Decoding Human Breath from the Perspective of Molecular Communication

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***Abstract*—The Internet of bio-nano-things is a rapidly advancing field focused on enabling localized medical diagnostics and long-term monitoring of metabolic processes. A critical aspect of this technology involves transmitting information from an in-body network of biological and nanodevices to an external data collection and reporting center. This work-in-progress paper addresses the challenge through the lens of molecular communication. Emphasis is laid on the non-invasive detection of agents in exhaled breath, analyzing their properties to reveal internal health and metabolic conditions. It also highlights the potential of commercially available sensors in achieving this objective.**

I. Introduction

Respiration enables gas exchange between the respiratory and cardiovascular systems. Oxygen enters the blood via pulmonary *alveoli*, while carbon dioxide is expelled during exhalation [1]. Metabolic needs, neurological regulations, and environmental conditions influence breath characteristics. Therefore, understanding these factors is crucial to advance medicine, enhance athletic performance, and improve patient monitoring in clinical settings.

Molecular communication (MC) presents a unique opportunity to study human health by analyzing the properties of exhaled breath [2]. In MC, information is transmitted through molecules or nanoparticles [3], offering an innovative approach for medical diagnostics by detecting biomarkers and identifying patterns in breath flow dynamics [4].

MC exists in both its natural and synthetic forms [5]. Natural MC describes the information exchange using chemical messengers [5], as observed in nature, e.g., in the endocrine system of humans [6]. Synthetic MC focuses on creating artificial communication links using chemical methods [5]. Thus, synthetic MC represents a communication paradigm inspired by biological means.

This work-in-progress paper explores an early-stage approach to linking naturally occurring MC in medical diagnostics—via exhaled breath—to conventional communication models. The focus is on non-invasive detection of biochemical agents and their properties, encoding valuable health and metabolic information. Furthermore, this work highlights the feasibility of using commercial sensors for such applications, showcasing their potential in breath-based diagnostics.

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II. System Model

The system model is described in Fig. 1. The transmitter comprises *information source*, which generates data such as health conditions (e.g., diabetes, lung cancer, or asthma), their severity, and their location within the body. *Source encoding* occurs when metabolic processes encode this information in exhaled biomarkers with respective probability distributions, indicating the health condition, origin, and severity. During *channel encoding*, redundancy is introduced through repeated occurrences of biomarkers over time, reducing the impact of transmission noise. In *modulation*, the properties of exhaled biomarkers, such as concentration, type, temporal dynamics, spatial distribution, or combinations thereof, carry encoded health information [7].

The transmission channel governs *propagation* of biomarkers through air-based *physical medium*, influenced by mechanisms such as diffusion, advection, gravity, velocity, and buoyancy [8]. In addition, the channel introduces *noise* from sources such as background biomarkers, turbulence, temperature variations, or obstacles.

The receiver *demodulates* the biomarkers using specialized sensors, such as metal-oxide gas sensors, which detect their temporal dynamics, type, concentration, etc. During *channel decoding*, noise and distortions are corrected to retrieve the original information. The *source decoder* then maps the biomarkers back to the specific health conditions, their severity, and locations within the body. Finally, the *information sink* delivers this decoded data to healthcare providers, enabling accurate diagnosis and treatment.

III. Hardware Setup and Preliminary Results

MC is inherent in exhaled breath flow, transmitting biochemical and biophysical health information. Breath carries gaseous biomarkers like volatile organic compounds and carbon dioxide, encoding physiological states. These patterns serve as non-invasive tools for diagnosing metabolic and pathological conditions.

To investigate respiratory states, the MQ-135 gas sensor, which senses exhaled carbon dioxide, is used to measure the flow dynamics of the breath originating from both the nose and the mouth. Connected to an Arduino Nano via A0, the sensor samples at every $125\,\mathrm{ms}$. Positioned close to the nose and mouth, it minimizes gas diffusion into ambient air.

The experimental setup evaluates eupnea (normal breathing), bradypnea (slow breathing), and tachypnea (rapid breathing). As described in [9], eupnea (12–20 breaths per minute) maintains gas exchange and homeostasis. Bradypnea (<12 breaths per minute) may signal neurological impairments,

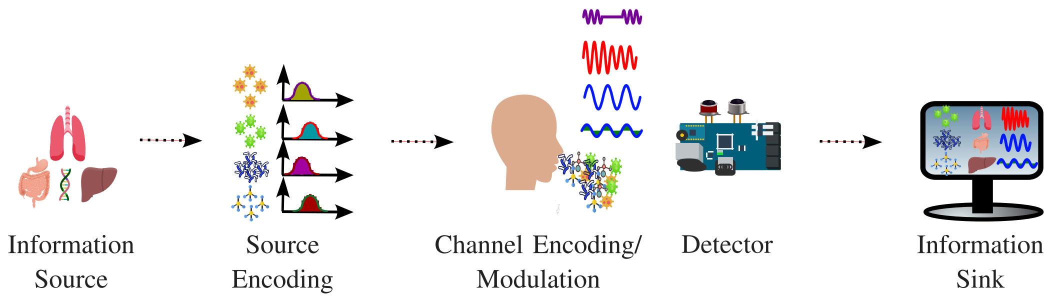

Fig. 1: System model comprising the transmitter, the transmission channel, and the receiver depicting flow of information.

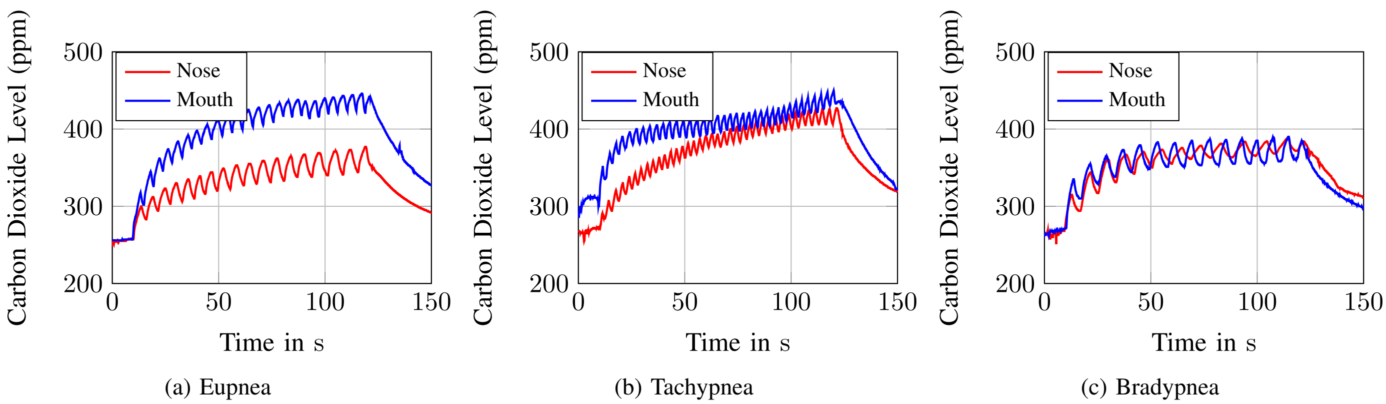

Fig. 2: Carbon dioxide levels as detected by MQ-135 gas sensor depicting eupnea, tachypnea, and bradypnea.

metabolic imbalances, or sedative effects. Tachypnea (>20 breaths per minute) is linked to fever, shock, anxiety, and exercise. These scenarios are artificially replicated and detected by an MQ-135 gas sensor, as shown in Fig. 2.

The sensor data captures distinct breath pattern peaks, highlighting temporal and amplitude differences. It is also observed that the carbon dioxide amplitude from the mouth is higher than that from the nose as a result of a greater exhaled volume. Both show a rising trend due to the sensor's non-linear behavior [10]. These findings support breath-based MC for detecting health anomalies, enabling advanced non-invasive diagnostics for early disease detection.

IV. Conclusion

This work compares MC-based breath diagnostics to a communication system model, highlighting the potential of commercial sensors for practical implementation. Future research will expand the dataset by integrating multiple sensors to simultaneously detect various health parameters, including temperature, humidity, and diverse biomarkers. This multi-sensor approach aims to enhance diagnostic accuracy and enable comprehensive real-time health monitoring.

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