rely on digital technology and cloud platforms, supply chains are now under threat from virtual attack. A logistics company, for example, may use a cloud service to keep track of shipments. If this is not eliminated, then the platform could be subject to ransomware, data breach or DOS attacks. To fight such threats, security solutions including multi-factor authentication (MFA), encryption technology, firewall appliances, and intrusion detection systems (IDS) have become standard practice. These tools protect the data that lies at the heart of supply chain logistics from illegal access or theft of the customer information, order details and payment data.

### b) *Preventing Fraud all along the Supply Chain*

*Switching of supply chains:* Fraud is one of the most common problems in the supply chains as they involve many suppliers and also third-party logistics providers. For example, a supplier that provides inferior or fake goods, but charges for higher-quality items. To address this, several organizations have turned to advanced security measures including blockchain technology to provide traceability, real-time transaction monitoring, and AI-based fraud detection systems. Such solutions help in making sure that all transactions are legitimate and also that the products actually meet the quality standards. For instance, the non-editable record of blockchain can track the complete lifecycle of a product, a verifiable and open chain of the verification of each step from source to its final destination, making it simpler to detect fraudulent activities in the supply chain

*Access Control and Insider Threat Mitigation,* Insider threats occur when employees or trusted partners intentionally undermine security for personal gain, leading to significant concern for supply chains. A logistics company, for instance, may have employees with access to sensitive shipping data, warehouse inventories, and financial transactions. They introduce strict access controls, role-based access management, and monitoring of employee activities to curb insider threats. Insider threats become all the more fatal especially considering that the alleged insider has sensitive information that could be stolen. Security solutions such as identity and access management (IAM) tools, encryption of sensitive data, as well as an organization's end-user education via security awareness training can all help mitigate the risks associated with insider threats. AI-driven anomaly detection systems can also monitor unusual behavior within an organization, prompting alerts to be set off when unauthorized access or modification of information takes place.

*Physical Security Protection of Assets:* Cybersecurity is obviously an area of focus, but we must also remember that physical security is key to protect assets from supply chain threats. The continuity plan can take several forms, but one common is the one when high value goods are stolen from a warehouse or in transit. Physical security solutions such as video surveillance, RFID (Radio Frequency Identification) tracking systems, GPS tracking systems for shipment, and real-time monitoring systems are deployed for protecting physical assets (Business Process & IT Process). For example, a drug manufacturer might attach RFID tags and GPS sensors to pallets of expensive drugs that are in transport, tracking their location and preventing vary from the proper delivery path, either due to a diversion or theft.

Supply chains play an essential role in the trade of these goods. To be able to realize a connected world with no boundary restrictions in terms of goods and services, it is imperative to keep the associated supply chains transparent, secure, and trustworthy. The use of such technologies has also considerably opened up various security threats and risks which have widened the attack surface on the entire end-to-end supply chain, [15-16]. In recent developments, blockchain has been used in supply chain in different ways to handle security and privacy issues [21,22,23,24,25,26]. Importantly, blockchain integrated supply chain solutions are good in providing security and privacy of data that does not allow to modify the data records or to misuse the data.

## V. Discussion

Cloud analytics, blockchain, and next-gen security will be key components of the future of the supply chain. The immediate need for organizations to adopt such technologies will only enhance the potential for more innovation and optimal use of resources around such technologies for decades to come.

*Embedded AI and ML:* Cloud analytics will not only be embedded with more complex ML and AI models for hyper-accuracy and faster decisions, but also hidden deeper into cloud services. Improvements in these technology solutions can drive better demand forecasting, inventory planning and logistics which can translate into delivery savings and customer satisfaction.

*Blockchain-enabled Real-Time Contracts:* The list of blockchain use cases will go beyond making goods more transparent and traceable, it will expand into the smart contracts arena executing and enforcing real-time agreements, which will reduce administrative burden, improve collaboration, and guarantee compliance among multiple parties across the supply chain.

*Connecting Edge Computing and IoT:* The increasing decentralization of sensors or Internet of Things devices will integrate edge computing capabilities in the supply chain and enable data collection as close to the source as possible. This, in turn, will reduce response times, enable better tracking of all goods, and allow for predictive maintenance of machines and tools to maximize efficiencies.

*Globalization & Digital twins:* As the addition of global supply chains brings massive complexity with it, the age of digital twins virtual models of physical supply chains will come into reality. These models will allow businesses to create real-time simulations of their supply chain performance, forecasting disruptions and optimizing routes, inventory levels and production schedules.

## VI. Conclusion

Cloud-based analytics, blockchain technology, and advanced security solutions are revolutionizing supply chain management. Together these technologies solve important challenges such as inefficiency, lack of transparency and susceptibility to fraud or cyber attacks. Positive stack analytics is growing on cloud which is a powerful implementation model for coupling analytic algorithms in terms of operational gains. The transparency and traceability offered by blockchain helps build trust within supply chain networks. On the other hand, strong security solutions guarantee the safety of sensitive data, preserving the integrity of the whole structure. With these technologies coming to forefront it would transform the way businesses will operate and eliminate inefficient processes.

In the future, the business ecosystem is bound to witness rapid innovation with widespread adoption driving growth in supply chain management. As AI will be utilized for extensive data analysis, blockchain to optimize smart contracts and improve cybersecurity and privacy, supply chains will also become more adaptive, security-focused, and stable. With global challenges like supply chain disruptions and the rising need for environmental sustainability, the incorporation of these technologies will help the companies develop efficient yet environmentally and security-conscious supply chains that are more resilient and future-proofed. In the end, such technological advancement will navigate the current state of business, equipping them with the resources required for survival in your growing connected digital economy.

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# Optimal Cooling Systems in Current Data Centers

By M. Bakir Faique & Dr. Nuwan Kuruwitaarachchi

*Northwood University*

*Introduction-* Technological advancement has shown a vital impact in current world trends. It has enabled communication information processing and collaboration among various aspects from personal use to departmental collaborations in workplace organisation. Therefore, it is important to understand the concepts of Information Technology (IT) infrastructure taking roles in evolving for the landscape of adaptability of information technology for the ever-changing demandson organisational needs. IT infrastructure components such as the hardware, software and the operating systems requires to have well designed IT infrastructure enhancing productivity, security, and accessibility. Hence adapting to technological demands and changes with innovation. [1]

In the 21st century, the information world has evolved from the physical presence making information itself one of the most important aspects in the current world. Whether it be on customers, users' organisational information has derived from raw input of data which is collected, organised and processed. Therefore, it is important to have the availability to store this information in specific locations such as a storage device in a computer such as a hard drive or a solid-state drive. However, to store massive exabytes of data and information it would require an abundance of storage to store these large data often known as big data. Data centers provide the infrastructure which includes networking and power for big data applications to rely on.

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OPTIMALCOOLINGSYSTEMSINCURRENTDATACENTERS

*Strictly as per the compliance and regulations of:*

# Optimal Cooling Systems in Current Data Centers

M. Bakir Faique [α] & Dr. Nuwan Kuruwitaarachchi [σ]

## I. Introduction

Technological advancement has shown a vital impact in current world trends. It has enabled communication information processing and collaboration among various aspects from personal use to departmental collaborations in workplace organisation. Therefore, it is important to understand the concepts of Information Technology (IT) infrastructure taking roles in evolving for the landscape of adaptability of information technology for the ever-changing demandson organisational needs. IT infrastructure components such as the hardware, software and the operating systems requires to have well designed IT infrastructure enhancing productivity, security, and accessibility. Hence adapting to technological demands and changes with innovation. [1]

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### a) *Importance of Cooling Data Centers*

Data centers hold a variety of IT infrastructure equipment which tends to *generate heat* in the hardware. Overheating is the biggest threat to data centers. When the equipment starts generating heat those servers in a data center reduce in performance making it slower to perform tasks and certain damages can occur internally causing the hardware's lifespan to reduce. Therefore, preventing heat can ensure reliability in the data centers which needs to operate at ideal temperatures to reduce maintenance cost and maintain the reliability and uptime of data centers. [2]

Another point to add in maintenance is optimal performance levels of data integrity. The heat generated can cause these data centers to perform at such a slower rate reducing their efficiency and processing speed hence data integrity has a high chance of getting compromised, increasing the risk of making those data corrupted or even lost.

On the other hand, demand is ever growing for informational needs in current world therefore organisations will have to maintain and install most service resulting in a higher need of IT infrastructure to house these servers in a data center. This increased need of more service can cramp up and increase the server density to give services such as networking, security cloud storage, cloud computing, etc.

Finally, cooling systems improve the data centers energy efficiency when maintaining operations in optimal temperatures further improving reliability on the hardware. This can give the longevity on the hardware servers in the data centers which can hence enhance performance preventing throttling and processing speeds of the hardware such as the CPU or GPU

As a result, cooling the data centers has their plethora of reasons and with the growth of demand on data also increases the importance of the cooling systems in data centers as well.

### b) *Challenges in Cooling Systems*

According to [3], there are 3 main components in the data center. They are-

- IT infrastructure
- Cooling systems
- Power Distribution Unit (PDU)

As the importance of data centers cooling system provide energy efficiency within the hardware of the servers, it still has a high energy consumption to the data center overall itself as the power the computers, network, and servers all to store and process data. Global data center electricity consumption shows a rough estimate between 220-320 TWh. This represents almost 1.3% of global demands [3]. This comprise of higher energy costs for an organisation to maintain with the addition of cooling systems.

There are other challenges as followed.

*Infrastructure:* Accounting to higher cooling system consumption takes a toll on a high operational cost. Contributing 320 TWh, the cooling system takes up to 50% of the power to keep the temperature at an optimal

*Author α σ:* Northwood University, Michigan American National College.
e-mail: bakir.faique786@gmail.com

level. Therefore, with higher data demands comes with increased server density in the data center which could make an even higher cooling demand to keep those servers in check for temperature. This can also lead to these data centers to have retrofitting facilities. Older datacenters will be redundant as they are not able to support such modern cooling systems like liquid cooling hence these facilities will be expensive to revamp or relocate and even complex to manage data migration [3].

*Environmental Factors:* Location plays a huge role in data centers whether it be a start-up cost or an energy cost. Data centers in warmer climates would consume more cooling as the cooling system demand in these regions will be high. Further, this can also have thermal pollution. Further this also accounts for carbon emission as for power they require the full based Poly extraction which can cause a destruction to habitats and ecosystems [4].

*Regulatory Compliance:* The growth of data demand over the course of the years large organisations have implemented their own data centers scattered across a country or outsourcing it two other countries for a low cost therefore it is easily exploitable in terms of energy and emission. Data center compliances must adhere on set up legal impositions. Therefore, certain frameworks must govern this to ensure that the data handling and the energy consumption can ensure that these data centers achieve the CIA triad (Confidentiality, Integrity, Availability).

- ISO 50001-the International Standard Organisation choose this as energy management to make organisation commit to efficient energy management. To set targets and implement energy saving innovations. Especially, ISO 50001: 2018 investigates green data centers providing energy saving plans and targets [5].
- A shrae Thermal Guidelines-this regulation is set by the American Society of Heat, Refrigerating and Air Conditioning Engineers to follow thermal guidelines for data centers.
    - This standard helps the balance between hardware performance and cooling needed.
    - Recommended that data center has a recommended temperature between 18 to 27°C and a recommended humidity between 20 to 80% [5]

PUE- the Power Usage Effectiveness measures efficiency in energy in data centers. This is the calculation of the total energy that the facility uses by the energy used in IT hardware [6].

- PUE= Total Energy used/ IT equipment energy usage
- An ideal PUE measurement is 1.0. Lower the PUE, better the efficiency. This ensures PUE minimises waste energy from cooling.

c) *Overview of Traditional VS Modern Cooling solutions*

The study on cooling system is to find what are the optimal cooling systems required for data centers and how it can be effective in the future with comparison to traditional and modern techniques and also future trends on how it will be possible to effectively manage these data centers.

*Table 1*

| | Traditional Cooling Methods | Modern Cooling Solutions |
|---|---|---|
| Cooling Methods | Air-Based | Liquid-based |
| Efficiency | Moderately efficient although high energy consumption. Prone to issues of Overheating, reliability, and performance. | Significantly efficient as it operates without the risk of overheating especially required in a higher density data center. |
| Scalability | Easier to scale up by adding more units of AC however densities will increase the cost of scale. | More complex to implement thermal load however manages efficiently without significant scale up in energy use. And adaptable to growth and future proofing. |
| Environmental Factors | Due to heavy consumption of energy with AC's and fans, ensures high amount of greenhouse gas emissions to the environment. | Eco friendly, comparatively lower energy consumption which results to a reduced carbon emission. |
| Cost | Easy and cheaper to start up, however long-term scale up with cooling can adapt to high energy consumption. | Excessive cost and investment and install specialised equipment however maintenance and energy costs significantly drop as it is energy efficient. |
| Examples | CRAC/CRAH, Raised floor, Chiller system | Liquid cooling, AI driven Cooling |

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## II. Background Study

*a) Early Cooling Methods*

According to [8] Data centers have been operational and being in the industry since the 1970s and ever since the beginning of these innovations it has been a prone aspect to generate heat. Therefore, for the past 50 years there has been significant improvement in efficiency of cooling systems on how it has been operational with AC and ventilation systems. As mentioned earlier with Computer Room Air Conditioner (CRAC) and Computer Room Air Handler (CRAH) control the temperature of the data centers with pressurised air further this also had raised floor systems to be delivered making CRAC the most efficient and prominent way of maintaining temperatures in the data centers. To this day, CRAC and CRAH I still operating in data centers where CRAC performance with raised floor systems of servers however has been inefficient due to the rising costs on maintenance. The density created has significantly impacted the cooling systems making it difficult to maintain temperature at an optimal level between 18 to 27°C.

*b) Hyperscale of Data Centers*

To maintain demand on data companies in the current world have significant demand for storage as well. Information is one of the crucial nontangible assets that any person can hold on to, but which can also have reduced in value over time. Therefore these companies will have to maintain their dim and on data centers well also make it efficient on storage facilities especially in high performing and operating companies such as Google, Microsoft and AWS, the hyper scale of data centers have made these large companies around the world to have that data centers to operate more than 40 MW.

These companies can have over 5000 servers physically especially to maximise their server capacity with high density server racks. This can help with maximising storage space, increase performance, and have a higher-powered AI chip for their storage to provide services.

It inevitably comes about having to consume a vast amount of power to run and operate the datacenters therefore looking into the power supplies with renewable energy like solar and wind power can help move away from fossil Ford powered data centers to make them energy sustainable. With the help of recycling old chips and hardware the transformation on the data centers can be potentially efficient and reduce on waste [9].

*c) Evolution of Cooling Methods*

Table 2

| | |
|---|---|
| 1950-1970 | Air conditioning and Ventilation systems (IBM was the first to introduce liquid cooling for their System 360 Model 91 computers) [10] |
| 1980s | Raised floors with CRAC and CRAH |
| 1990-2000 | Server density increased which introduced hot/cold aisle containment and Chiller cooling systems |
| 2010s | Liquid cooling became the trend with immersion cooling. |
| Present | Advance liquid immersion cooling andevaporation cooling with integration of IOTon AI |

## III. Application and Usage

*a) Traditional Cooling Methods*

i. *Hot/Cold Aisle Containment & Raised Floor Cooling*

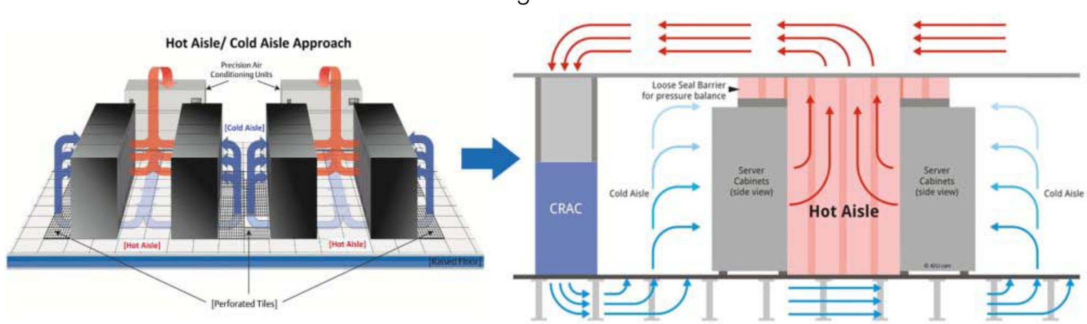
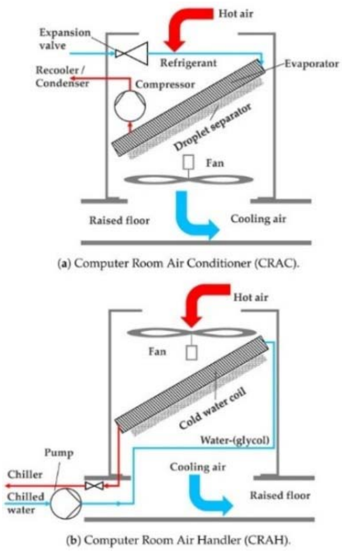



Figure 1

This has a strategic organising layout for the server racks in the data centers to ensure there is efficiency in the cooling method. This investigates an improved energy consumption where it has reduced costs with cooling systems with an effective air flow management. According to [12] the hot and cold aisle containment revolves an alternating row of server racks facilitating cold air intakes and hot air exhaustion on the opposite direction. Further this also involves an innovation in server organisation by using raised floors. [13]




(a) Computer Room Air Conditioner (CRAC).

(b) Computer Room Air Handler (CRAH).

*Figure 2*

ii. *CRAC & CRAH*

*CRAC*- Computer Room Air Conditioner is almost align with traditional air conditioning designed to maintain an optimal temperature in the data centers for their operations allowing key air distribution and humidity control in the server rooms for the data centers. CRAC in takes the warm air from the environment using a direct expansion on refrigeration cycle where the air is cooled through a cooling coil that has a refrigerant. The coil is kept cold by the compression where the excess heat is ejected through glycol mix with water and ambient air.

*CRAH*- Computer Room Air Handler are like CRAC. Instead of refrigerant, it has the chilled water that uses the fan to blow over the cooling coils to remove excess heat. This fills up with chilled water rather than the refrigerant which draws in the warm air from the computer room itself which is then transferred to regulate fan speed and ensure that the temperatures are at the optimal level to be stable allowing variability with humidity as well. [14]

iii. *Chiller based*

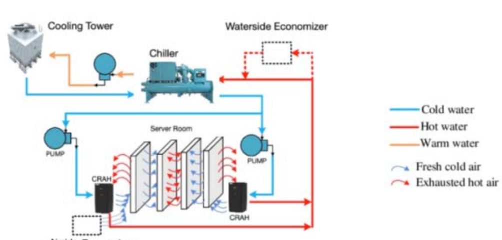



*Figure 3*

The chiller-based cooling system draws in both water-cooled chillers and air-cooled towers. The chilled water from the water-based chillers must be between 8 to 15°C which is pumped through pipes to manage CRAH units. The cooling tower takes in the warm water from that she loves and eject the waste heat to the atmosphere that removes vapour compression and then uses the absorption refrigeration cycle that diverts the chilly air back to the chiller to start the process all over again. The humidity is 100% transferred to the Airstream to minimise thermal pollution it reuses the circulated water. [15]

Based on [15], in a similar basis especially in the winter months the water side economizer uses the evaporating cooling system to produce chilled water instead of the water-based chiller as it operates on ambient conditions. However, the water side economizer generates heat and therefore the outside air is sufficient to cool the condenser for a heat change between the loop from the cooling tower to the servers in the data centers.

b) *Advanced Cooling Techniques*

i. *AI Driven Cooling Systems*

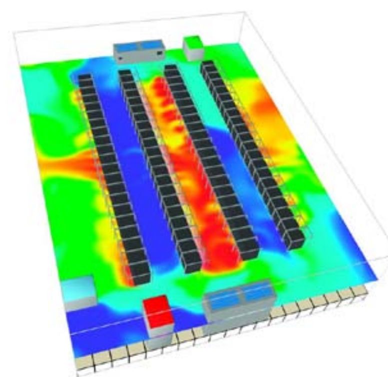


*Figure 4*

In [16], ensures that the air flow in the data center does not restrict the CRAC units. This measures with thermal imaging as shown in the picture above and allowing sensors to record the temperature in the server/computer rooms in the data center. AI adjusts airflow dynamically using real time data recorded by these sensors with thermal imaging ensuring that temperature and humidity is maintained at an optimal level grasping to cut the cooling cost by 40%. Using thermal optimization mentioned in [17] shows that it makes manual optimization on consistent temperatures to be obsolete and therefore has made an improved performance in the data centers with data collection and analysis integrated with CRAC cooling systems.

ii. *Free Cooling*

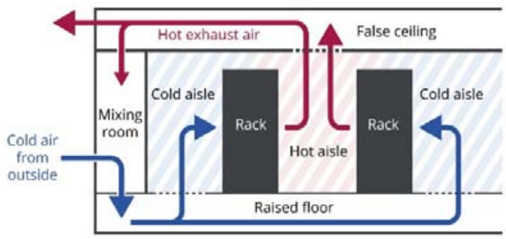



Figure 5

As simple as it sounds the free cooling system principle follows drawing frigid air from the outside to maintain air flow for the cooling systems, this helps naturally cooling the data centers from the outside. however regardless of free cooling system it still uses pumps and fans to distribute the frigid air through the server racks in the data centers. Later it dissipates the warm air back into the environment outside the data center which has a significant recyclable cooling system. As a result, to improve efficiency and to significantly reduce energy cost using passive air from the outside. [27]

iii. *Immersion Cooling & Direct-to-Chip*

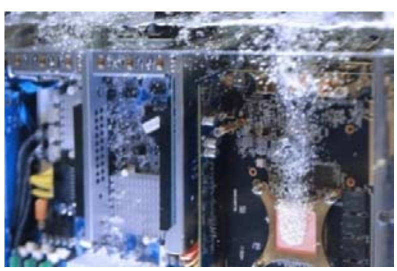


Figure 6

*Immersion Cooling:* This form of liquid cooling in data centers shows that the servers in the data centers are submerged into a non-conductive liquid where the heat can be transferred directly to the liquid itself without any need for cooling components such as fans or CRAC. Gigabyte said that in [20], the services are packed closely together making their hardware components more compact making it more effective two dissipating heat with immersion cooling and is also set to increase the power usage effectiveness and having minimal maintenance required. There are two types of immersion cooling:

- *Single Phase-* The server components submerged into a thermally conductive coolant which the heat is transferred to the liquid itself. This liquid does not boil or freeze as it maintains the liquid form.
- *Two Phase-* The server components in the data center are submerged in the thermally conductive coolant. However, the liquid it is submerged in has a low temperature of evaporation where the vapour is then cooled with a heat exchange method using a condenser coil having a recyclable system to cool the server components again. [22].

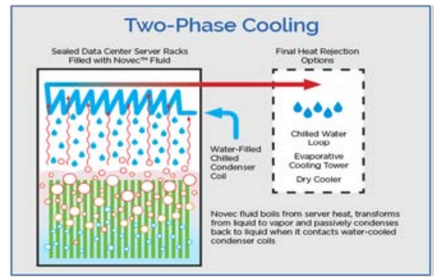



Figure 7

Direct-to-Chip-this component also uses a liquid coolant but rather than completely submerging the servers in the liquid, the liquid is transferred to the heatprone IT infrastructure such as the CPU, GPU, and memory which those components come with a cold plate attached to the chip. The coolant transfers those heat through the liquid itself through a closed looping system which eliminates the need of completely submerging the whole server in the liquid coolant and allows server density to increase effectively where the servers can be compacted in the data center making it effective for certain organisations to carry out their operations such as cloud computing and networking. [23]

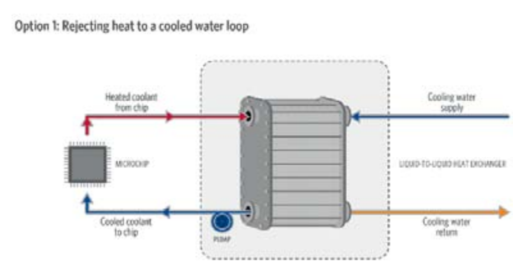



Figure 8

c) *Comparison between Traditional & Modern Cooling Systems*

Table 3

| Type | Conventional Methods | Advanced Methods |
|---|---|---|
| Air Based Cooling | • CRAC<br>• CRAH | • AI Driven Cooling |
| Air Flow Management | • Hot/Cold Aisle<br>• Raised Floor | • Free Cooling |
| Liquid Based | • Chiller based | • Immersion Cooling<br>• Liquid Cooling |

*d) Conventional Methods*

*Table 4*

| | Advantages | Disadvantages |
|---|---|---|
| CRAC | [24]<br>• Widely used as it has a cheaper initial cost.<br>• Precise temperature | [24]<br>• High energy consumption<br>• Operation costs will increase when scaling up |
| CRAH | [24]<br>• Widely used in large/hyperscale data centers<br>• Effectively beneficial with chiller-based cooling | [24]<br>• High initial cost<br>• Depends on an external water system |
| Hot/Cold Aisle Containment | [25]<br>• Effective airflow management<br>• Reduced cooling energy as it takes. | [25]<br>• Server density will make the cooling system require additional cooling.<br>• Requires careful architecturefor the air to flow |
| Raised Floor | [26]<br>• Better air flow system and management<br>• Provide ample space for cable and power management if the data center is scaling up. | [26]<br>• Installation and initial costs are high. (Strong structural)<br>• Risk of obstruction due to cable dusts and debris making it prone to fire and could also block air flow |
| Chiller Based | [15]<br>• Effectively beneficial with CRAH<br>• Efficiency in costs for large scale data centers | • High energy and maintenance cost due to regular maintenance and surveillance<br>• A large amount of water is used in the chiller for the system to work. |

*e) Advanced Methods*

*Table 5*

| | Advantages | Disadvantages |
|---|---|---|
| AI Driven Cooling | • Dynamic temperaturecontrol reduces energy costs.<br>• Can predict and enhance efficiency reducing failure.<br>[16][17] | • Requires AI and machine learning and real time monitoring which can be complex to implement.<br>• Initial costs are high.<br>[16][17] |
| Free Cooling | • Uses the natural air from the outside hence reducing energy costs.<br>• Cost effective and is sustainable due to eco friendliness.<br>[27] | • Only suitable in limited regions due to temperature and humidity<br>• Requires a contingency during warmer periods.<br>[27] |
| Immersion Cooling | • Highly efficient as it does not require air.<br>• Effective form higher server density datacenters.<br>[20] | • Higher initial costs<br>• Requires a complex and significant infrastructure of the data center.<br>[20] |
| Direct-to-Chip | • Delivers the coolant liquid only two the high heat generating infrastructure.<br>• Effective on the cooling efficiency leading to high performance workload.<br>[23] | • Prone to leaks in the server causing the structural integrity to fail.<br>• Requires modification on the IT components in the server for cold plate integration.<br>[23] |

## IV. Current Trends

*a) Meta Data center Cooling System, Singapore*

*State Point Liquid Cooling (SPLC):* SPLC users are patented cooling systems from Nortek to the meta data centers cooling system which is an advanced evaporating cooling system. This eliminates mechanical cooling in the data center making their environmental contribution on pollution redundant while also having flexibility in data center design as their data center in Singapore have not taken up too much space. Therefore, there is room for expansion. It is said that in [28] [29], the PUE at the Meta data center is at 1.19 making it energy efficient. This would mean that when the PUE of 1.19 shown in the data center energy consumption, 1 unit is used in IT equipment for power while the 0.19 you need are used for other non-computerised equipment.

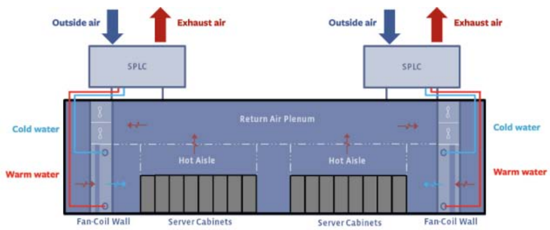



*Figure 9*

*b) Green Mountain Data Center, Norway*

*Free Cooling:* This data center is considered one of the most sustainable and green as data centers in Rennesoy, Norway. The cooling system utilizes the Fjord water which is powered with the expression of natural cooling. The combination of both the cold air and the water from the outside environment keep the several components in the data center at the optimal temperature to maintain the operations of cloud storage. This is a manner of renewable hydro powered free cooling system which does not have or need any energy intensive Power Distribution units (PDU) to regulate energy towards at the components in the data center. This also achieves a PUE of 1.06-1.10 making it one of the most efficient data centers around the world contributing 0 carbon emission in their cooling operations. [30]

*c) Google Data Center, Maya County, Oklahoma*

*AI Driven Cooling System:* one of the first hyperscale data center that uses Deep Mind AI from their machine learning and artificial intelligence that uses real time data for optimal energy consumption. It is said that [31] shows a 40% reduction in cooling system costs with the integration of Deep Mind AI in 2016. However, to implement the machine learning took two years for it to work out and how their data centers operate efficiently. The dynamic cooling option uses census to dynamically control hyper scale data centers like the one in Oklahoma for Google as it is optimizable unsustainability where Google is trying to achieve net zero emission and can be dynamic to outside temperature holds. [31]

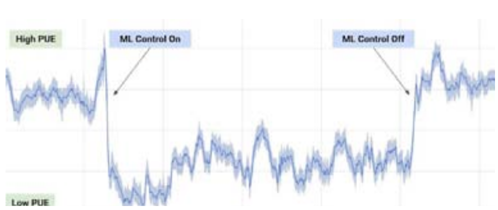



*Figure 10*

*d) Future Trends- Cryogenic Cooling System*

Conventional data centers around the world rely on either air or a liquid state for cooling. Cryogenic takes it a notch higher with possibilities on future data center operations which gives rise to higher performance in computing and quantum computing to take place which would hence rely on cryogenic cooling in the complementary-metal-oxide-semiconductor (CMOS).

Data centers can give services to supercomputers with a higher clock speed, performance on the data service with data allocation and highly increase energy efficiency for a better research path on quantum computing. Cryogenic temperature is below-150°C [33]. Further this would give rise to potential possibilities for sophisticated and complex data centers such as the ones owned by AWS, Microsoft, and Google for cryogenic system accommodation. This would have liquid nitrogen to take into considering a combination of Power Distribution and cryogenic cooling system. [32]

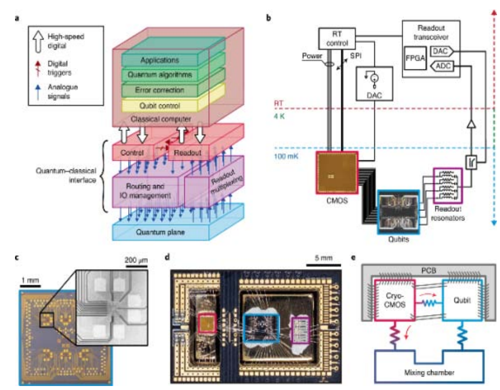



*Figure 11*

## V. Conclusion

As data centers give rise to large scale organisation to reach their hyper scale level for data storage and allocation. However, the demand comes from the data itself therefore organisations who specialised in cloud computing and networking and has the sufficient funds to operate a data center would want to get keep their information from been given without value. TO determine what cooling system is optimal is ambiguous. Therefore, certain cooling systems have their specific advantages and disadvantages depending on their use. For example, a free cooling system works well in colder regions where the data center is at their optimal, small scale, if the server density increases, energy consumption increases, heat generation increases making Free cooling system ineffective resulting in higher PUE. Whereas an evaporative or liquid cooling is better used in warmer, humid regions making them effective in their own operations. This will have a higher PUE, but data centers can scale up with server density, achieving economies of scale in the long run countering the heat to cold transfer cooling systems of the data center is future proofed.

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# The Reducibility of Modal Syllogisms based on the Syllogism □EI+O-2

By Long Wei & Xiaojun Zhang

*Anhui University*

*Abstract-* Syllogistic reasoning plays a crucial part in natural language information processing. For the purpose of providing a consistent interpretation for Aristotelian modal syllogistic, this paper firstly proves the validity of the syllogism □EI+O-2, and then takes it as the basic axiom to derive the other 38 valid modal syllogisms by taking advantage of some reasoning rules in classical propositional logic, the symmetry of two Aristotelian quantifiers (i.e. some and no), the transformation between any one of Aristotelian quantifiers and its three negative quantifiers, as well as some facts in first order logic.

In other words, there are reducible relations between the modal syllogism □EI+O-2 and the other 38 valid modal syllogisms. There are infinitely many instances in natural language corresponding to any valid modal syllogism. Therefore, this study has theoretical value and practical significance for natural language information processing in computer science.

*Keywords:* *aristotelian syllogisms, aristotelian modal syllogisms, validity, reducible relation.*

*GJCST-G Classification:* *LCC: QA75 -76*

THEREDUCIBILITYOFMODALSYLLOGISMSBASEDONTHESYLLOGISMEI+O-2

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# The Reducibility of Modal Syllogisms Based on the Syllogism □EI+O-2

Long Wei [α] & Xiaojun Zhang [σ]

*Abstract-* Syllogistic reasoning plays a crucial part in natural language information processing. For the purpose of providing a consistent interpretation for Aristotelian modal syllogistic, this paper firstly proves the validity of the syllogism □EI+O-2, and then takes it as the basic axiom to derive the other 38 valid modal syllogisms by taking advantage of some reasoning rules in classical propositional logic, the symmetry of two Aristotelian quantifiers (i.e. some and no), the transformation between any one of Aristotelian quantifiers and its three negative quantifiers, as well as some facts in first order logic.

In other words, there are reducible relations between the modal syllogism □EI+O-2 and the other 38 valid modal syllogisms. There are infinitely many instances in natural language corresponding to any valid modal syllogism. Therefore, this study has theoretical value and practical significance for natural language information processing in computer science.

*Keywords: aristotelian syllogisms, aristotelian modal syllogisms; validity, reducible relation.*

## I. Introduction

Syllogistic reasoning plays a crucial part in natural language information processing (Long, 2023). Various common syllogisms have been researched and discussed, including generalized syllogisms (Murinov and Novak, 2012), Aristotelian syllogisms (Hui, 2023), Aristotelian modal syllogisms (Cheng, 2023), and so on. In this paper, we restrict our attention to the reducibility of Aristotelian modal syllogisms (Xiaojun, 2018).

Some scholars such as Łukasiewicz (1957), Triker (1994), Nortmann (1996) and Brennan (1997) believed that it is almost impossible to find consistent formal models for Aristotelian modal syllogistic. Smith (1995) summarized the previous researches and proposed that Aristotelian modal syllogistic is incoherent. This view is still prevailing today. In view of this situation, this article attempts to explore a consistent interpretation for Aristotelian modal syllogistic. Specifically, this paper firstly proves the validity of the syllogism □EI+O-2, and then take this syllogism as the basic axiom to derive the other 38 valid modal syllogisms according to modern modal logic and generalized quantifier theory.

*Author α σ: School of Philosophy, Anhui University, Hefei, China.*
*e-mails: 657703460@qq.com, 591551032@qq.com*

## II. Preliminaries

In this article, it is convenient to represent the lexical variables by capital letters *P*, *M* and *S*, the universe of lexical variables by *D,* any one of the four Aristotelian quantifiers (i.e. *all*, *no*, *some* and *not all*) by *Q.* For Aristotelian syllogisms, there are four types of sentences including 'All *P* are *M'*, 'No *P* are *M*', 'Some *P* are *M*' and 'Not all *P* are *M*'. They are abbreviated as the proposition A, E, I and O respectively. An Aristotelian modal syllogism can be obtained by adding one to three non-overlapping necessary operator (i.e.■) or/and possible operator (i.e.+) to an Aristotelian syllogism.

For example, an Aristotelian modal syllogism can be described as the following.

*Major premise:* No women are necessarily NBA players.

*Minor premise:* Some millionaires are NBA players.

*Conclusion:* Not all millionaires are possibly women.

Let *P* be the set of all the women in the universe, *M* be the set of all the NBA players in the universe, and *S* be the set of all the millionaires in the universe. Therefore, this example can be formalized by ■*no*(*P*, *M*)→(*some*(*S*, *M*)→+*not all* (*S*, *P*)), whose abbreviation is□EI +O-2, similarly to other Aristotelian modal syllogisms.

The following definitions, facts and rules can be obtained from modal logic (Chellas, 1980) and generalized quantifier theory (Peters and Westerståhl, 2006). For the sake of convenience, 'if and only if' is abbreviated as 'iff'.

*Definition 1:*

1. *All* (*P, M*) is true iff $P \subseteq M$ is true.
2. ■*all* (*P, M*) is true iff $P \subseteq M$ is true in any possible world.
3. +*all* (*P, M*) is true iff $P \subseteq M$ is true in at least one possible world.
4. *No* (*P, M*) is true iff $P \cap M = \emptyset$ is true.
5. ■*no* (*P, M*) is true iff $P \cap M = \emptyset$ is true in any possible world.
6. +*no* (*P, M*) is true iff $P \cap M = \emptyset$ is true in at least one possible world.
7. *some* (*P, M*) is true iff $P \cap M \neq \emptyset$ is true.
8. ■*some* (*P, M*) is true iff $P \cap M \neq \emptyset$ is true in any possible world.

9. +*some* (*P*, *M*) is true iff $P \cap M \neq \emptyset$ is true in at least one possible world.
10. *not all* (*P*, *M*) is true iff $P \not\subseteq M$ is true.
11. ■*not all* (*P*, *M*) is true iff $P \not\subseteq M$ is true in any possible world.
12. +*not all* (*P*, *M*) is true iff $P \not\subseteq M$ is true in at least one possible world.

*Definition 2:* Q¬ (*P*, *M*) $=_{def}$ *Q* (*P*, *D*−*M*).

*Definition 3:* ¬Q (*P*, *M*) $=_{def}$ It is not that *Q* (*P*, *M*).

The following Fact 1 to Fact 4 are the basic knowledge in generalized quantifier theory, so it is reasonable to omit the proofs of them here.

*Fact 1:* (1) *some* (*P*, *M*)↔*some* (*M*, *P*);
(2) *no* (*P*, *M*) ↔*no*(*M*, *P*).

*Fact 2:* (1) *all* (*P*, *M*)=*no*¬(*P*, *M*);
(2) *no* (*P*, *M*)=*all*¬(*P*, *M*);
(3) *some* (*P*, *M*)=*not all*¬(*P*, *M*);
(4) *not all* (*P*, *M*)=*some*¬(*P*, *M*).

*Fact 3:* (1) ¬*all* (*P*, *M*)=*not all* (*P*, *M*);
(2) ¬*no* (*P*, *M*)=*some* (*P*, *M*);
(3) ¬*some* (*P*, *M*)=*no* (*P*, *M*);
(4) ¬*not all* (*P*, *M*)=*all* (*P*, *M*).

*Fact 4:* (1) ⊢*all* (*P*, *M*)→*some* (*P*, *M*);
(2) ⊢*no* (*P*, *M*)→*not all* (*P*, *M*).

According to modal logic (Chellas, 1980), + is definable in terms of ¬ and ■, that is to say that ■*Q*(*P*, *M*)□ ↔¬+¬*Q*(*P*, *M*) and +*Q*(*P*, *M*) ↔¬■¬*Q*(*P*, *M*) hold at every possible world. The following Fact 5 to Fact 8 can be proved by modal logic (Chagrov and Zakharyaschev, 1997).

*Fact 5:* (1) ¬■*Q* (*P*, *M*)=+¬*Q* (*P*, *M*);
(2) ¬+*Q*(*P*, *M*) =■¬*Q* (*P*, *M*).

*Fact 6:* ⊢■*Q* (*P*, *M*)→*Q* (*P*, *M*).

*Fact 7:* ⊢*Q* (*P*, *M*)→+*Q* (*P*, *M*).

*Fact 8:* ⊢■*Q* (*P*, *M*)→+*Q* (*P*, *M*).

The following rules in first order logic can be applied to Aristotelian syllogistic and Aristotelian modal syllogistic, in which *p*, *q*, *r* and *s* represent propositional variables.

*Rule 1:* (Subsequent weakening): From ⊢(*p*→(*q*→*r*)) *and* ⊢(*r*→*s*) infer ⊢(*p*→(*q*→*s*)).

*Rule 2:* (anti-syllogism): From ⊢(*p*→(*q*→*r*)) infer ⊢(¬*r*→(*p*→¬*q*)) or ⊢(¬*r*→(*q*→¬*p*)).

## III. Reduction Between the Syllogism □EI+O-2 and the Other 38 Modal Syllogisms

Theorem 1 means that the syllogism □EI+O-2 is valid. The following theorems from Theorem 2 to Theorem 9 demonstrate that there are reducible relations between the syllogism□EI +O-2 and the other 38 valid modal syllogisms. For example, '(2.1) □EI+O-2⇒□E■AE- 1' in Theorem 2 means that the validity of syllogism ■E■AE-1 can be derived from the validity of □EI+O-2. This sheds light on the reducibility between the two syllogisms. Other cases are similar.

*Theorem 1 (□EI+O-2):* ■*no*(*P*, *M*)→(*some*(*S*, *M*)→+*not all*(*S*, *P*)) is valid.

*Proof:* The syllogism □EI +O-2 is the abbreviation of the second figure syllogism ■*no*(*P*, *M*)→(*some*(*S*, *M*)→ +*not all*(*S*, *P*)). Suppose that +*no*(*P*, *M*) and *some*(*S*, *M*) are true, then $P \cap M = \phi$ is true at any possible world in terms of the clause (5) in Definition 1, and $S \cap M \neq \phi$ is true in terms of the clause (7) in Definition 1. Now it is clear that $S \not\subseteq P$ is true in at least one possible world. Therefore, +*not all*(*S*, *P*) is true according to the clause (12) in Definition 1. It indicates the validity of ■*no*(*P*, *M*)→(*some*(*S*, *M*)→+*not all*(*S*, *P*)), just as desired.

*Theorem 2:* The validity of the following two syllogisms can be inferred from □EI+O-2 :

(2.1) □EI+O-2⇒■E■AE-1

(2.2) □EI+O-2⇒I □ A+I-3

*Proof:* For (2.1). In line with Theorem 1, it follows that □EI+O-2 is valid, and its expansion is that ■*no*(*P*, *M*)→(*some*(*S*, *M*)→+*not all*(*S*, *P*)). And then it can be derived that ¬+*not all*(*S*, *P*) →(■*no*(*P*, *M*)→¬*some*(*S*, *M*)) in the light of Rule 2. According to Fact 5, what is obtained is that ■¬*not all*(*S*, *P*)→(■*no*(*P*, *M*)→¬*some* (*S*, *M*)). One can obtain that ¬*not all*(*S*, *P*)=*all*(*S*, *P*) and ¬*some*(*S*, *M*)=*no*(*S*, *M*) on the basis of the clause (4) and (3) in Fact 3. Therefore, it can be seen that ■*all*(*S*, *P*)→(■*no*(*P*, *M*)→*no*(*S*, *M*)) is valid. That is to say that ■E■AE-1 can be deduced from □EI +O-2, as desired. The proof of (2.2) is similar to that of (2.1).

*Theorem 3:* The validity of the following four syllogisms can be inferred from □EI+O-2:

(3.1) □EI+O-2⇒ □ EI+O-1

(3.2) □EI+O-2⇒■E■AE-1⇒■E■AE-2

(3.3) □EI+O-2⇒■E■AE-1⇒■A■EE-4

(3.4) □EI+O-2⇒■E■AE-1⇒■A■EE-4⇒■A■EE-2

*Proof:* For (3.1). According to Theorem 1, it follows that □EI+O-2 is valid, and its expansion is that ■*no*(*P*, *M*)→(*some*(*S*, *M*)→+*not all*(*S*, *P*)). In line with the clause (2) in Fact 1, it can be seen that □*no*(*P*, *M*) ↔□*no*(*M*, *P*). Therefore, it can be seen that □*no*(*M*, *P*)→(*some*(*S*, *M*)→ +*not all*(*S*, *P*)), i.e.□EI +O-1 can be deduced from □EI+O-2. The proofs of the other cases are along similar lines to that of (3.1).

*Theorem 4:* The validity of the following four syllogisms can be inferred from □EI+O-2:

(4.1) □EI+O-2⇒■E■AE-1⇒■E■AO-1

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(4.2) □EI+O-2⇒■E■AE-1⇒■E■AE-2⇒■E■AO-2

(4.3) □EI+O-2⇒■E■AE-1⇒■A■EE-4⇒■A■EO-4

(4.4) □EI+O-2⇒■E■AE-1⇒■A■EE-4⇒■A■EE-2⇒■A■EO-2

*Proof:* For (4.1). According to (2.1) □EI+O-2⇒■E■AE-1, it follows that ■E■AE-1 is valid, and its expansion is that ■*no*(*P, M*)→( ■*all*(*S, P*)→*no*(*S, M*)). It can be seen that ⊢ *no*(*Y, X*) →*not all*(*Y, X*), using the clause (2) in Fact 4. Hence, ■*no*(*P, M*)→(□*all*(*S, P*)→*not all*(*S, M*)) is valid by means of Rule 1. In other words, ■E■AO-1 can be derived from □EI+O-2. The other cases can be similarly demonstrated.

*Theorem 5:* The validity of the following two syllogisms can be inferred from □EI+O-2:

(5.1) □EI+O-2⇒ □ AO+O-2

(5.2) □EI+O-2⇒■E■AE-1⇒■A■AA-1

*Proof:* For (5.1). In line with Theorem 1, it follows that □EI+O-2 is valid, and its expansion is that +■*no*(*P, M*)→(*some*(*S, M*)→+*not all*(*S, P*)). It is clear that *no*(*P, M*)=*all*¬(*P, M*) and *some*(*S, M*)=*not all*¬(*S, M*) hold on the basis of the clause (2) and (3) in Fact 2. Then one can infer that□ *all*¬(*P, M*)→(*not all*¬(*S, M*)→+*not all*(*S, P*)). It can be seen that *all*¬(*P, M*)=*all*(*P, D*−*M*) and *not all*¬(*S, M*)=*not all*(*S, D*−*M*) according to Definition 2. Hence, the validity□ of *all*(*P, D-M*)→ (*not all*(*S, D*−*M*)→+*not all*(*S, P*)) is straightforward. That is to say that □AO +O-2 can be deduced fro□□I +O-2, as desired. The proof of (5.2) is along a similar line to that of (5.1).

*Theorem 6:* The validity of the following six syllogisms can be inferred from □EI+O-2:

(6.1) □EI+O-2⇒■E■AE-1⇒■A■AA-1⇒■A■AI-1

(6.2) □EI+O-2⇒■E■AE-1⇒■A■AA-1⇒■A■AI-1⇒■A■AI-4

(6.3) □EI+O-2⇒ □EI+O4

(6.4) □EI+O-2⇒I□ A+I-3⇒□ AI+I-3

(6.5) □EI+O-2⇒I□ A+I-3⇒ □ AI+I-3 ⇒I □ A+I-4

(6.6) □EI+O-2⇒I□ A+I-3 ⇒ □AI+I-3⇒ □ AI+I-1

*Proof:* For (6.1). In line with (5.2) □EI +O-2⇒■E■AE-1⇒■A■AA-1, it follows that ■A■AA-1 is valid, and its expansion is that ■*all*(*P, M*)→( ■*all*(*S, P*)→*all*(*S, M*)). Then, it can be seen that *all*(*S, M*)→*some*(*S, M*) according to the clause (1) in Fact 4. Hence, it can be proved that ■*all*(*P, M*)→( ■*all*(*S, P*)→*some*(*S, M*)) is valid. In other words, the syllogism ■A■AI-1 can be derived from □EI+O-2.

For (6.2). According to (6.1) □EI+O-2⇒■E■AE-1⇒■A■AA-1⇒■A■AI-1, it follows that ■A■AI-1 is valid, and its expansion is that ■*all*(*P, M*)→(■*all*(*S, P*)→*some* (*S, M*)). Then, what is obtained is that ■*some*(*S, M*)↔ ■*some*(*M, S*), using the clause (1) in Fact 1. It is reasonable to say that ■*all*(*P, M*)→(■*all* (*S, P*)→ ■*some*(*M, S*)) is valid. That is to say that the syllogism ■A■AI-4 can be derived from ■A■AI-1. The proofs of other cases are along similar lines to that of (6.2).

*Theorem 7:* The validity of the following five syllogisms can be inferred from □EI◇O-2:

(7.1) □EI+O-2⇒■E■AE-1⇒■A■AA-1⇒O□A+O-3

(7.2) □EI+O-2⇒■E■AE-1⇒■E■AE-2⇒■E■AO-2⇒□AA+ I-3

(7.3) □EI+O-2⇒■E■AE-1⇒■A■EE-4⇒■A■EO-4⇒□EA+ O-4

(7.4) □EI+O-2⇒■E■AE-1⇒■A■AA-1⇒■A■AI-1⇒■AE+ O-2

(7.5) □EI+O-2⇒■E■AE-1⇒■A■AA-1⇒■A■AI-1⇒■AE+ O-2⇒E■A+O-3

*Proof:* For (7.1). In line with (5.2) □EI+O-2⇒E■AE-1⇒■A■AA-1, it follows that ■A■AA-1 is valid, whose expansion is that ☑*all*(*P, M*)→(■*all*(*S, P*)→*all*(*S, M*)). And then it can be derived that ¬*all*(*S, M*)→( ■*all*(*S, P*)→¬■*all*(*P, M*)) in the light of Rule 2. Thus one can obtain that ¬*all*(*S, M*)→(■*all*(*S, P*)→+¬*all*(*P, M*)) according to Fact 5. It is clear that ¬*all*(*S, M*)=*not all*(*S, M*) and ¬*all*(*P, M*)=*not all*(*P, M*) based on the clause (1) in Fact 3. Therefore, it can be seen that *not all*(*S, M*)→(■*all*(*S, P*)→ +*not all*(*P, M*)) is valid. That is to say that O□A+O-3 can be deduced from □EI+O-2. The proofs of other cases follow the similar pattern as that of (7.1).

*Theorem 8:* The validity of the following four syllogisms can be inferred from □EI+O-2:

(8.1) □EI+O-2⇒□EI+O-4⇒□EI+O-3

(8.2) □EI+O-2⇒■E■AE-1⇒■A■EE-4⇒■A■EO-4⇒□EA+ O-4⇒□EA+O-3

(8.3) □EI+O-2⇒■E■AE-1⇒■A■AA-1⇒■A■AI-1⇒■AE+ O-2⇒■AE+O-4

(8.4) □EI+O-2⇒■E■AE-1⇒■A■AA-1⇒■A■AI-1⇒■AE+ O-2⇒E■A+O-3⇒E■A+O-4

*Proof:* For (8.1). In line with (6.3) □EI+O-2⇒□EI+O-4, it follows that □EI+O-4 is valid, and its expansion is that ■*no*(*P, M*)→(*some*(*M, S*)→ +*not all*(*S, P*)). Then, what is obtained is ■*no*(*P, M*)↔ ■*no*(*M, P*), using the clause (2) in Fact 1. Hence, it can be proved that ■*no*(*M, P*) →(*some*(*M, S*)→ +*not all*(*S, P*)) is valid, i.e. the syllogism □EI+O-3 can be derived from □EI+O-2. The other cases can be similarly proved.

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*Theorem 9:* The validity of the following eleven syllogisms can be inferred from ▯EI+O-2:

(9.1) ▯EI+O-2⇒■E■AE-1⇒■E■A+E-1

(9.2) ▯EI+O-2⇒■E■AE-1⇒■E■AE-2⇒■E■A+E-2

(9.3) ▯EI+O-2⇒■E■AE-1⇒■A■EE-4⇒■A■E+E-4

(9.4) ▯EI+O-2⇒■E■AE-1⇒■A■EE-4⇒■A■EE-2⇒■A■E+E-2

(9.5) ▯EI+O-2⇒■E■AE-1⇒■E■AO-1⇒■E■A+O-1

(9.6) ▯EI+O-2⇒■E■AE-1⇒■E■AE-2⇒■E■AO-2⇒■E■A+O-2

(9.7) ▯EI+O-2⇒■E■AE-1⇒■A■EE-4⇒■A■EO-4⇒■A■E+O-4

(9.8) ▯EI+O-2⇒■E■AE-1⇒■A■EE-4⇒■A■EE-2⇒■A■E O-2⇒■A■E+O-2

(9.9) ▯EI+O-2⇒■E■AE-1⇒■A■AA-1⇒▯A■A+A-1

(9.10) ▯EI+O-2⇒■E■AE-1⇒■A■AA-1⇒■A■AI-1⇒■A■A+I-1

(9.11) ▯EI+O-2⇒■E■AE-1⇒■A■AA-1⇒■A■AI-1⇒■A■AI-4⇒■A■A+I-4

*Proof:* For (9.1). In line with (2.1) ▯EI+O-2⇒■E■AE-1, it follows that ■E■AE-1 is valid. It is clear that E⇒+E according to Fact 7. Therefore, the validity of ■E■A+E-1 is straightforward. The proofs of other cases follow the same pattern as that of (9.1).

So far, the other 38 valid Aristotelian modal syllogisms have been derived from the validity of the syllogism ▯EI+O-2 on the basis of modern modal logic and generalized quantifier theory.

## IV. Conclusion and Future Work

This paper firstly demonstrates the validity of the syllogism ▯EI+O-2, and then takes it as the basic axiom to derive the other 38 valid modal syllogisms by taking advantage of some reasoning rules in classical propositional logic, the symmetry of two Aristotelian quantifiers (i.e. *some* and *no*), the transformation between an Aristotelian quantifier and its three negative quantifiers, and some facts in first order logic. In other words, there are reducibility between the syllogism ▯EI+O-2 and the other 38 valid Aristotelian modal syllogisms. Moreover, the above deductions may provide a consistent interpretation for Aristotelian modal syllogistic. There are infinitely many instances in natural language corresponding to any valid modal syllogism. Therefore, this study has significant theoretical value and practical significance to natural language information processing in computer science.

Can the remaining valid Aristotelian modal syllogisms be derived from a few valid modal syllogisms (such as □E▯I□O-2, □E□I◇O-2, □E◇I◇O-2, □E□IO-2, ◇EI◇O-2, E◇I◇O-2, □EI◇O-2, E□I◇O-2, □EIO-2, E□IO-2 and EI◇O-2), and how to construct a coherent formal system for Aristotelian modal syllogistic? These questions need to be explored in depth.

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The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

**Keywords**

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in a research paper?" Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

**Numerical Methods**

Numerical methods used should be transparent and, where appropriate, supported by references.

**Abbreviations**

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

**Formulas and equations**

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

**Tables, Figures, and Figure Legends**

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

**Figures**

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

## Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

## Tips for writing a good quality Computer Science Research Paper

Techniques for writing a good quality computer science research paper:

***1. Choosing the topic:*** In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

***2. Think like evaluators:*** If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

***3. Ask your guides:*** If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

***4. Use of computer is recommended:*** As you are doing research in the field of computer science then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

***5. Use the internet for help:*** An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

***6. Bookmarks are useful:*** When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

***7. Revise what you wrote:*** When you write anything, always read it, summarize it, and then finalize it.

***8. Make every effort:*** Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

***9. Produce good diagrams of your own:*** Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

***10.Use proper verb tense:*** Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

***11. Pick a good study spot:*** Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

***12. Know what you know:*** Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

***13. Use good grammar:*** Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

***14. Arrangement of information:*** Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

***15. Never start at the last minute:*** Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

***16. Multitasking in research is not good:*** Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

***17. Never copy others' work:*** Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

***18. Go to seminars:*** Attend seminars if the topic is relevant to your research area. Utilize all your resources.

***19. Refresh your mind after intervals:*** Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

**20. *Think technically:*** Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

**21. *Adding unnecessary information:*** Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

**22. *Report concluded results:*** Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

**23. *Upon conclusion:*** Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

## Informal Guidelines of Research Paper Writing

***Key points to remember:***

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

**Final points:**

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

*The introduction:* This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

**The discussion section:**

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

**General style:**

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

**To make a paper clear:** Adhere to recommended page limits.

*Mistakes to avoid:*

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.
- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

**Title page:**

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

**Abstract:** This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

*Reason for writing the article—theory, overall issue, purpose.*

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

**Approach:**

- o Single section and succinct.
- o An outline of the job done is always written in past tense.
- o Concentrate on shortening results—limit background information to a verdict or two.
- o Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

**Introduction:**

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

*The following approach can create a valuable beginning:*

- o Explain the value (significance) of the study.
- o Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- o Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- o Briefly explain the study's tentative purpose and how it meets the declared objectives.

**Approach:**

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

**Procedures (methods and materials):**

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

**Materials:**

*Materials may be reported in part of a section or else they may be recognized along with your measures.*

**Methods:**

- o Report the method and not the particulars of each process that engaged the same methodology.
- o Describe the method entirely.
- o To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- o Simplify—detail how procedures were completed, not how they were performed on a particular day.
- o If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

**Approach:**

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

**What to keep away from:**

- o Resources and methods are not a set of information.
- o Skip all descriptive information and surroundings—save it for the argument.
- o Leave out information that is immaterial to a third party.

**Results:**

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

**Content:**

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

**What to stay away from:**

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

**Approach:**

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

**Figures and tables:**

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

**Discussion:**

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

**Approach:**

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

## The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

*Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection*.

*Segment draft and final research paper:* You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

*Written material:* You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

## Criterion for Grading a Research Paper (Compilation) by Global Journals Inc. (US)

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| Topics | Grades | | |
|---|---|---|---|
| | **A-B** | **C-D** | **E-F** |
| ***Abstract*** | Clear and concise with appropriate content, Correct format. 200 words or below | Unclear summary and no specific data, Incorrect form<br><br>Above 200 words | No specific data with ambiguous information<br><br>Above 250 words |
| ***Introduction*** | Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited | Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter | Out of place depth and content, hazy format |
| ***Methods and Procedures*** | Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads | Difficult to comprehend with embarrassed text, too much explanation but completed | Incorrect and unorganized structure with hazy meaning |
| ***Result*** | Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake | Complete and embarrassed text, difficult to comprehend | Irregular format with wrong facts and figures |
| ***Discussion*** | Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited | Wordy, unclear conclusion, spurious | Conclusion is not cited, unorganized, difficult to comprehend |
| ***References*** | Complete and correct format, well organized | Beside the point, Incomplete | Wrong format and structuring |

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