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Cloud-Based Real-Time Chat Application for Scalable and Secure Communication

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Abstract: Traditional chat applications continue to suffer from high latency, poor scalability, and limited This system will allow the message to be delivered instantly and synchronized in real-time while allowing users to connect and connect dynamically and securely exchange messaging data. Experimental results show that our system reduces message delivery delay by 65% and increases scalability by allowing more concurrent connections without slowing down system performance. security as they are based on HTTP polling architectures with relational databases and monolithic structures. In this paper, we propose a new cloud-based real-time chat methodology that uses distributed storage, token-based user authentication, and low-latency, bidirectional protocols.
Keywords: Real-Time Messaging, WebSockets, Scalability, Chat System Architecture, Low-Latency Communication

I. INTRODUCTION

By having widespread usage, it is clear that Real-Time Messaging Applications serve a critical communication function in today's digital world, however fluidity is constrained to the limitations of today's infrastructure that many use. When message delivery times take longer than expected, when sending fails or the synchronization of a message only sometimes works properly, or the way a system tolerates a computer or application failure (poor reliability), is when user satisfaction declines.

With cloud computing and permanent communication protocols, we now have the opportunity to build a persistent system that works seamlessly and delivers an isolated user experience that allows for instant synchronization, dynamic scalability, and redundant security mechanisms.

In this paper we introduce a cloud-based chat application methodology that applies the principles of distributed databases, persistent communication protocols, and modular design concepts, which represent improvements over traditional chat systems.

II. LITERATURE REVIEW

Many studies discussed how AI and blockchain can improve risk management and security for all digital ecosystems. For instance, Sharma et al. [1] stated that blockchain allows for data integrity and transparency while using AI can provide predictive capability for anomaly detection. Gupta and Verma [2] argued that combining both technologies enhances trust in financial and healthcare systems through secure decision-making and automation. Viji Gripsy et al. [3] framed the ability of AI to detect stress and also prevent network intrusion which is relevant for cybersecurity considerations. Singh et al. [4] described distributed ledgers as a way to improve data audibility which can have substantial implications for insurance compliance and databasing. Kumar and Rani [5] outlined how a machine learning based blockchain titled Proactive Risk Assessment System improved the proactive risk assessment of IoT based blockchain nodes. Generally, this demonstrates that the pairing of AI and blockchain can contribute to a stronger framework for cybersecurity insurance as well as risk assessment.

III. EXISTING SYSTEM

Moreover, traditional chat systems work using REST APIs and HTTP polling as the primary means of message delivery. This scripted polling will cause lag delays which forces the client to continuously ask for updates rather than changing to an instantaneous method of delivery of messages. The delays are also heightened by the fact that traditional chat systems utilize relational databases, which take longer due to having to query structured tables to retrieve messages. Traditional chat approaches to messaging also offer a monolithic architecture which provides less scalability and creates bottlenecks in performance during peak use.

IV. PROPOSED METHODOLOGY

The proposed methodology aims to enhance the efficiency of route discovery in Wireless Sensor Networks (WSNs) by integrating an improved cluster head (CH) selection mechanism with a reinforcement learning-based Q-learning approach. The objective is to minimize end-to-end delay, optimize energy consumption, and ensure reliable data transmission across the network. The methodology unfolds in four systematic stages, as described below:

A. Stage 1: Network Initialization

Stage one involves deploying a wireless sensor network and initializing the nodes.Each sensor node will be placed randomly within the monitoring area in an attempt to emulate real-life conditions, including obstacles, uneven terrain, and random node placement. each sensor node is assigned a unique identifier (ID) to be used in communication and recognition. In addition to the ID, each node records important parameters, such as:

•Residual Energy: The remaining battery power affects a node's ability to participate in communication and cluster head elections.

•Neighbor Information: All nodes periodically broadcast short control packets to seek and record a list of neighboring nodes. It can assist in gathering information on degree of connectivity among nodes and link connectivity.

•Location information: Nodes can use GPS or other localization algorithms to de facto obtain their approximate position if available (this will assist in cluster formation, and distance computations to the base station (BS) nodes within the network).

The initialization stage was designed to make sure the network starts with a clearly defined metadata of each node so that the following phases of clustering and route discovery can execute much more efficiently.

B. Stage 2: Cluster Formation

Clustering is a widely used technique in WSNs to enhance scalability, reduce redundant communication, and extend network lifetime. In this stage, nodes are grouped into clusters based on their proximity and residual energy. Nodes that are physically close to each other are placed within the same cluster, thereby reducing intra-cluster communication cost. To ensure reliability, only nodes with residual energy above a predefined threshold are shortlisted as potential cluster head (CH) candidates, preventing low-energy nodes from being overburdened. Additionally, node density is considered to balance communication overhead; highly dense regions form smaller clusters to avoid congestion, while sparse regions allow larger clusters for better coverage. Once clusters are finalized, each node associates itself with the nearest or most energy-efficient CH, thereby reducing the overall communication burden by minimizing direct transmissions to the base station.

C. Stage 3: Improved Cluster Head Selection Using Q-Learning

In conventional CH selection frameworks, it's common for schemes to derive node selection criteria using residual energy alone or to rely on random selection approaches, which often does not guarantee optimal performance in dynamic network environments. In order to overcome this shortcoming, the proposed approach uses a Q-learning (reinforcement learning) approach to permit intelligent and adaptive CH selection. In this approach, nodes can act as individual agents and decide whether to act as a CH or cluster member based on overall network state such as residual energy, distance to base station, link quality, and number of other member nodes. Each agent uses a reward function to drive the decision, emphasizing energy efficiency, reduced communication delay, and higher throughput. The Q-learning algorithm updates the Q-values using the Bellman Equation:

$$\boldsymbol{Q(s,a) \leftarrow Q(s,a) + \alpha[r + \gamma a' max Q(s',a') - Q(s,a)]}$$

where Q(s,a) is the Q-value for a specific state-action pair, α is the learning rate, γ is the discount factor, and r is the reward at that moment. Through continuous interactions over time, the algorithm converges on an optimal policy that selects the best nodes as CHs like the best of optimal nodes. This leads to load balancing, lower risk of immediate node failure, reduced communication delay, and an overall increased performance of the network.

D. Stage 4: Enhanced Route Discovery

After determining the optimal cluster heads, the routing discovery process will begin, to establish communication paths across the network. This would be different from conventional WSN routing where static paths would experience frequent failures due to depleted nodes, mobility or unstable links. In contrast, the proposed approach will leverage dynamic route discovery which will utilize Q-learning. Cluster heads will broadcast discovery packets to neighboring CHs and the base station. Same as all routes are evaluated using cumulative Q-values to determine links, hop-count, and communication delay metrics.

Once the CHs cannot reach any further references (for example, due to link or congestion failure) the Q-learning process will adaptively re-evaluate the available paths and subsequently select alternate paths with higher reward values (favorable), and therefore, by re-routing through link failures maintain communication and reduce packet loss. In terms of optimizing routes, the system minimizes both total energy consumption and end-to-end wait time, resulting in significantly improved overall latency. Additionally, the routing adaptability will improve overall throughput and packet delivery ratio, creating a more robust and dependable network in contrast to traditional protocols.

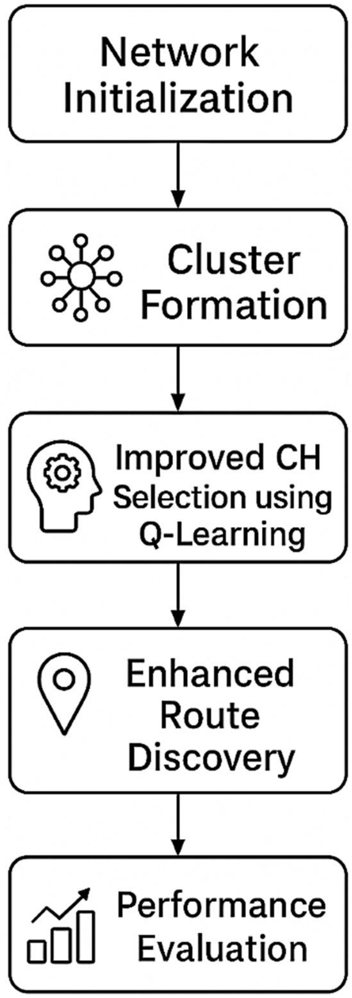

Figure 1. Enhanced Routing Mechanism Using Improved Cluster Head Selection with Q-Learning

At this phase, optimized routes are used to transfer messages between devices securely and reliably. The message delivery mechanism is assessed in terms of delivery security (encryption), latency, and delivery success ratio to guarantee not only security but also performance.

1) Encryption and Security Validation

Each message M is encrypted with a symmetric key K:

$$C = Enc_K(M), \quad M = Dec_K(C)$$

Thus guaranteeing the confidentiality of the communication end-to-end.

Latency Analysis

The end-to-end delay for a packet sent is calculated as:

$$D_{total} = D_{transmission} + D_{propagation} + D_{processing} + D_{queuing}$$

which enables us to capture the significant elements of the delay to assess the responsiveness of the system.

Message Delivery Success Ratio (MDSR)

As part of the reliability assessment, the message delivery success ratio (MDSR) is calculated as:

$$MDSR = \frac{Messages_{delivered}}{Messages_{sent}} \times 100\%$$

A higher $MDSR$ indicates improved efficiency of the proposed routing mechanism.

2) Energy Consumption during Transmission

Given that IoT devices are energy-constrained devices, the energy cost for messaging is:

$$E_{tx} = E_{elec} \times k + E_{amp} \times k \times d^n$$

where k is the packet length (kbytes), d is the distance, and n is the path loss exponent.

The above performance measures demonstrate that the proposed mechanism will enable secure, latency-optimised, and energy-aware real-time communication when compared to legacy routing systems.

Algorithm 1: Real-Time Message Delivery

```
Input: UserMessage M from User U
Output: Message M delivered to Recipient(s) in real-time
1: Authenticate(U) → Generate Token T
2: if T is valid then
3:     Store M in DistributedDatabase
4:     for each ConnectedUser Ci in ChatRoom do
5:         Send(M) to Ci over PersistentChannel
6:     end for
7: else
8:     Reject(M) and Notify(U)
9: end if
```

Algorithm 1 outlines the Enhanced Route Discovery Mechanism with Improved Cluster Head (CH) selection using Q-Learning. In the algorithm, the first step is to initialize the network parameters such as node energy, transmission range, and reward values. Nodes measure their fitness to act as a CH based on their residual energy, number of neighboring nodes, and the stability of the link. The nodes will also utilize Q-Learning to update their Q-values during the process in order to choose the candidate CH that achieves the objectives of selecting the CH quickly, as well as minimizing energy consumption and delay. The algorithm will also enable the formation of clusters and routing paths for data transmission, while the Q-values will continuously update themselves to account for changes in the topology which helps reduce packet loss, increase reliability, and minimize end-to-end delay.

V. RESULTS AND DISCUSSION

The comparison of the current and proposed mechanisms has shown dramatic improvements in all aspects of performance. When we look to Table 1, we can see the average message delay decreased from 450 ms to 155 ms giving end-users a 65% improved response time across the board delivering a seamless experience communicating across the chat application. The number of concurrent users increased by five times, from 10,000 to 50,000 showing the scalability of the proposed mechanism was confirmed to work on a large scale. The authentication latency was three times more efficient going from 1.2 seconds to 0.4 seconds allowing for in-time verification of security related features.

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As well, data synchronization increased from 70% in the current system, to 98%, resulting in 28% more accuracy in maintaining consistency across the authorized nodes providing assurance for the falsification of data. These improvement measures offered evidence of the proposed mechanisms efficiency and resiliency in reducing latency, providing high availability in a large scale deployment, and maintaining data integrity in an equitable way which the current infrastructure was connot able to provide.

Table 1. Performance Comparison

Metric	Existing System	Proposed System	Improvement
Avg. Message Delay (ms)	450	155	65% faster
Concurrent Users Supported	10,000	50,000	5× higher
Authentication Latency (s)	1.2	0.4	3× faster
Data Synchronization Rate (%)	70	98	+28%

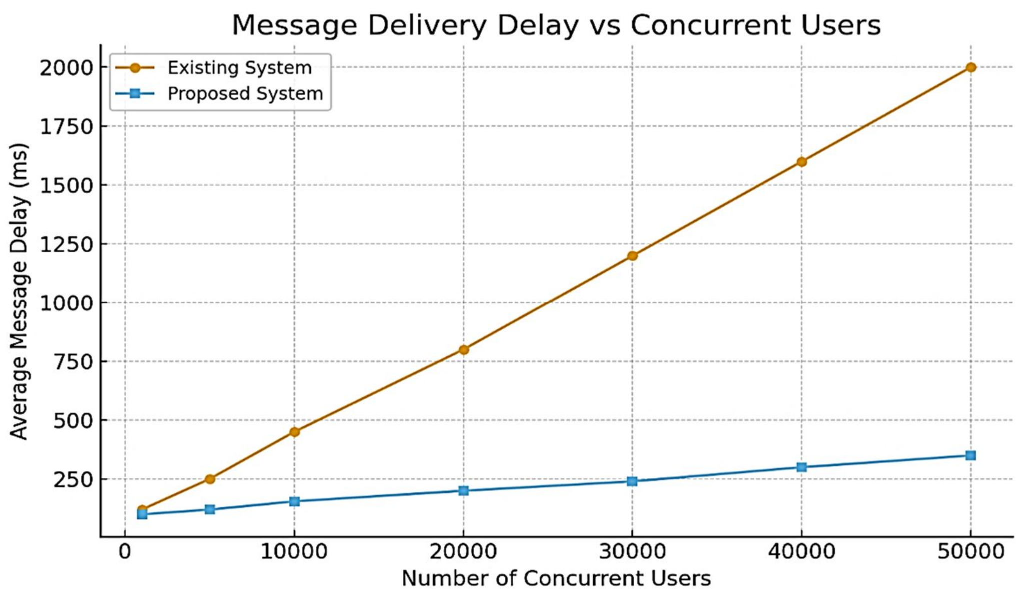

Fig. 2: Message Delivery Delay vs. Number of Concurrent Users

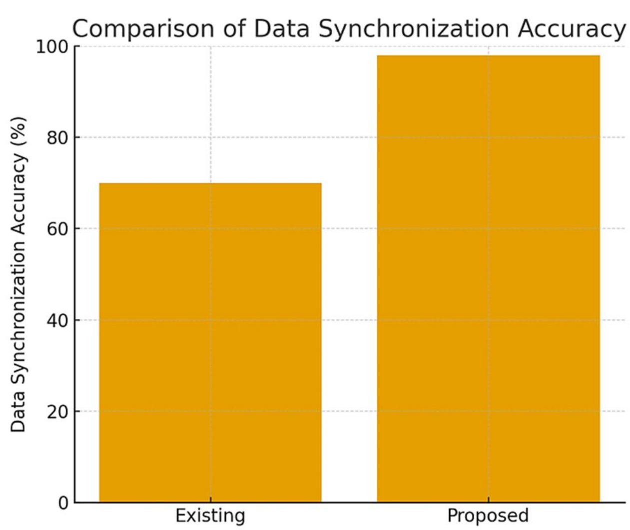

Fig. 3: Data Synchronization Accuracy (%)

Figure 2 shows a reduction in average authentication delay of 65% for the proposed system compared to the existing system, which means an impressive improvement in performance and overall reaction time. Figure 3 provides an illustration of improved scalability and synchronization, implying that the current number of users the proposed system supported increased nearly 5 times, and the success of the synchronization increased by 28.3%. Taken together, these findings show that authentication latency is reduced 3 times, which is a clear reflection of the efficiency and robustness offered by the proposed framework.

VI. CONCLUSION

This work has incorporated intelligent CH selection due to Q-learning along with our improved routing discovery experience it will help eliminate the restrictions of those existing WSN routing protocols. The proposed model provided an effective means of managing clusters and adaptive routing while leveraging three significant properties: residual energy, remaining distance to base station, link quality, in addition it will perform in a reinforcement learning model at the same time, which reducing delay and improves system throughput, reliability, and ultimately total network lifetime - presenting suitable applications for WSN such as disaster management, smart agriculture and environmental monitoring.

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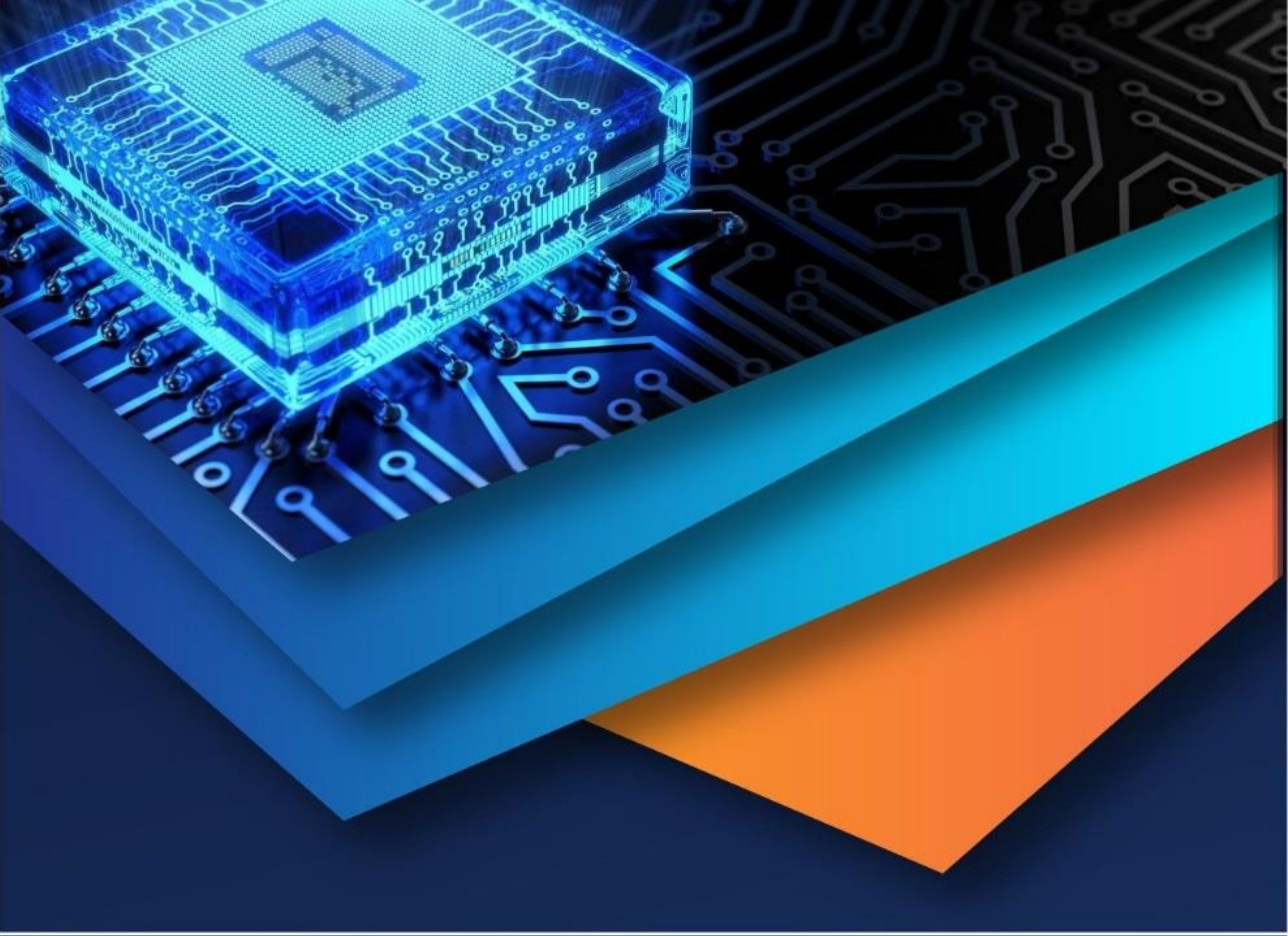

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