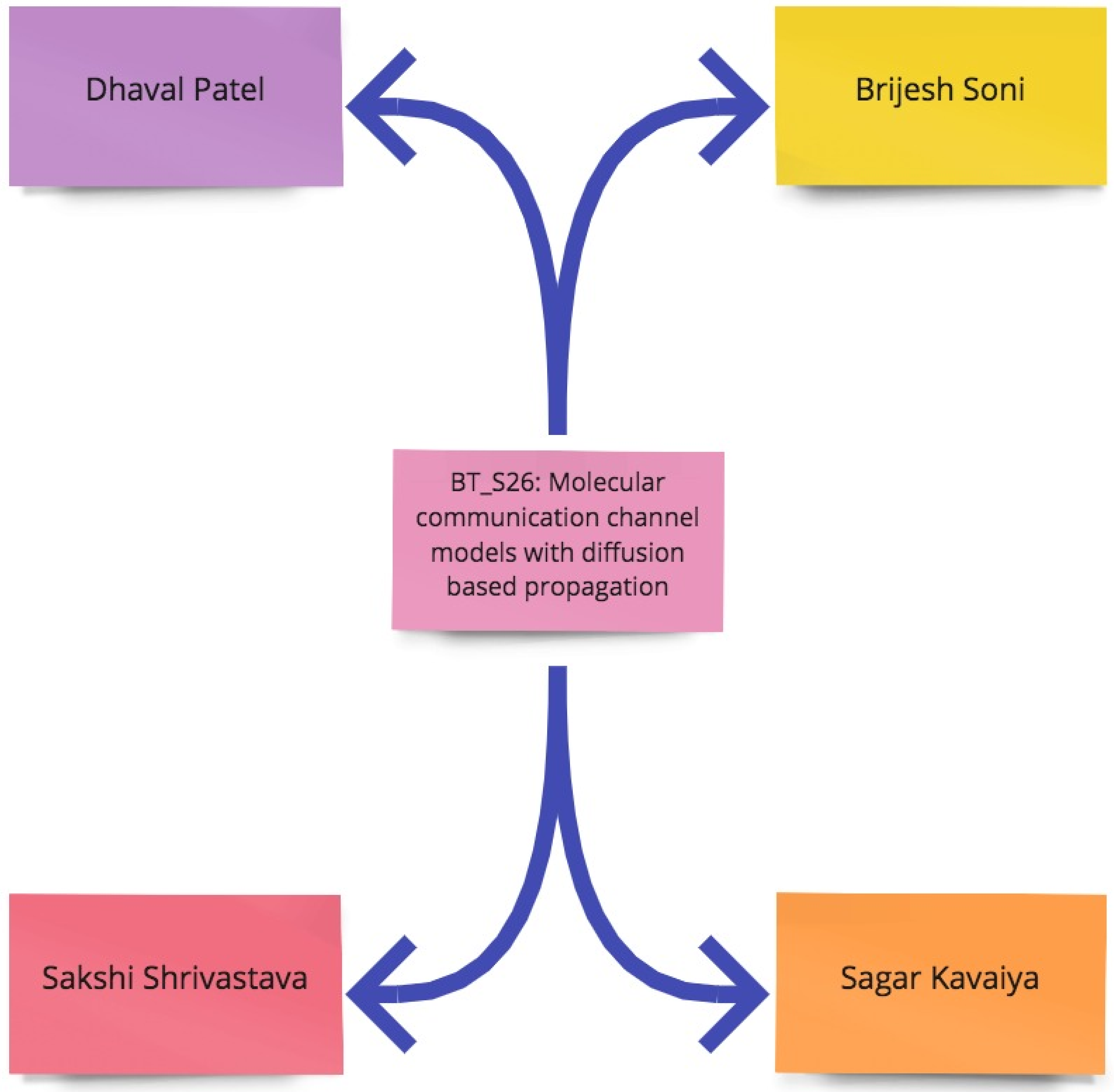
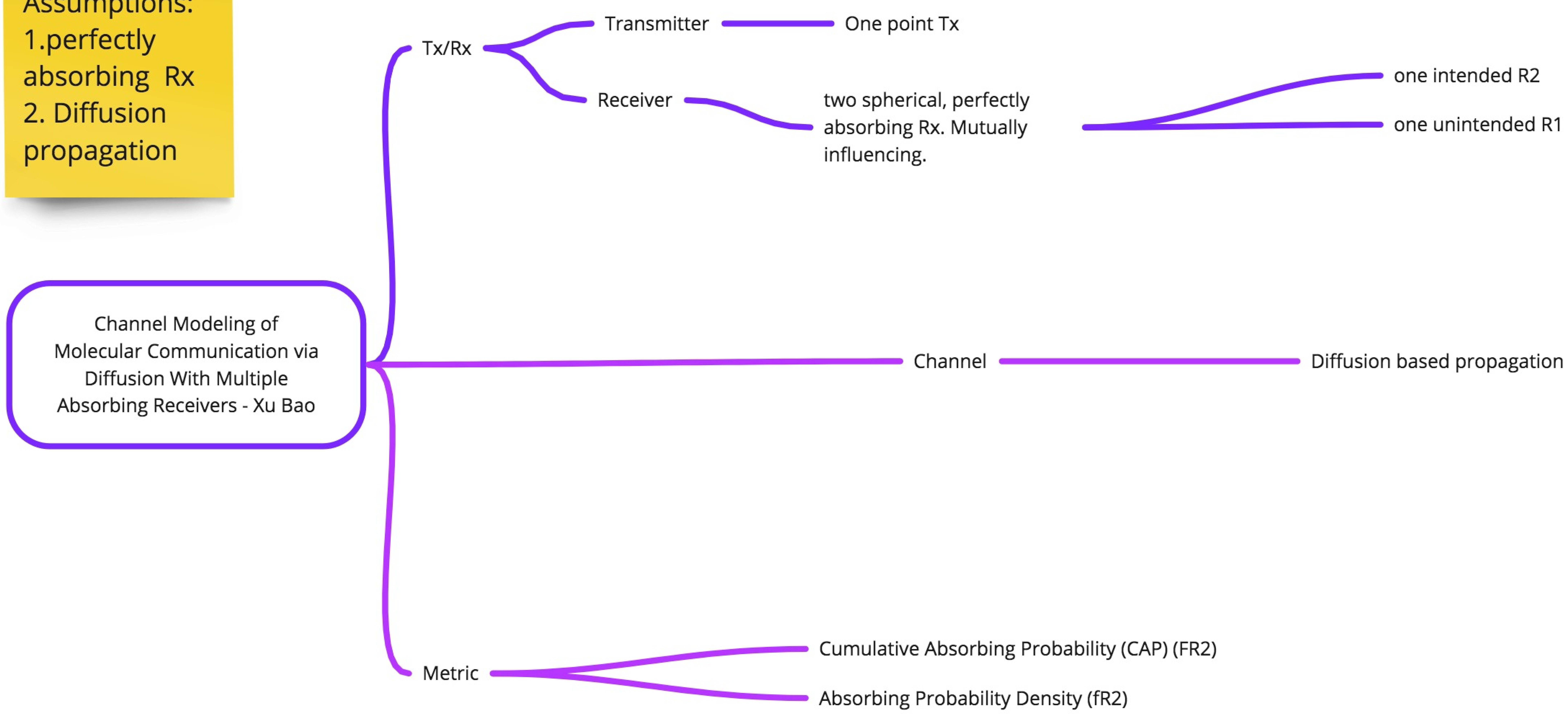
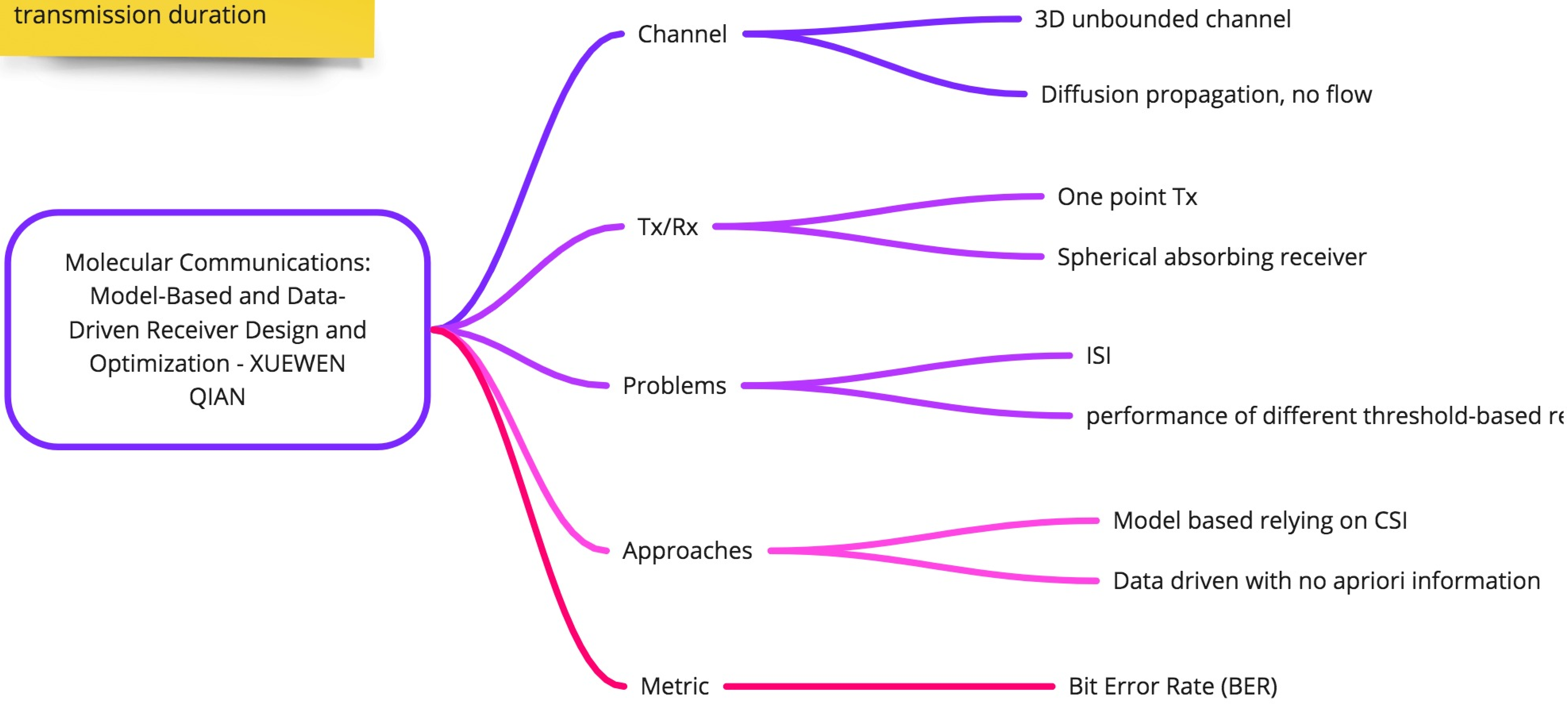

Dhaval Patel
Brijesh Soni
BT_S26: Molecular communication channel models with diffusion based propagation
Sakshi Shrivastava
Sagar Kavaiya
miro

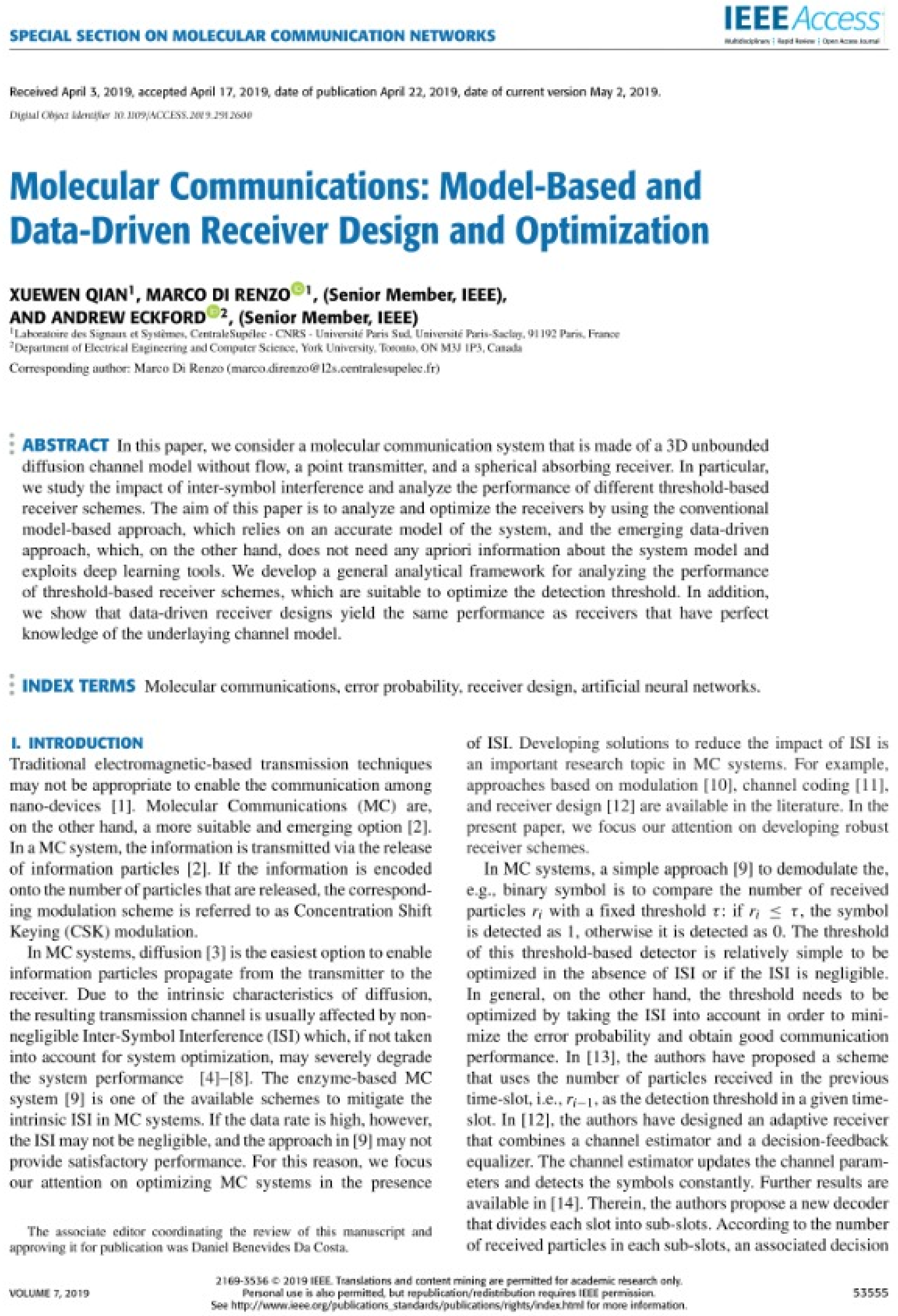

info molecules released by transmitter nano-machine (Tx, x=0)
info molecules degrade over time
Molecules
info molecules stochastically reaching receiver nano-machine (Rx, x=d)
Channel Model and Capacity Analysis of Molecular Communication with Brownian motion
- Tadashi Nakano
Modulation
Naive (one molecule for '1' and no molecule for '0')
Extended (using extra molecules)
Conclusions
channel capacity is largely influenced by the molecule life expectancy and the channel capacity can be improved at the expense of extra molecules
nearly one bit per slot can be achieved when the type and number of molecules are optimally selected for molecular communication
Environment
one dimensional environment (-∞, d] (d > 0)
propagation via brownian motion
Channel
MC channel is a time slotted binary channel with memory (Tx is synced with Rx. Time is slotted by τ and slot n ∊ {1, 2, ...} refers to time period [(n-1) τ, n τ]).

Assumptions:
1.perfectly absorbing Rx
2. Diffusion propagation



Assumptions:
1. temperature is constant
2. the viscosity η remains unchanged during the whole transmission duration





SPECIAL SECTION ON MOLECULAR COMMUNICATION NETWORKS

IEEE Access

Received April 3, 2019, accepted April 17, 2019, date of publication April 22, 2019, date of current version May 2, 2019.

Digital Object Identifier 10.1109/ACCESS.2019.2912600

Molecular Communications: Model-Based and Data-Driven Receiver Design and Optimization

XUEWEN QIAN[1], MARCO DI RENZO[1], (Senior Member, IEEE), AND ANDREW ECKFORD[2], (Senior Member, IEEE)
[1]Laboratoire des Signaux et Systèmes, CentraleSupélec - CNRS - Université Paris Sud, Université Paris-Saclay, 91192 Paris, France
[2]Department of Electrical Engineering and Computer Science, York University, Toronto, ON M3J 1P3, Canada
Corresponding author: Marco Di Renzo (marco.direnzo@l2s.centralesupelec.fr)

ABSTRACT In this paper, we consider a molecular communication system that is made of a 3D unbounded diffusion channel model without flow, a point transmitter, and a spherical absorbing receiver. In particular, we study the impact of inter-symbol interference and analyze the performance of different threshold-based receiver schemes. The aim of this paper is to analyze and optimize the receivers by using the conventional model-based approach, which relies on an accurate model of the system, and the emerging data-driven approach, which, on the other hand, does not need any apriori information about the system model and exploits deep learning tools. We develop a general analytical framework for analyzing the performance of threshold-based receiver schemes, which are suitable to optimize the detection threshold. In addition, we show that data-driven receiver designs yield the same performance as receivers that have perfect knowledge of the underlaying channel model.

INDEX TERMS Molecular communications, error probability, receiver design, artificial neural networks.

I. INTRODUCTION

Traditional electromagnetic-based transmission techniques may not be appropriate to enable the communication among nano-devices [1]. Molecular Communications (MC) are, on the other hand, a more suitable and emerging option [2]. In a MC system, the information is transmitted via the release of information particles [2]. If the information is encoded onto the number of particles that are released, the corresponding modulation scheme is referred to as Concentration Shift Keying (CSK) modulation.

In MC systems, diffusion [3] is the easiest option to enable information particles propagate from the transmitter to the receiver. Due to the intrinsic characteristics of diffusion, the resulting transmission channel is usually affected by non-negligible Inter-Symbol Interference (ISI) which, if not taken into account for system optimization, may severely degrade the system performance [4]–[8]. The enzyme-based MC system [9] is one of the available schemes to mitigate the intrinsic ISI in MC systems. If the data rate is high, however, the ISI may not be negligible, and the approach in [9] may not provide satisfactory performance. For this reason, we focus our attention on optimizing MC systems in the presence of ISI. Developing solutions to reduce the impact of ISI is an important research topic in MC systems. For example, approaches based on modulation [10], channel coding [11], and receiver design [12] are available in the literature. In the present paper, we focus our attention on developing robust receiver schemes.

In MC systems, a simple approach [9] to demodulate the, e.g., binary symbol is to compare the number of received particles r_l with a fixed threshold τ: if $r_l \leq \tau$, the symbol is detected as 1, otherwise it is detected as 0. The threshold of this threshold-based detector is relatively simple to be optimized in the absence of ISI or if the ISI is negligible. In general, on the other hand, the threshold needs to be optimized by taking the ISI into account in order to minimize the error probability and obtain good communication performance. In [13], the authors have proposed a scheme that uses the number of particles received in the previous time-slot, i.e., r_{l-1}, as the detection threshold in a given time-slot. In [12], the authors have designed an adaptive receiver that combines a channel estimator and a decision-feedback equalizer. The channel estimator updates the channel parameters and detects the symbols constantly. Further results are available in [14]. Therein, the authors propose a new decoder that divides each slot into sub-slots. According to the number of received particles in each sub-slots, an associated decision

The associate editor coordinating the review of this manuscript and approving it for publication was Daniel Benevides Da Costa.

Preferable base article

Channel Model of Molecular Communication via Diffusion in a Vessel-like Environment Considering a Partially Covering Receiver assumption: underlying system model is perfectly known

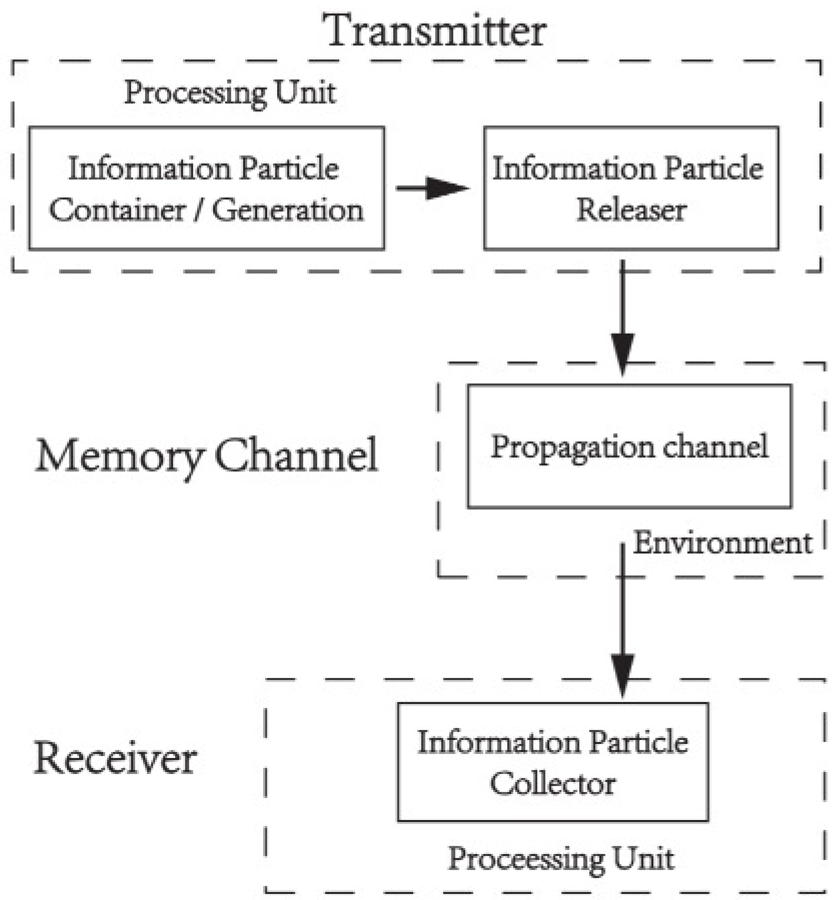


FIGURE 1. **Block diagram of a typical MC system.**

add to paper:
1. doppler shift or moving Tx or Rx
2. QPSK modulation

ISI

background noise per unit time

$$I_i = \lambda_0 T + \sum_{j=1}^{\infty} s_{i-j} C_j$$

sum of ISI and background noise

$$r_i \sim Poisson(I_i + s_i C_0)$$

no of rcvd particles at the ith time slot

s ̄i is the estimate of symbol si at time-slot i

$$\bar{s}_i = \begin{cases} 0, & r_i \leq \tau \\ 1, & r_i > \tau \end{cases}$$

Demodulation rule

λ0 = background noise per unit time

slot length

demodulation threshold

$$\tau = \frac{C_0}{ln(1 + \frac{C_0}{\sum_{i=1}^{L} C_i/2 + \lambda_0 T})}$$

$$P_e(s_{i-1}, \tau) = \frac{1}{2}[Q(\lambda_0 T + \sum_{j=1}^{L} s_{i-j} C_j, \lceil \tau \rceil)$$

$$+ 1 - Q(\lambda_0 T + \sum_{j=1}^{L} s_{i-j} C_j + C_0, \lceil \tau \rceil)]$$

BER eq

average received particles at the jth time-slot if NTX particles are released

SNR

$$SNR = 10 log_{10} \frac{C_0}{2\lambda_0 T}$$

no of released particles

$$N_{TX} = 2\lambda_0 T 10^{\frac{SNR}{10}} / P_0$$

$$C_j = N_{TX} P_j$$

probability that one particle hits the receiver

$$P_{i-1} = \frac{r}{d}\{erfc(\frac{d-r}{\sqrt{4DiT}}) - erfc(\frac{d-r}{\sqrt{4D(i-1)T}})\}$$

LIMITATIONS

- 3D unbounded environment
- ON/OFF Keying modulation
- perfect knowledge of the underlying channel model.
- Diffusion without flow
- perfectly absorbing spherical receiver
- No transmitter or receiver diversity
- linear system of noise
- one way communication

Innovation Framework

old hitting rate

pdf

$$f_{hit}^{3D}(t) = \frac{r(d-r)}{d\sqrt{4\pi D t^3}} e^{-\frac{(d-r)^2}{4Dt}}$$

new hitting rate

cdf

$$F_{\text{hit}}(t) = N^{\text{Tx}}\ \Phi(\Omega)\ \text{erfc}\left(\frac{d}{\sqrt{4Dt}}\right)$$

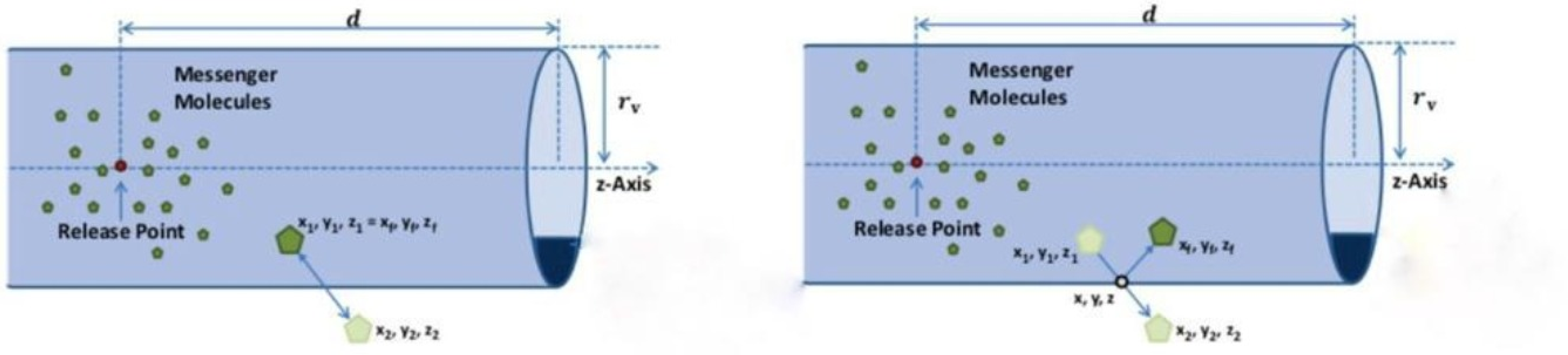
$$\Phi(\Omega) = \frac{\text{A}(\Omega)}{\pi r_{\text{v}}^2}$$

Area of vessel

Area of receiver

Impact on demodulation threshold?

New System Model



(a) Rollback strategy

(b) Elastic reflection strategy

miro