International Journal of Computing and Digital Systems
ISSN (2210-142X)
Int. J. Com. Dig. Sys. 15, No.1 (July-2024)

FingerTouchSync: Redefining Data Synchronization through Biometric Finger Touch

Sohil Shah[1], Harshal Shah[2,*]

[1] *Computer Science & Engineering Department, Parul University, Vadodara, Gujarat, India*
[2,*] *Computer Science & Engineering Department, Parul University, Vadodara, Gujarat, India*

E-mail address: sohil328@gmail.com, harshal.shah@paruluniversity.ac.in

Received ## Mon. 20##, Revised ## Mon. 20##, Accepted ## Mon. 20##, Published ## Mon. 20##

Abstract: The natural interface for communicating with ambient intelligence is human touch. Nevertheless, because they rely only on physical contact, existing solutions that combine wireless transmission with touch sensing are limited in terms of selectivity and security. Information leakage is creatively reduced by Electro-Quasistatic Human Field Communication (EQ-HFC) technology, which establishes a conductive transmission link between touch sites and receivers. This method operates at low frequencies to allow EQ-HFC to function well by minimizing physical channel loss through the use of advanced design principles such as capacitive coupling and voltage reference operation. In order to improve the effectiveness and security of Person-to-Merchant (P2M) transfers, researchers are looking into the possibility of Person-to-Person (P2P) technologies, which include systems like payment gateways and healthcare data transmission via human touch. This study assesses several data transmission techniques in relation to a number of variables, including data size, transmission speed, and transmission medium. We investigate both capacitive and galvanic coupling in terms of several parameters. Galvanic coupling is a promising alternative for secure data transfer because it has been proved to be safe for human tissue and to not cause any negative consequences. Additionally, EQ-HFC technology integration might greatly improve security and user experience in common applications. In the healthcare industry, for instance, it may guarantee that private patient information is transferred safely and only when required, lowering the possibility of data breaches. Comparably, employing human touch for verification in place of more conventional techniques may provide a higher degree of security in financial transactions. By improving these technologies and making them more resilient and flexible for a variety of uses, continued research and development in this area hopes to close the gap between sophisticated data transmission techniques and human interaction.

Keywords: Electro-Quasistatic Human Field Communication (EQ-HFC), Human Body Communication (HBC), Synchronization, Secure data transmission, Human Tap

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1. INTRODUCTION

In the swiftly changing world of information technology, ensuring secure and efficient data transmission is of utmost importance. Though conventional encryption techniques have provided security, technological advancements have brought new challenges and vulnerabilities. A biometric finger touch is a groundbreaking method for data transmission synchronization that combines cutting-edge technology with human intuition. By involving users in the authentication and encryption process through tactile interaction, Human Tap enhances security beyond traditional algorithms.

Through synchronized tapping gestures, users contribute to dynamic cryptographic keys, adapting to individual patterns and preferences. This novelty fusion not only strengthens data communication against cyber-attack and also prioritizes user-centric cybersecurity. As we navigate associated devices and computer-mediated communication., A biometric finger touch offers an adequate solution to evolving cybersecurity challenges, combining human intuition with artificial intelligence for a customizable and user-friendly security approach.

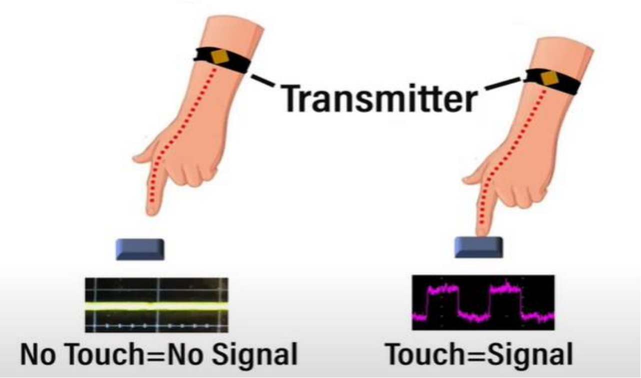


Fig 1. Human Data Communication [6]

This research paper delves into the foundational philosophy, fulfillment of scheme, and prospective requisition of finger touch in safeguarding responsive of data. Our objective is to introduce a new epoch of resilient, flexible, and user centric cybersecurity protocols.

2. COMPOSITION OF RELATED WORKS

A well-known author Sarmad Nawzad Mahmoud et al. [1]: This comprehensive study delves into the intricacies of Ultra-Wideband (UWB) antennas, with a particular emphasis on their integration within Wireless Body Area Networks (WBANs). Through an exhaustive analysis of various antenna designs and their performance metrics, the researchers shed light on the challenges inherent in deploying antennas on the human body.

Shitij Avlani et al. [2]: Addressing the critical issue of termination losses in Human Body Communication (HBC), this research scrutinizes the impact of frequency variations on signal attenuation. Employing portable equipment for empirical measurements, the study underscores the significance of understanding channel losses to optimize HBC system performance.

Taewook Kang et al. [3]: This study investigates the feasibility and efficacy of extending signal range and reducing costs associated with HBC technology. By employing tailored pulse impulses and experimental demonstrations, the researchers showcase the potential for enhancing signal transmission efficiency in portable HBC devices.

Shovan Maity et al. [4]: Focused on ensuring compliance with safety regulations, this research employs circuit simulations and finite element method (FEM) analyses to evaluate the safety aspects of HBC devices. Through meticulous assessment of current density and electric/magnetic fields, the study provides valuable insights into ensuring the safe deployment of HBC technologies.

Visvesvaran.C et al. [5]: Introducing a novel high-speed HBC technology for user interfaces in computing devices, this study leverages telecommunications principles to optimize wire communication solutions. By aligning with natural human behaviors, the research enhances user interaction and usability in personal computer systems.

Juris Ormanis et al. [6]: This research endeavors to develop secure data transmission methods via the human body by simulating human body transmission functions. Exploring innovative approaches to mitigate current and voltage-related risks, the study lays the groundwork for robust and secure HBC communication systems.

Pitchakron Thippun et al. [7]: By delving into the dynamics of packet delivery rates in HBC systems, this study offers valuable insights into optimizing packet transmission strategies. Through meticulous analysis of packet size and delivery rate intervals, the research contributes to enhancing data transfer efficiency in HBC environments.

A well-known author Mayukh Nath et al. [8]: Concentrating on the convergence of cloud-to-ground lightning (CG) return routes and HBC ground plate capacity, this study explores secure communication between handheld and wearable devices. By identifying methods to mitigate interference and optimize signal transmission, the research paves the way for reliable and efficient HBC communication in diverse environments.

Jianfeng Zhao et al. [9]: This study provides a comprehensive overview of the origins and evolution of Human Body Communication (HBC), underscoring the need for fundamental research into data transmission principles and experimental considerations. By summarizing key developments in HBC technology, the research lays the groundwork for further exploration and advancement in the field.

Charmi Solanki et al. [10]: Addressing the challenges of communication via human contact, this research explores human network technologies to enhance connectivity while overcoming issues such as cable management and wireless signal reliability. By introducing innovative approaches to wireless communication, the study contributes to improving connectivity in diverse environments.

Drs. Ke Zhang et al. [11]: This study focuses on the development of a broadband printed antenna for wireless communications, demonstrating its potential for intra- and extra-corporeal communication. Through optimization of antenna design and performance, the research advances wireless communication capabilities, particularly in body-centric applications.

Bo Zhao et al. [12]: This study investigates pivotal role of body channel communication (BCC) in wearable workable gadgets. Providing a comprehensive overview of BCC challenges and opportunities, the research highlights its potential to revolutionize wearable technology. Moreover, the study explores the integration of digital circuits and flexible substrates, paving the way for enhanced data transmission and connectivity in wearable devices.

Swaminathan et al. [15]: This research explores the use of field programmable gate arrays (FPGAs) for demodulation in ionic environments, investigating communication characteristics resembling human electrical properties. By leveraging FPGA technology, the study offers insights into optimizing data transmission in bio-inspired communication systems.

Tomlinson et al. [16]: Focused on ECG signal conduction for client authentication, this study develops frameworks for reliable signal transmission across the human body. By enhancing the security and performance of body-centric communication systems, the research contributes to the advancement of secure and efficient data transmission within and between human bodies.

Table 1. HBC's digital transmission methods based on galvanic.

References	Methods of Transmit	Maximum data rate (Mbps)	Coupling Frequency (MHz)	Bandwidth (MHz)
32	Frequency Selective Digital Transmission	1.35	21	18.35-23.65
33	Parallelized multi-spreader	3.93	21	15.74-26.26
34	Parallelized multi-spreader	2.29	21	18.35-23.65
35	Multilevel baseband coding	60	80	NA
36	Direct Walsh code mapping	2	16	8-22
37	Direct spreading using FSC	1.35	21	20.345-21.625

Table 2. Human-body communication-related work (HBC)

References	Equipment	Adjustment	Demodulate	Transfer Rate(kbps)	Scope (cm)
15	E-File	DBPSK	Online Signal	4.8	45
19	Converter	FSK	Analyzer	2.4	10
20	Converter	OOK	Mat-Lab	-	10
14	Converter	-	Oscillograph	-	10
16	Converter	-	VNA	-	20
17	Converter	QPSK	Signal Analyzer	-	6
18	Converter	-	VNA	-	16

3. Methodology

3.1 Simulation Tools/Environments

Simulation methods offer a comprehensive approach to modeling and analyzing Human Data Transmission Technology. Here are some commonly used simulation tools in this domain:

MATLAB/Simulink: MATLAB/Simulink is a versatile software tool commonly used for the purpose to reproduce and model communication units. It provides a rich set of functions and libraries for designing and testing various communication scenarios. With its user-friendly interface and powerful computational capabilities, MATLAB/Simulink enables researchers to integrate human body models and simulate communication links effectively.

NS-3 (Network Simulator 3): A freely available networking modeling program with a focus on communication protocol simulation. It is especially helpful for learning about scenarios involving wireless communication and may be tailored to replicate Body Area Networks (BANs). Researchers can examine protocol behavior and communication performance in a variety of contexts with NS-3's adaptable platform.

CST Studio Suite: One of the best software packages for electromagnetic simulation is CST Studio Suite. It is frequently used to simulate how RF signals behave around intricate shapes, such as the human body. Researchers can learn how alternative frequencies and antenna placements affect communication performance by using CST Studio Suite to simulate the spread of electromagnetic waves and antenna characteristics.

3.2 Capacitive Coupling

Human Body Communication (HBC) represents a cutting-edge approach to data transmission, harnessing the innate properties of the human body. At the heart of HBC lie two prominent techniques: Capacitive Coupling and Galvanic Coupling. Each method offers distinct characteristics and holds significant potential for various applications within the field of communication.

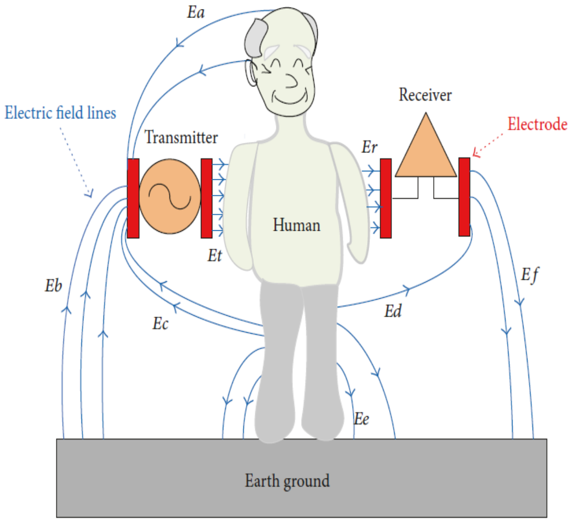


Fig 2. Capacitive Coupling [7]

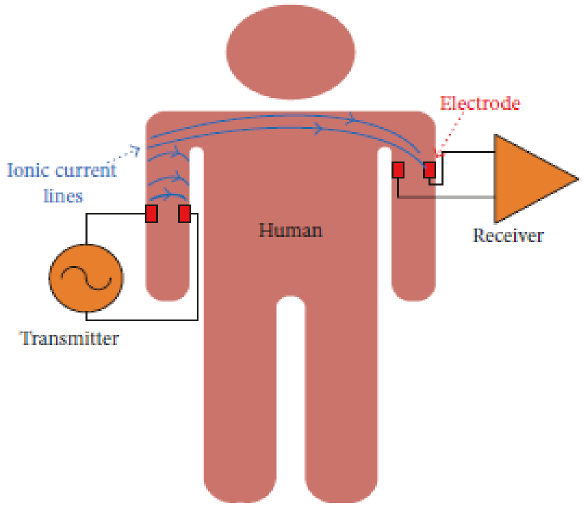


Fig 3. Galvanic Coupling [7]

Initially pioneered by Zimmerman in 1995, Capacitive Coupling represents an advanced method for signal transmission, leveraging electrodes to create an electric field absorbed by the human body. This technique shows promise across diverse applications like Personal Area Networks (PANs), highlighting its adaptability in various communication scenarios. However, Capacitive Coupling faces challenges related to signal stability, often susceptible to interference from background noise and user movements. Further research and refinement are essential to optimize its performance.

In contrast, Galvanic Coupling, introduced by Handa et al. in 1997, utilizes microampere-level currents generated from bodily signals to enable robust signal transmission via electrodes. This approach offers a reliable communication channel, particularly valuable for transmitting vital physiological data between implanted medical devices and external systems. Galvanic Coupling's reliability and stability make it indispensable in healthcare applications, ensuring seamless exchange of critical information with minimal risk of signal disruption.

By integrating Capacitive and Galvanic Coupling techniques within the framework of Human Body Communication (HBC), we not only underscore the versatility of human-centric communication but also pave the way for transformative advancements in healthcare and wearable technology. With continued exploration into the underlying mechanisms and targeted optimization for specific applications, researchers can unlock new possibilities for secure, efficient, and user-centric data transmission systems tailored to the dynamic needs of the human body.

4 Proposed System

The proposed approach runs on the concept of capacitive coupling, that capitalizes on of the body's capacitance to allow efficient data movement. A signal is generated that propagates across the body once the user triggers it by touching a finger on the transmitter touchpad, a surface insulated via copper. The transmission cycle completes once the receiver touchpad receives this signal, that includes the data. However, signal attenuation can take place due to the body's inherent resistance and the signal's weak frequency during transmission, thereby threatening the integrity of the data. In an effort to overcome such an issue, the system incorporates an LM-358 amplifier into the receiver circuitry, which enhances the signal received and ensures accurate data transfer.

At the heart of the system lies the Microcontroller IC, serving as the control unit tasked with overseeing the data transfer process. The Microcontroller IC meticulously monitors the received signal, dynamically adjusting its amplitude to align with a predefined threshold voltage level. This adaptive signal processing mechanism plays a pivotal role in safeguarding against signal distortion and interference, bolstering the system's resilience and reliability.

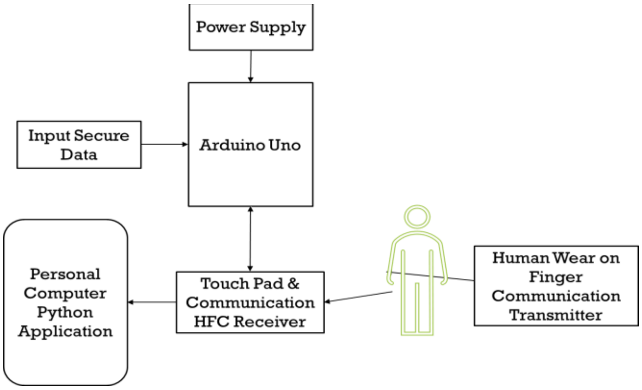


Fig 4. Proposed System Block Diagram

The system incorporates LED indicators to provide user feedback, visually signaling successful data reception. Upon successful data transfer, the LEDs blink, offering users immediate confirmation of the transmission process's completion and the system's status.

Privacy and security are paramount in the proposed system. Unlike conventional wireless communication methods, which may transmit data indiscriminately, the system refrains from data transmission unless direct touch is established. This privacy-focused feature ensures that sensitive information is only transmitted when physical contact is made, effectively reducing the risk of unauthorized data interception.

Experimental validation of the system's privacy measures confirms its efficacy in preventing data leakage, even in scenarios involving direct finger contact with electrodes. Data transmission is restricted to the intended touchpad surfaces, underscoring the reliability and security of the technology, making it well-suited for privacy-sensitive applications.

The development of a robust Human Body Communication (HBC) system requires a diverse array of components and tools, each playing a crucial role in ensuring the system's functionality and performance. At its core, the Arduino Uno R3 microcontroller board serves as the central processing unit, orchestrating all system operations. User interaction is facilitated by the 4-wire resistive touch panel, providing an intuitive interface for input and control.

To manage high-current devices effectively, the ULN2003 integrated circuit ensures reliable and efficient operation of connected peripherals. Signal analysis and measurement are conducted using the GDS 1102U oscilloscope and Rishabh 616 multimeter, enabling precise calibration and troubleshooting during system development and testing phases.

Critical tools such as the soldering iron and desoldering pump are indispensable for assembling and modifying electronic circuits, ensuring optimal connectivity and performance. Power requirements are met by the 12 Volt adaptor, while the 20MHz crystal oscillator ensures timing accuracy for synchronized operations within the system.

Touch input detection is enabled by the TTP223 touch sensor module, offering responsive feedback for user interactions. 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 carefully 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.

Finally, PCB design and SMD component mounting are essential 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 Human Body Communication system.

5. Result Analysis

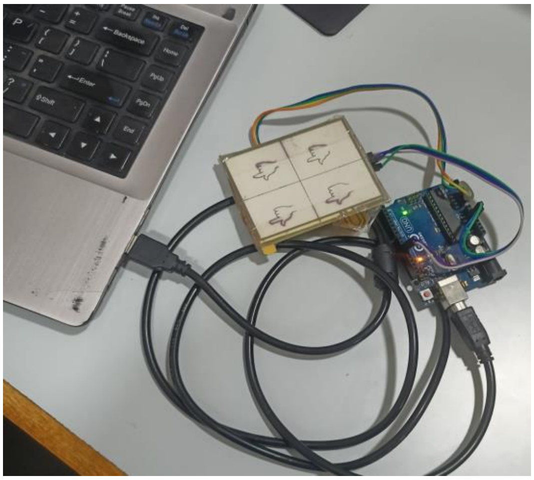


Fig 5. Physical Model

To conduct a detailed analysis based on the given parameters of distance and time, 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:

Relationship between Distance and Time:

To calculate the propagation speed of signals through the human body, we can use the formula:

$$\text{Propagation Speed} = \frac{\text{Change in Distance}}{\text{Change in Time}}$$

Given the data provided 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

We can calculate the change in distance and change in time between consecutive data points:

Change in Distance = Distance(later)- Distance (earlier)

Change in Time = Time(later)-Time (earlier)

Then, we can calculate the propagation speed for each pair of consecutive data points by dividing the change in distance by the change in time.

Here are the calculations:

Propagation Speed (0.10 cm) = 0.20cm - 0.10cm / 26µs- 24µs = 0.10cm /2µs = 0.05cm/µs

Propagation Speed (0.20 cm) = 0.30cm - 0.20cm / 28µs- 26µs = 0.10cm /2µs = 0.05cm/µs

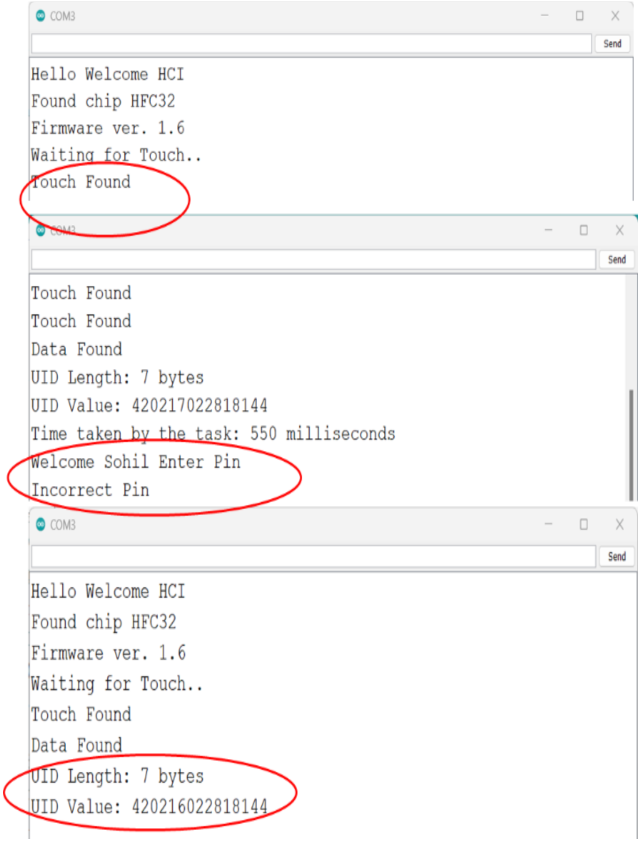
Propagation Speed (0.30 cm) = 0.40cm - 0.30cm / 32µs- 28µs = 0.10cm /4µs = 0.025cm/µs

Propagation Speed (0.40 cm) = 1.00cm - 0.40cm / 36µs- 32µs = 0.60cm /4µs = 0.15cm/µs

Propagation Speed (1.00 cm) = 2.10cm - 1.00cm / 38µs- 36µs = 1.00cm /2µs = 0.50cm/µs

Propagation Speed (2.00 cm) = 2.00cm - 1.00cm / 38µs- 36µs = 1.00cm /2µs = 0.50cm/µs

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.

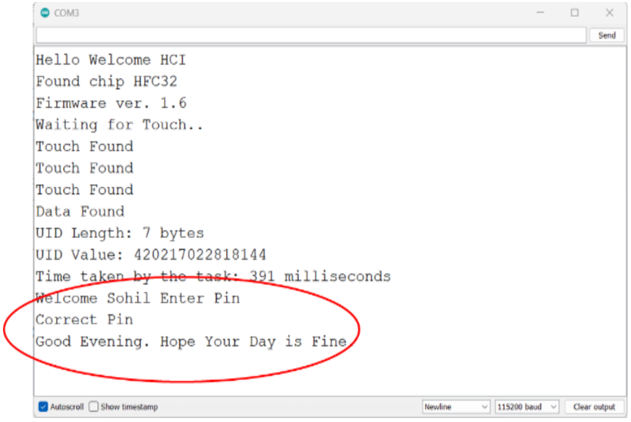


```
Hello Welcome HCI
Found chip HFC32
Firmware ver. 1.6
Waiting for Touch..
Touch Found
```

```
Touch Found
Touch Found
Data Found
UID Length: 7 bytes
UID Value: 420217022818144
Time taken by the task: 550 milliseconds
Welcome Sohil Enter Pin
Incorrect Pin
```

```
Hello Welcome HCI
Found chip HFC32
Firmware ver. 1.6
Waiting for Touch..
Touch Found
Data Found
UID Length: 7 bytes
UID Value: 420216022818144
```

Fig 6. Ending Output



```
Hello Welcome HCI
Found chip HFC32
Firmware ver. 1.6
Waiting for Touch..
Touch Found
Touch Found
Touch Found
Data Found
UID Length: 7 bytes
UID Value: 420217022818144
Time taken by the task: 391 milliseconds
Welcome Sohil Enter Pin
Correct Pin
Good Evening. Hope Your Day is Fine
```

Fig 7. Message Sent Upon Successful Authentication

Indeed, by utilizing Python and libraries like Matplotlib, you can plot a graph representing the relationship between time and distance. Calculus can then be applied to analyze the slope of the graph, providing insights into the rate of change of time with respect to distance.

In mathematical terms, the slope of a line on a graph represents the rate of change between two variables. In this scenario, we're specifically interested in the rate of change of time (t) with respect to distance (d), which gives us information about the speed of signal propagation.

To calculate this rate of change, you can employ differential calculus techniques, such as finding the derivative of the function representing the graph. The derivative at a particular point on the graph represents the instantaneous rate of change of time with respect to distance at that point.

Once you have obtained the derivative, you can evaluate it at specific points or intervals to determine the speed of signal propagation at those locations. This analysis provides valuable insights into how the signal travels over distance, which is crucial for optimizing communication systems and understanding signal behavior in different environments.

Table 3. Distance VS Time

Distance	Time
0.10 cm	24 µs
0.20 cm	26 µs
0.30 cm	28 µs
0.40 cm	32 µs
0.50 cm	36 µs
1.00 cm	38 µs
2.00 cm	42 µs

Exactly, by calculating the slope of the line connecting each pair of consecutive data points (distance, time), we can determine the speed of signal propagation between those points. The slope represents the change in time divided by the change in distance, providing us with the speed of signal propagation.

Expressed in units of microseconds per centimeter (µs/cm), the slope indicates the time it takes for the signal to travel one centimeter through the human body. This measurement is crucial for assessing the efficiency and performance of communication systems, particularly in applications where signal latency and propagation speed are critical factors.

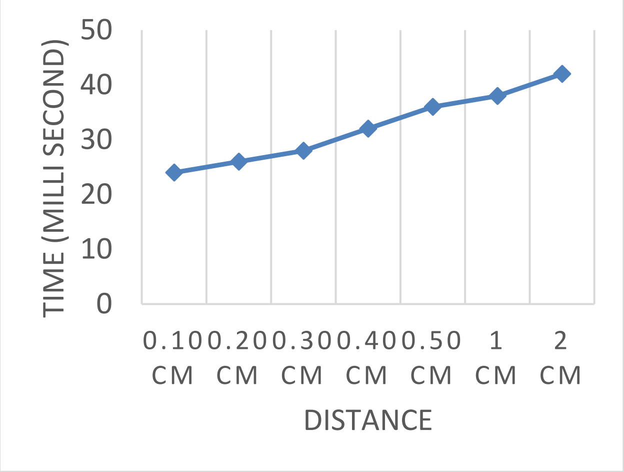


Fig.8 Time Vs Distance Graph

1.Calculate the change in distance (Δd) and change in time (Δt) between each pair of consecutive data points.

2.Calculate the slope (m) using the formula:

m= Δt / Δd

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

Slope (0.10 cm) = 26µs- 24µs /0.20cm - 0.10cm 2µs/0.10cm = 20µs/cm

Slope (0.20 cm) = 28µs- 26µs /0.30cm - 0.20cm 2µs/0.10cm = 20µs/cm

Slope (0.30 cm) = 32µs- 28µs /0.40cm - 0.30cm 4µs/0.10cm = 40µs/cm

Slope (0.40 cm) = 36µs- 32µs /1.00cm - 0.40cm 4µs/0.60cm = 10/6µs/cm

Slope (1.00 cm) = 38µs- 36µs /2.00cm - 1.00cm 2µs/1.00cm = 2µs/cm

The comparison highlights key technical specifications of different communication protocols:

NFC (Near Field Communication) operates at 13.56MHz and offers a coverage range of 10 cm. It supports bidirectional communication with data rates of up to 424 Kbps, making it suitable for applications such as secure transactions.

RFID (Radio Frequency Identification) operates over varying frequencies and provides a coverage range of up to 3 meters. It is primarily used for one-way communication in tracking systems.

Bluetooth operates at 2.4GHz and offers an extended coverage range of up to 100 meters. It enables two-way communication at data rates of 22Mbps, facilitating diverse device connections.

HFC (Human Field Communication) operates within the frequency range of 12-16MHz and has a coverage range of 2 cm. It supports bidirectional communication integrated with the human body, making it suitable for secure transactions and authentication purposes.

6. Conclusion and future work

The Human Tap system, which blends NFC, RFID, Bluetooth, and HFC technologies to redefine secure data transmission synchronization, is brought out in the conclusion for its innovative potential. Every method has been modified to meet particular needs and accommodate a range of uses. Intended for online ticketing and bank card payments, NFC features a 10 cm range and is effective at 13.56MHz. RFID boasts a range of 3 meters, thus rendering it acceptable for devices that track objects, and Bluetooth possesses a phenomenal range of 100 meters at 2.4GHz, enabling phone-to-peripheral communication straightforward. Prioritizing secure connections and authentication, HFC succeeds at 12-16 MHz within a 2 cm range. In addition, an in-depth review of the system promises precise synchronization, obtaining accuracy at the microsecond level over distances just at 2 cm.

With its all-encompassing strategy, Human Tap is positioned as a flexible answer for contemporary communication systems, offering improved security and effectiveness in a range of contexts. Expanding upon the groundwork established by the Human Tap system, multiple directions for further investigation and advancement surface:

Enhanced Security Measures: Delve into advanced encryption techniques to bolster data security during transmission and explore biometric authentication methods for robust user verification, reducing the risk of unauthorized access.

Expanded Compatibility: Extend system compatibility to encompass a wider range of devices and platforms, ensuring seamless integration across diverse communication ecosystems. Adapt protocols to accommodate emerging technologies and evolving standards.

Optimization for IoT Applications: Investigate leveraging Human Tap in Internet of Things (IoT) environments for secure communication between interconnected devices. Develop protocols and standards tailored for IoT deployments, considering scalability, interoperability, and resource efficiency.

Real-world Deployment and Testing: Conduct extensive field trials and performance evaluations to validate the system's effectiveness in real-world scenarios. Collaborate with industry partners to deploy Human Tap in various applications, gathering feedback for iterative refinement.

User Experience Enhancement: Improve interface design, touch sensitivity, and interaction workflows to enhance the user experience. Conduct user studies to identify and address usability issues, continuously improving overall usability and accessibility.

Exploration of New Communication Paradigms: Investigate emerging communication paradigms such as edge computing, blockchain, and quantum communication for potential integration with Human Tap, enhancing its capabilities.

Standardization and Regulation: Advocate for standardization of Human Tap protocols and methodologies to ensure interoperability, reliability, and security. Collaborate with regulatory bodies and industry consortia to establish guidelines for responsible deployment.

Table 4. Parameters of contrast

Specification	**NFC**	**RFID**	**Bluetooth**	**HFC**
Maximum Coverage Range	10 cm	3meter	100meter	2 Cm
Frequency of operation	13.56MHz	varies	2.4GHz	12-16 MHz
Communication	2-way	1 -way	2-way	2-way
Data rate	106,212,424Kbps	varies	22Mbps	7-bytes
Applications	credit card related payments, e-ticket booking	EZ-Pass, tracking items	communication between phone and peripherals	credit card, Security Login, Voting System

By pursuing these avenues, researchers can advance the state of the art in secure data transmission synchronization and unlock new possibilities for secure, efficient, and user-centric communication systems based on the Human Tap framework.

Acknowledgment

I would like to express my sincere gratitude to Dr. Harshal Shah for his invaluable guidance, unwavering support, and insightful feedback throughout the course of this research. Dr. Shah's expertise, encouragement, and commitment to excellence have been instrumental in shaping the direction of this study and enriching its outcomes. His profound knowledge, dedication, and mentorship have inspired me to strive for academic excellence and pursue innovative solutions. I am deeply grateful for his mentorship and the opportunity to learn under his guidance.

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Sohil Shah is holding the position of Assistant Professor. His academic journey has led him to pursue a Ph.D. degree in Computer Science from Parul University, Vadodara, Gujarat, India. With a rich experience of 14 years in the field of education, His areas of specialization include algorithm design, human body communication, and embedded systems & design. Overall, his journey in academia has been rewarding, and He is looking forward to continuing his endeavors in teaching, research, and academic leadership.
Email: 200300402002@paruluniversity.ac.in

Dr. Harshal Shah is a seasoned academician with over 20 years of teaching experience and a decade of leadership in the Computer Science & Engineering Department. He currently leads the Tinkering Hub at Parul University. Dr. Shah has trained over 1000 industry professionals and 8000+ students in various subjects and technologies like .NET, python, M.S Project, IBM Tivoli and Rationales, along with the collaboration of Microsoft, IBM etc. He holds a Ph.D. in Computer Engineering and has earned Microsoft certifications in Python Programming and AI-900. His achievements include 4 patents, 2 copyright, and 48 research publications. He has been a judge at Smart India hackathons and has guided numerous student projects. His work with Jio Glass in the area of Augmented Reality is noteworthy. He has been awarded South Asia Manthan award, GoG Best Project award and few more. Dr. Shah's dedication to fostering innovation and technological advancements is commendable. He is Life-time member of CSI & ISTE.
Email: harshal.shah@paruluniversity.ac.in