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# BioTapSync: revolutionizing data synchronization with human touch

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**ABSTRACT**

Human Tap introduces a new way to ensure secure data transmission synchronization by integrating advanced technologies. Motivated by the need for secure and efficient communication, it uses both near field communication (NFC) and human field communication (HFC) to provide a wide range of secure communication solutions. The aim is to create a system with detailed specifications, including maximum coverage range, frequency of operation, type of communication, and data rate for each protocol. These specifications are tailored for various applications, such as credit card payments, e-ticket bookings, E-ZPass systems, and item tracking. A notable contribution of Human Tap is its ability to achieve microsecond-level accuracy for distances up to 2 cm by thoroughly analyzing the relationship between distance and time. This innovative synchronization method not only ensures a secure data transmission environment but also shows remarkable flexibility, effectively addressing the challenges of modern communication systems. Human Tap sets a new benchmark for secure and adaptable data transmission technologies, paving the way for future advancements in the field. The objective is to establish a robust and versatile data transmission method that can be adapted to a wide range of modern applications.



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## 1. INTRODUCTION

In today's rapidly evolving information technology landscape, the need for secure and efficient data transmission is more critical than ever [1], [2]. Traditional encryption and synchronization methods have provided effective safeguards, but the continuous advancement of technology has introduced new complexities and vulnerabilities in protecting sensitive information [3]–[5]. Human Tap offers a revolutionary approach to secure data transmission synchronization by bridging the gap between cutting-edge technology and human intuition [6], [7]. This method represents a significant shift in data protection, combining artificial intelligence with human cognitive capabilities to create a robust and adaptable solution [8]–[10]. Human Tap integrates human interaction into the data transmission synchronization process, allowing users to actively participate in authentication and encryption [11], [12]. By introducing a tactile element, it enhances the security of data transmission beyond the capabilities of traditional algorithms [13]. The aim of this research is to explore the potential of Human Tap to provide a dynamic and secure data transmission method that addresses the challenges posed by modern communication systems.

Figure 1 demonstrates the concept of Human Tap, a secure data transmission method that relies on human touch [14]. On the left side, it shows that without touch, no signal is transmitted, indicated by a flat line on the signal graph. This means that the system remains inactive and does not transmit data when there is no human interaction. On the right side, it depicts that when a person touches the transmitter, a signal is generated, as shown by the active signal on the graph [15]. This touch activates the system, enabling secure data transmission. The human interaction introduces a tactile element, enhancing security by ensuring that data transmission only occurs with intentional physical contact [16]. This approach leverages the natural human action of touch to create a more secure and controlled data transmission process [17].

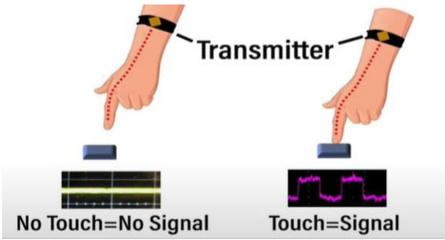


Figure 1. Human data communication [6]

## 2. LITERATURE STUDY

In the field of secure data transmission, leveraging human interaction for enhancing security protocols has gained significant attention. Human body communication (HBC) and related technologies offer innovative approaches for secure and efficient data exchange, especially within wireless body area networks (WBAN). Research has extensively explored various aspects of HBC, including antenna designs, signal propagation models, and system performance evaluations. On-/off-body body ultra-wideband antennas for WBANs, highlighting their design and performance metrics [1]. We can measure HBC channels using wearable devices across a broad frequency range, showcasing the feasibility of such technologies in practical applications [2]. We can evaluate human body characteristics for electric signal transmission, providing insights into body impulse responses [3]. We can discuss the safety aspects of HBC, ensuring its viability for biomedical applications [4]. Osteoconduct introduced, a wireless data transfer method based on bone conduction, demonstrating a novel application of HBC [5]. We can also examine the use of human skin as a data transmission medium, focusing on privacy and usability in wearable electronics [6]. The experimental studies on the dynamic capabilities of WBANs, contribute to the understanding of network performance under various conditions [7]. We can return path capacitance in capacitive HBC, enhancing the comprehension of signal propagation mechanisms [8]. HBC discussing signal propagation models, communication performance, and experimental issues [9]. We can investigate data transfer through the human body, furthering the development of HBC technologies [10]. Transmission designed a low-profile, wideband antenna for concurrent on-/off-body communications, addressing the need for versatile communication solutions [11]. Analysis suggests the challenges and roles of body channel communication in wearable flexible electronics [12].

Developing a multi-path model for galvanic coupled intra-body communication, providing a framework for analyzing signal transmission through layered tissues [13]. By enabling wireless implant communications via galvanic coupling, broadening the scope of HBC applications [14]. By introducing an intrabody communication transceiver for biomedical applications, emphasizing the potential of HBC in healthcare [15]. We can estimate bit error rates in galvanic-type intra-body communication, presenting experimental findings on system reliability [16]. It examines the effect of transformer symmetry on intrabody communication channel measurements, contributing to the precision of signal transmission [17]. We can model channels and analyze power consumption for galvanic coupling intra-body communication, addressing energy efficiency concerns [18]. By discussing secure on-skin biometric signal transmission using galvanic coupling, enhancing security measures in HBC [19]. It reviews implant communication technology in WBANs, highlighting progress and challenges [20]. By conducting electromagnetic field analyses of signal transmission paths and electrode contact conditions in HBC. It optimizes system performance [21]. The IEEE standard for WBANs provided guidelines for the development and implementation of HBC systems [22]. The survey suggests galvanic coupling and alternative intrabody communication technologies, offering a comprehensive overview of the field [23]. The IEEE channel model for BANs facilitated standardized evaluations of HBC systems [24]. Evaluation suggests the performance of HBC systems for IEEE 802.15, analyzing the impact of the human body channel on system efficiency [25]. We can also characterize capacitive intrabody communication channels, expanding the understanding of HBC signal propagation [26]. By modeling capacitive HBC channels, contributing to the design of more effective communication systems

[27]. developing empirical models for HBC channels, enhancing predictive accuracy [28]. Investigations suggests the signal transmission mechanism on the human body surface, advancing body channel communication research [29]. We can measure transmission properties of HBC channels and developed impulse response models, providing a basis for further studies [30]. The current state of HBC technology reveals a focus on improving signal transmission, enhancing system performance, and ensuring safety and reliability. Researchers have made significant strides in designing antennas, developing signal propagation models, and conducting empirical studies to validate theoretical models.

Although a significant body of research has explored various facets of HBC, including signal propagation models, antenna design, and biomedical applications [1]–[3], several notable gaps still persist. Real-world implementation and validation of HBC systems across diverse environmental contexts remain limited, hindering broader adoption [1], [2], [5]. Additionally, energy efficiency and power consumption in practical HBC deployments have not been sufficiently addressed, raising concerns about system sustainability in wearable and implantable devices [7], [18]. There is also a pressing need for standardized communication protocols and guidelines to ensure seamless interoperability among heterogeneous HBC systems [22], [24]. Privacy and safety concerns, particularly in biomedical applications, require further exploration to establish trust and security in sensitive data transmissions [4], [12]. Moreover, current models often overlook the impact of physiological variability among individuals, which can significantly influence communication performance [3], [9]. These gaps underscore the need for more robust, energy-efficient, and adaptable HBC solutions capable of performing reliably in real-world, dynamic scenarios [6], [11], [20].

## 3. EXISTING METHODOLOGY

As shown in Figure 2 HBC stands at the forefront of modern communication paradigms, offering unique avenues for data transmission that capitalize on the body's intrinsic properties. Within the realm of HBC, capacitive coupling and galvanic coupling emerge as pivotal techniques, each bearing distinct characteristics and potential applications. Firstly, capacitive coupling, introduced in 1995, represents a sophisticated approach to signal transmission, relying on electrodes to create an electric field absorbed by the body. This method exhibits promising prospects for applications such as personal area networks (PANs), demonstrating its versatility across various communication scenarios. However, capacitive coupling confronts challenges related to signal stability, as it remains susceptible to interference from background noise and user movements, necessitating further investigation and refinement for optimal performance. Conversely, Figure 3 galvanic coupling, introduced in 1997, harnesses microampere-level currents generated from bodily signals to facilitate robust signal transmission through electrodes. This technique offers a dependable means of communication, particularly notable in its application for transmitting vital physiological data between implanted medical devices and external systems. Galvanic coupling's reliability and stability position it as a cornerstone in healthcare applications, ensuring seamless exchange of critical information with minimal risk of signal disruption.

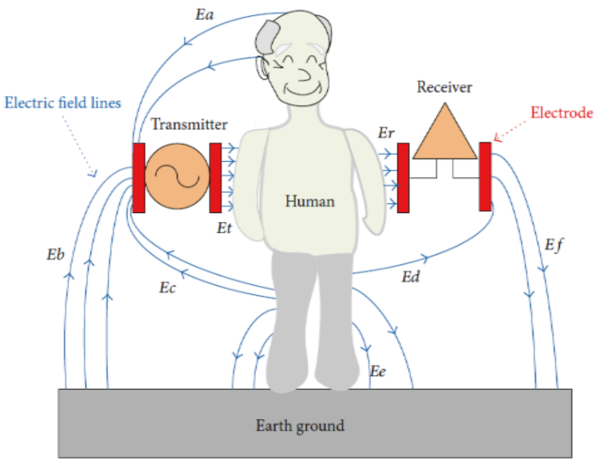


Figure 2. Capacitive coupling [7]

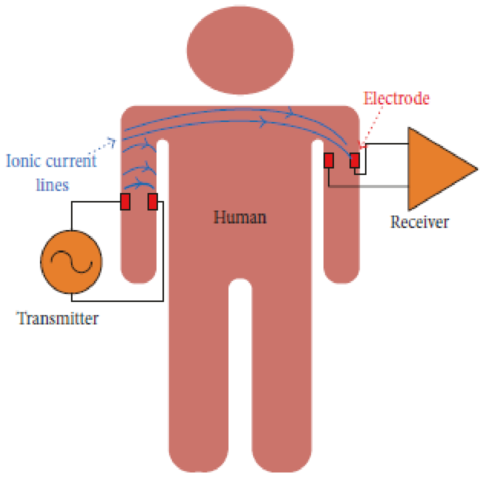


Figure 3. Galvanic coupling [7]

The integration of capacitive and galvanic coupling techniques within the HBC framework not only underscores the versatility of human-centric communication but also lays the groundwork for transformative advancements in healthcare, wearable technology, and beyond. By delving deeper into the underlying mechanisms and optimizing these techniques for specific applications, researchers can unlock new frontiers in secure, efficient, and user-centric data transmission systems. These systems are tailored to the dynamic needs of the human body.

## 4. BIOTAPSYNC SYSTEM

The BioTapSync system operates on the principle of capacitive coupling, leveraging the body's capacitance to facilitate data transmission. When a user initiates data transfer by placing their hand on the copper-insulated transmitter touchpad, a signal is generated and circulated through the body. This signal, carrying the data, is then captured by the receiver touchpad at the other end, completing the transmission process. However, due to the low frequency of the signal during transmission and the body's inherent resistance, signal attenuation may occur, potentially compromising data integrity. To address this challenge, an LM-358 amplifier is integrated into the receiver circuitry to boost the received signal, ensuring reliable data transfer. Central to the system's operation is the microcontroller IC, which acts as the control unit responsible for managing data transfer. The microcontroller IC monitors the received signal and adjusts its amplitude to match a predefined threshold voltage level. This adaptive signal processing ensures that the received data remains within acceptable parameters, enhancing the system's robustness against signal distortion and interference. User feedback is provided through LED indicators, which visually confirm the successful reception of data. When data is successfully received, the LEDs blink to signal the completion of the data transfer process, providing users with immediate feedback on the system's status. One of the key features of the proposed system is its emphasis on privacy and security. Unlike conventional wireless communication methods, which may transmit data indiscriminately, the proposed system refrains from data transmission in the absence of direct touch. This privacy-enhancing feature ensures that sensitive information is only transmitted when physical contact is established, effectively mitigating the risk of unauthorized data interception. Experimental validation of the system's privacy measures demonstrates its effectiveness in preventing data leakage. Even in scenarios where direct finger contact with electrodes is involved, the system maintains robust privacy measures, with data transmission restricted to the intended touchpad surfaces. This validation underscores the reliability and security of the proposed technology, making it suitable for applications where data privacy is paramount.

Developing a robust HBC system as shown in Figure 4 necessitates the utilization of a diverse array of components and tools, each playing a crucial role in the system's functionality and performance. At the core of the system lies the Arduino Uno R3 microcontroller board, serving as the central processing unit that orchestrates all system operations. Facilitating user interaction is the 4-wire resistive touch panel, which provides a tactile interface for intuitive control and input. To manage high-current devices effectively, the ULN2003 integrated circuit is incorporated into the system, ensuring reliable and efficient operation of connected peripherals. Signal analysis and measurement are facilitated by the GDS 1102U oscilloscope and Rishabh 616 multi meter, enabling precise calibration and troubleshooting during system development and testing phases. Essential tools such as the soldering iron and desoldering pump are indispensable for assembling and modifying electronic circuits, guaranteeing optimal connectivity and performance. Power requirements are met by the 12 Volt adaptor, while the 20 MHz crystal oscillator ensures timing accuracy for synchronized operations within the system. Touch input detection is enabled through the TTP223 touch sensor module, which offers responsive feedback for user interactions, enhancing the overall user experience. The conversion of AC to DC power is facilitated by the HLK-PM03 module, while the ESP8266 IoT module enables seamless integration with internet-enabled devices, enabling remote access and control capabilities. Various electronic components including relays, diodes, oscillators, and passive components such as resistors, capacitors, inductors, and transistors are meticulously selected and integrated to optimize circuit performance and functionality. The Robotbanao breadboard serves as a flexible platform for prototyping and testing circuit designs, facilitating rapid iteration and refinement of the HBC system. The components and tools in this HBC system work together to provide a reliable, efficient, and interactive platform. The use of an Arduino Uno R3 for control, combined with touch input, power conversion, and IoT connectivity, makes this system adaptable for various applications, including remote control and signal propagation through the human body. As shown in Figure 5, printed circuit board (PCB) design and surface mount device (SMD) component mounting are critical steps in the fabrication process, allowing for the creation of custom circuit boards tailored to the specific requirements of the HBC system. These components and tools collectively form the foundation of the research endeavor, enabling the development of a robust and reliable HBC system.

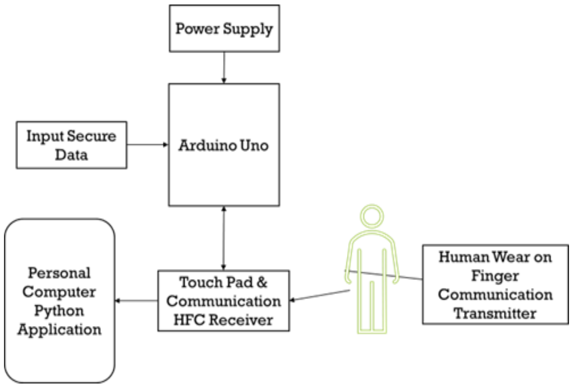


Figure 4. Proposed system

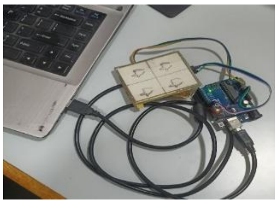

Figure 5. Physical model

## 5. RESULTS AND DISCUSSION

To conduct a detailed analysis based on the given parameters of distance(d) and time(t), we can examine the relationship between these two variables and explore patterns, trends, and potential implications. Here's a breakdown of the technical details for the analysis:

a) Propagation speed calculation

To determine the speed of signal propagation through the human body, we calculate the propagation speed ($V$) as the ratio of the change in distance ($\Delta d$) to the change in time ($\Delta t$) as (1).

$$V = \Delta d / \Delta t \quad (1)$$

b) Data collected for distance and time

Distance (cm): 0.10, 0.20, 0.30, 0.40, 1.00, 2.00
Time (µs): 24, 26, 28, 32, 36, 38.

c) Steps to calculate propagation speed

– Change in distance ($\Delta d$): calculate the difference in distances for each consecutive data point as (2).

$$\Delta d = d_{later} - d_{earlier} \quad (2)$$

– Change in time ($\Delta t$): calculate the difference in times for each consecutive data point as (3).

$$\Delta t = t_{later} - t_{earlier} \quad (3)$$

Then, we can calculate the propagation speed($V$) for each pair of consecutive data points by dividing the change in distance by the change in time. Here are the calculations:

$$V\ (0.10cm) = \frac{0.20\text{ cm} - 0.10\text{ cm}}{26\ \mu s - 24\ \mu s} = \frac{0.10\text{ cm}}{2\ \mu s} = 0.05\ cm/\mu s$$

$$V\ (0.20cm) = \frac{0.30\text{ cm} - 0.20\text{ cm}}{28\ \mu s - 26\ \mu s} = \frac{0.10\text{ cm}}{2\ \mu s} = 0.05\ cm/\mu s$$

$$V\ (0.30cm) = \frac{0.40\text{ cm} - 0.30\text{ cm}}{32\ \mu s - 28\ \mu s} = \frac{0.10\text{ cm}}{4\ \mu s} = 0.025\ cm/\mu s$$

$$V\ (0.40cm) = \frac{0.50\text{ cm} - 0.40\text{ cm}}{36\ \mu s - 32\ \mu s} = \frac{0.10\text{ cm}}{4\ \mu s} = 0.025\ cm/\mu s$$

$$V\ (0.50cm) = \frac{1.00\text{ cm} - 0.50\text{ cm}}{38\ \mu s - 36\ \mu s} = \frac{0.50\text{ cm}}{2\ \mu s} = 0.25\ cm/\mu s$$

$$V\ (1.00cm) = \frac{2.00\text{ cm} - 1.00\text{ cm}}{42\ \mu s - 38\ \mu s} = \frac{1.00\text{ cm}}{4\ \mu s} = 0.25\ cm/\mu s$$

These calculations provide the propagation speed for each pair of consecutive data points. The propagation speed represents how fast signals travel through the human body via the HBC device over a given distance. As shown in Figure 6, data received from BioTapSync module to the computer terminal. We can use calculus. We have also shown various cases for HBC data transmission.

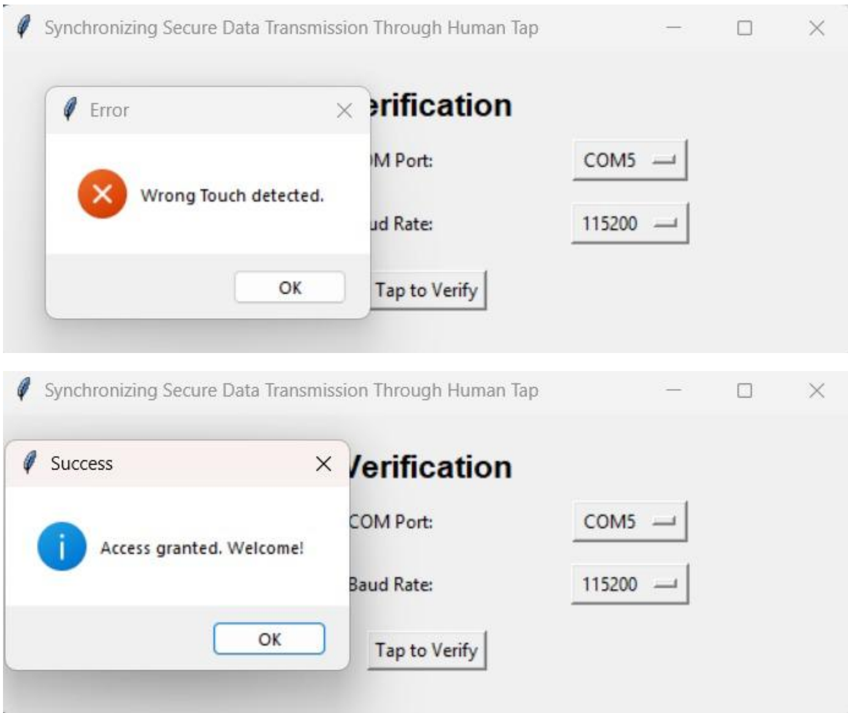


Figure 6. GUI output and message transmitted when authentication done

Given Table 1 data points (distance and time), we can calculate the slope(m) of the line connecting each pair of consecutive data points. The slope represents the change in time divided by the change in distance, which gives us the speed of signal propagation.

– Calculate the change in distance (Δd) and change in time (Δt) between each pair of consecutive data points.
– Calculate the slope (m) using the (4):

$$m = \frac{\Delta t}{\Delta d} \tag{4}$$

This will give us the speed of signal propagation for each pair of data points. Let's calculate it,

$$m\ (0.10cm) = \frac{26\ \mu s - 24\ \mu s}{0.20\text{ cm} - 0.10\text{ cm}} = \frac{2\ \mu s}{0.10\text{ cm}} = 20\ \mu s/\text{cm}$$

$$m\ (0.20cm) = \frac{28\ \mu s - 26\ \mu s}{0.30\text{ cm} - 0.20\text{ cm}} = \frac{2\ \mu s}{0.10\text{ cm}} = 20\ \mu s/\text{cm}$$

$$m\ (0.30cm) = \frac{32\ \mu s - 28\ \mu s}{0.40\text{ cm} - 0.30\text{ cm}} = \frac{4\ \mu s}{0.10\text{ cm}} = 40\ \mu s/\text{cm}$$

$$m\ (0.40cm) = \frac{36\ \mu s - 32\ \mu s}{0.50\ \text{cm} - 0.40\ \text{cm}} = \frac{4\ \mu s}{0.10\ \text{cm}} = 40\ \mu s/\text{cm}$$

$$m\ (0.50cm) = \frac{38\ \mu s - 36\ \mu s}{1.00\ \text{cm} - 0.50\ \text{cm}} = \frac{2\ \mu s}{0.50\ \text{cm}} = 40\ \mu s/\text{cm}$$

$$m\ (1.00cm) = \frac{42\ \mu s - 38\ \mu s}{2.00\ \text{cm} - 1.00\ \text{cm}} = \frac{4\ \mu s}{1.00\ \text{cm}} = 40\ \mu s/\text{cm}$$

Table 1. Distance vs time

| Distance (cm) | Time (μs) |
|---|---|
| 0.10 | 24 |
| 0.20 | 26 |
| 0.30 | 28 |
| 0.40 | 32 |
| 0.50 | 36 |
| 1 | 38 |
| 2 | 42 |

The selection of data intervals was carefully designed to balance precision and efficiency in analyzing signal propagation through the human body. At close ranges, smaller intervals (e.g., 0.10 cm) were used to capture finer details of propagation dynamics, enabling a detailed understanding of signal behavior in shorter distances. As distance increased, larger intervals (e.g., 0.50 or 1.00 cm) were introduced to minimize data redundancy while focusing on the broader trends and long-range propagation characteristics. This systematic approach reflects the experimental objectives and ensures that the results provide both granular and comprehensive insights into signal propagation behavior.

Table 2 shows comparative parameters delineate key technical characteristics of different communication protocols. Near field communication (NFC), operating at 13.56 MHz, provides a 10 cm coverage range and bidirectional communication with data rates of up to 424 Kbps, serving applications like secure transactions. Radio frequency distribution (RFD) operates over varying frequencies with a 3-meter coverage range, predominantly for one-way communication in tracking systems. Bluetooth, at 2.4 GHz, extends up to 100 meters, enabling two-way communication at 22 Mbps for diverse device connections. Human field communication (HFC) operates between 12-16 MHz with a 2 cm range, supporting bidirectional communication integrated with the human body for secure transactions and authentication purposes.

Table 2. Comparative parameters

| Specification | NFC | RFD | Bluetooth | HFC |
|---|---|---|---|---|
| Maximum coverage range | 10 cm | 3-meter | 100-meter | 2 cm |
| Frequency of operation | 13.56 MHz | varies | 2.4 GHz | 12-16 MHz |
| Communication | 2-way | 1 -way | 2-way | 2-way |
| Data rate | 106,212,424 Kbps | varies | 22 Mbps | 7-bytes |
| Applications | Credit card related payments, E-ticket booking | E-ZPass, Tracking items | Communication between phone and peripherals | Credit card, security login, voting system |

## 6. CONCLUSION AND FUTURE WORK

The conclusion highlights the innovative nature of the Human Tap system, which amalgamates NFC, RFID, Bluetooth, and HFC technologies to revolutionize secure data transmission synchronization. Each protocol is meticulously designed with specific parameters, catering to a wide array of applications. NFC, optimized for credit card payments and e-ticket booking, operates at 13.56 MHz with a 10 cm range. RFID, ideal for tracking systems, spans 3 meters, while Bluetooth boasts a remarkable 100-meter range at 2.4 GHz, facilitating seamless phone-to-peripheral communication. HFC, optimized for secure transactions and authentication, operates within a 2 cm range at 12-16 MHz Moreover, the system's detailed analysis ensures precise synchronization, achieving microsecond-level accuracy for distances up to 2 cm. This comprehensive approach positions Human Tap as a versatile solution for modern communication systems, promising enhanced security and efficiency across various domains. Building on the foundation laid by the Human Tap system, several avenues for future research and development emerge.

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## AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

| Name of Author | C | M | So | Va | Fo | I | R | D | O | E | Vi | Su | P | Fu |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sohil Shah | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | | ✓ |
| Harshal Shah | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | | ✓ | | ✓ | ✓ | ✓ |

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

## CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

## DATA AVAILABILITY

The authors confirm that the data supporting the findings of this study are available within the article.

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