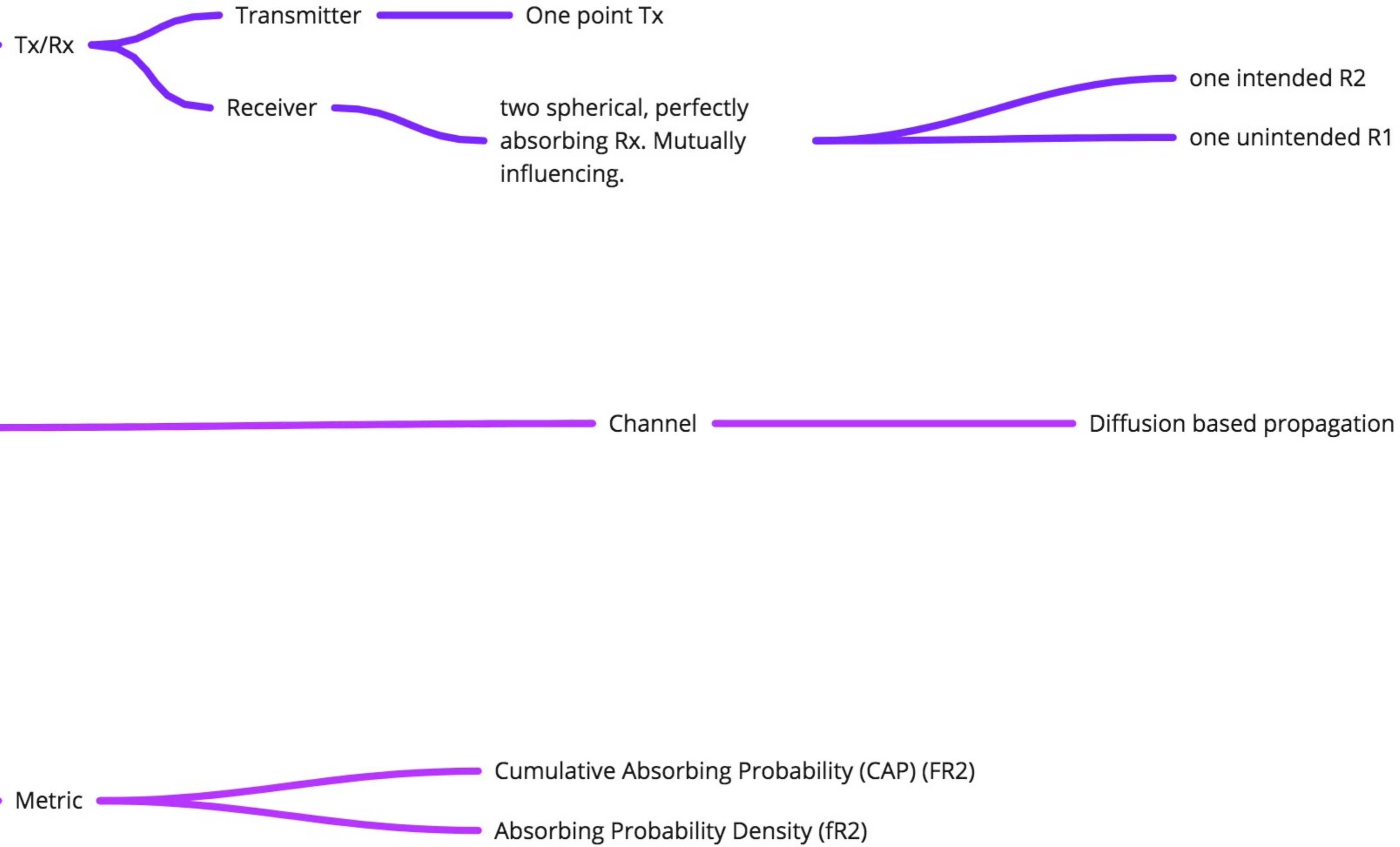


Assumptions:
1. perfectly absorbing Rx
2. Diffusion propagation

Channel Modeling of
Molecular Communication via
Diffusion With Multiple
Absorbing Receivers - Xu Bao



Assumptions:

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

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

Channel

- 3D unbounded channel
- Diffusion propagation, no flow

Tx/Rx

- One point Tx
- Spherical absorbing receiver

Problems

- ISI
- performance of different threshold-based receiver schemes

Approaches

- Model based relying on CSI
- Data driven with no apriori information

Metric

- Bit Error Rate (BER)

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

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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 underlying 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_i with a fixed threshold τ : if $r_i \leq \tau$, 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_{i-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

Assumption: devices that are just utilizing already existing tunnels for an artificial purpose (e.g., detecting lipids, bio-markers, or blood clots inside blood-vessels).

Channel Model of Molecular Communication via Diffusion in a Vessel-like Environment Considering a Partially Covering Receiver - Meriç Turan

Environment

Tunnel like, similar to a blood vein

Vessel walls reflect messenger molecules on contact

Elastic reflection strategy

Rollback strategy

Tx/Rx

Partially covering the cross-section of the vessel

One point transmitter

Analysis

Diffusion propagation of Messenger Molecules (MM).
Hitting location of MMs

Distribution in x and y axis

Distribution in the radius

Distribution of axial distances

Partially covering receiver

Channel Model of Molecular Communication via Diffusion in a Vessel-like Environment Considering a Partially Covering Receiver

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Abstract—By considering potential health problems that a fully covering receiver may cause in vessel-like environments, the implementation of a partially covering receiver is studied. In this work, distribution of hitting points of messenger molecules (MMs) is analyzed within the context of molecular communication via diffusion with the aim of channel modeling. The distribution of these MMs for a fully covering receiver is analyzed in two parts: regular and radial dimensions. For the regular dimensions, the receiver is divided into 360 slices to analyze the cases: covered receiver, and receiver at center of the slice. For the radial dimension, the receiver is divided into 360 slices to analyze the cases: covered receiver, and receiver at center of the slice. Also, two different implementations of the reflection from the vessel surface (i.e., elastic and elastic reflection) are compared and mathematical representation of elastic reflection is given. The results show that MMs have higher probability to hit the vessel surface than the vessel walls. By utilizing the uniformity of the hitting points, the partially covering receiver is modeled and the results are compared with the fully covering receiver.

Index Terms—Molecular communication, communication via diffusion, vessel-like environment, messenger molecules, receiver, partially covering receiver.

1. INTRODUCTION

Molecular communication via diffusion (MCVD) is one of the promising molecular communication (MOC) systems proposed to overcome the shortcomings, especially for in vivo applications. In contrast to the classical communication systems, MCVD utilizes molecules, messenger molecules (MMs) as information carriers, namely for high biocompatibility and energy efficiency. These molecules propagate in a fluid environment (e.g., intra-cellular fluids and extra-cellular fluids), which has nearly identical features than the physical layer of classical communication systems [1].

Most of the researches conducted regarding MCVD assume a free diffusion environment in which the MMs can move in an unrestricted manner. This free diffusion environment, while being very suitable for developing mathematical channel, noise, and performance models, has several shortcomings such as: limited range and limited applicability in in vivo environments. As shown in previous works [1]–[4], the performance of the MCVD system sharply decreases as the distance between

the transmitter pair exceeds several times of environment. This limited range severely hinders the applicability of MCVD in a free diffusion environment without any enhancement. Also, in vivo environments, such as complex living organisms, usually consist of large bodies of cells and so each slice or sub-body vessel-like environment, which are different than the sub-body and compartment free diffusion environments used in the MCVD literature.

As an alternative to the free diffusion environment, a vessel-like environment which closely mimics the walls of a blood vessel has been proposed in several works in the literature [5]–[9]. Unlike the free diffusion environment, in the vessel-like environment the MMs are bounded by the walls of the vessel, and upon impact with these walls they are either reflected back or absorbed, depending on the environmental factor. Since these walls constrain the movement of the MMs, the effective range of the system greatly increases.

In this work, we study the channel model of such a vessel-like environment considering a receiver that partially covers the cross-section of the vessel and vessel walls that reflect the MMs upon contact. In our analysis, we choose a partially covering receiver over a fully covering receiver for increased biocompatibility. We assume a vessel that are just utilizing already existing tunnels for an artificial purpose (e.g., detecting toxic biomarkers, or blood clot, tumor, blood clots).

The main contributions of the paper are summarized below:

- We describe and elaborate on the reflection strategies that can be used to simulate diffusion motion in a vessel-like environment, namely: elastic reflection strategy and rollback strategy.
- Using simulations, we show that the reflective strategy (elastic reflection) distribution of MCVD in the cross-section of the vessel follows uniform distributions in both regular and radial dimensions to control axial distances independently beyond a certain ratio of the distance to the vessel center.
- Based on the previous observation, we evaluate the hitting rate of molecules on a partially covering receiver as a function of the area of the receiver, the transmitter-receiver distance, and the radius of the vessel.

assumption:
underlying
system model
is perfectly
known

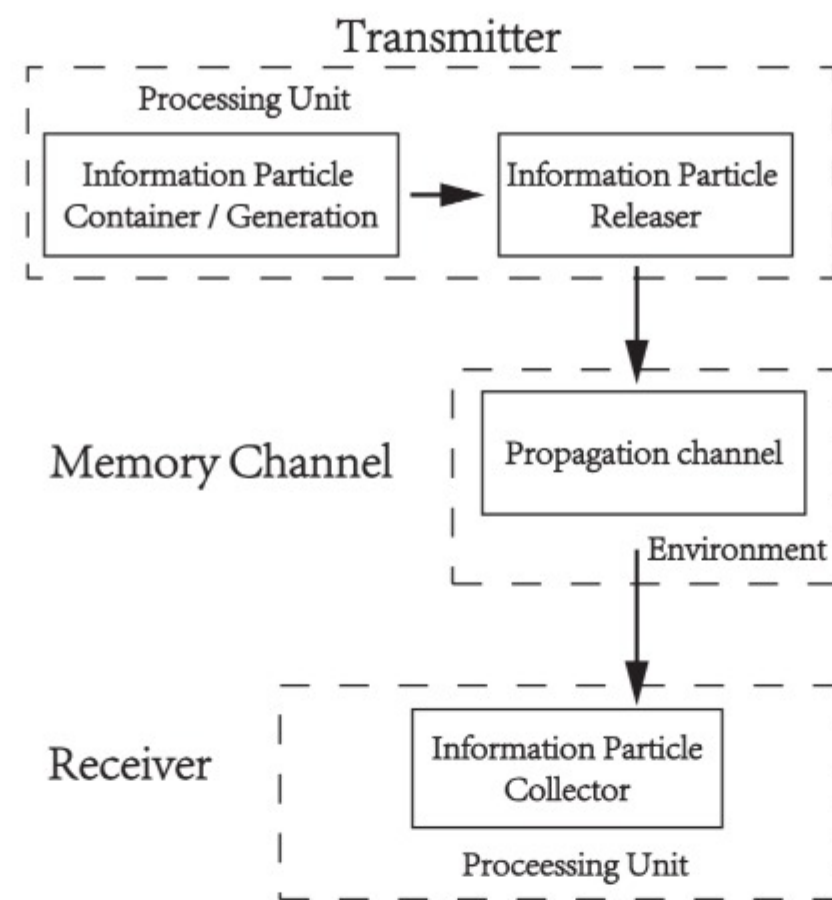
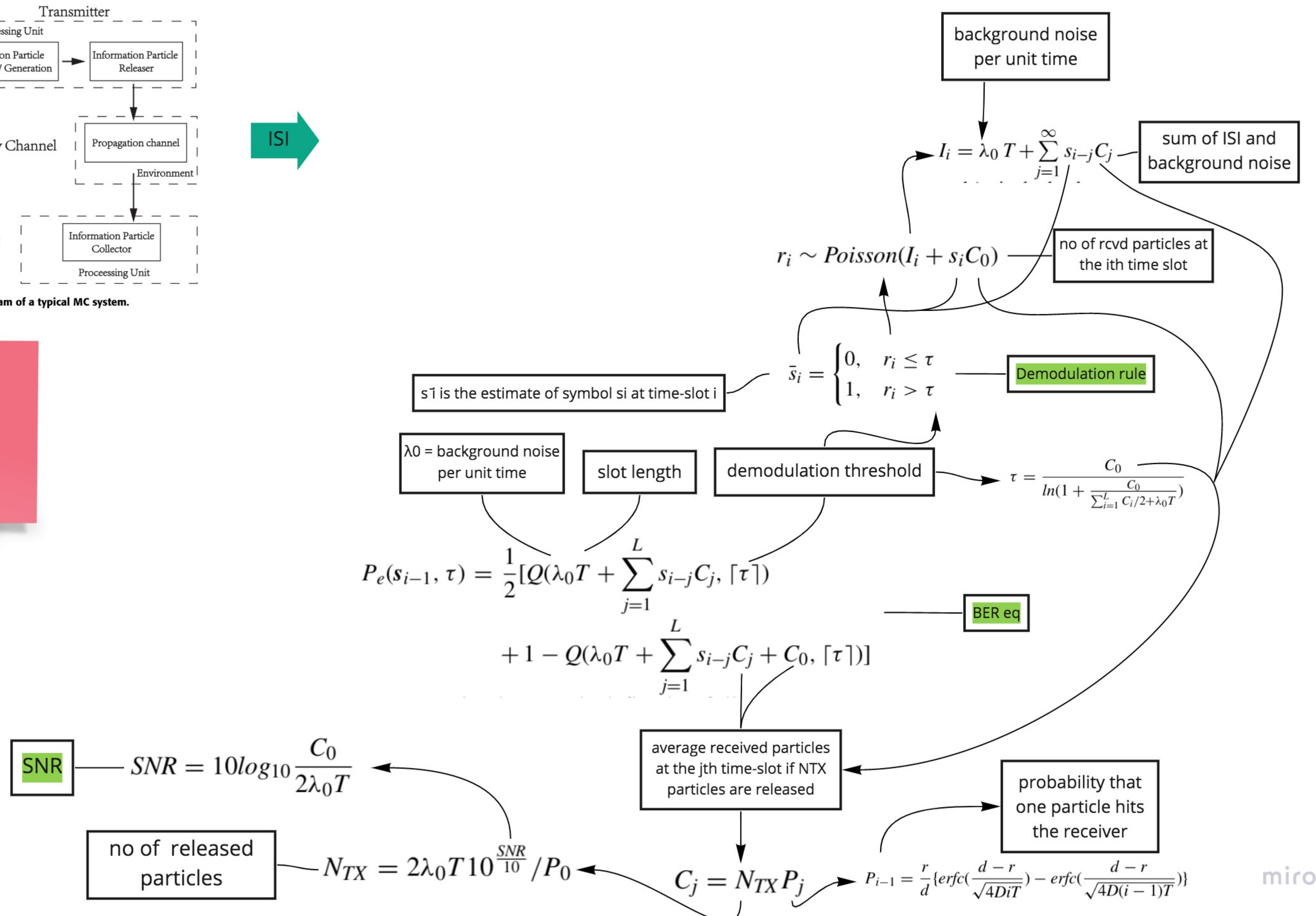


FIGURE 1. Block diagram of a typical MC system.

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



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

pdf

old hitting
rate

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

new hitting rate

cdf

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

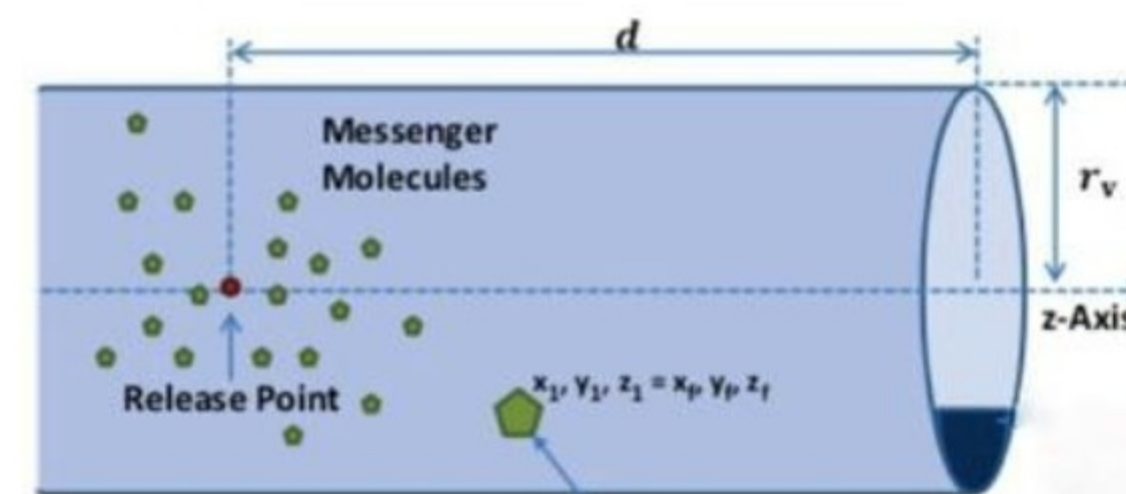
$$\Phi(\Omega) = \frac{A(\Omega)}{\pi r_v^2}$$

Area of vessel

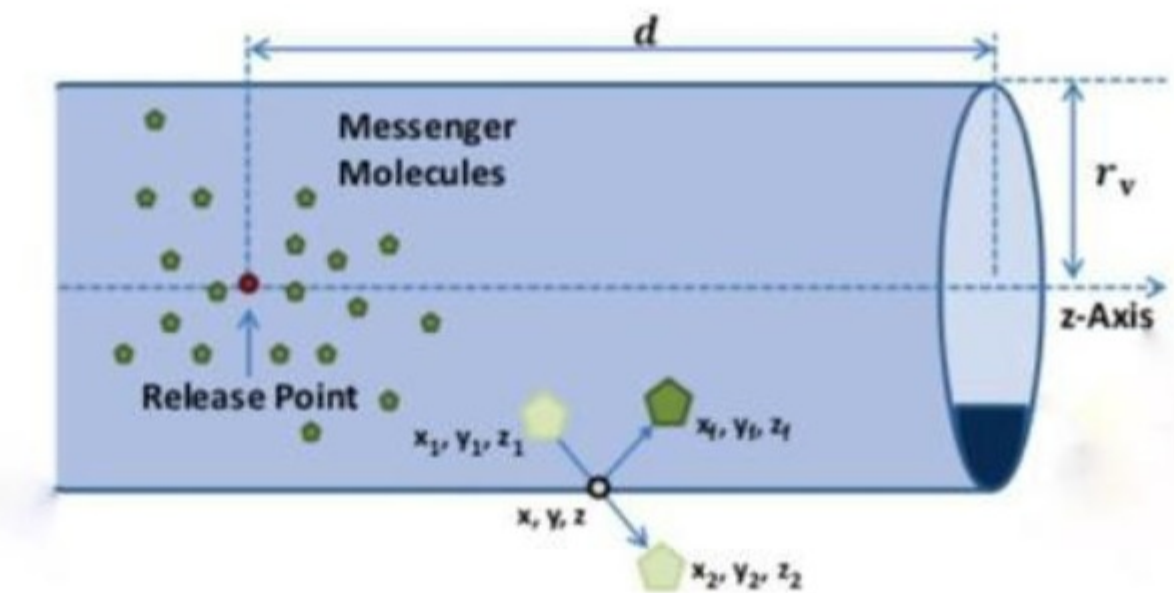
Area of
receiver

Impact on
demodulation
threshold?

New System Model



(a) Rollback strategy



(b) Elastic reflection strategy