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VaCoChain: Blockchain-based 5G-assisted UAV Vaccine distribution scheme for future pandemics

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***Abstract*—This paper proposes a generic scheme *VaCoChain*, that fuses blockchain (BC) and unmanned aerial vehicles (UAVs) underlying fifth-generation (5G) communication services for timely vaccine distribution during novel coronavirus (COVID-19) and future pandemics. The scheme offers 5G-tactile internet (5G-TI)-based services for UAV communication networks (UAVCN) monitored through ground controller stations (GCs). 5G-TI enabled UAVCN supports real-time dense connectivity at ultra-low round-trip time (RTT) latency of $< 1ms$ and high availability of 99.9999%. Thus, it can support resilient vaccine distributions in a phased manner at government-designated nodal centers (NCs) with reduced round trip delays from vaccine production warehouses (VPW). Further, UAVCNs ensure minimizes human intervention and controls vaccine health conditions due to shorter trip times. Once vaccines are supplied at NCs warehouses, then the BC ensures timestamped documentation of vaccinated persons with chronology, auditability, and transparency of supply-chain checkpoints from VPW to NCs. Through smart contracts (SCs), priority groups can be formed for vaccination based on age, healthcare workers, and general commodities. In the simulation, for UAV efficacy, we have compared the scheme against fourth-generation (4G)-assisted long term evolution-advanced (LTE-A), orthogonal frequency division multiplexing (OFDM) channels, and traditional logistics for round-trip time (RTT) latency, logistics, and communication costs. In the BC setup, we have compared the scheme against the existing 5G-TI delivery scheme (Gupta *et al.*) for processing latency, packet losses, and transaction time. For example, in communication costs, the proposed scheme achieves an average improvement of 9.13 for block meta-information. For 4000 transactions, the proposed scheme has a communication latency of 16s compared to 36s. The packet loss is significantly reduced to 2.5% using 5G-TI compared to 16% in 4G-LTE-A. The proposed scheme has a computation cost of 1.6 ms and a communication cost of 157 bytes, which indicates the proposed scheme efficacy against conventional approaches.**

***Index Terms*—5G, Blockchain, COVID-19, Future Pandemics, Tactile Internet, Unmanned Aerial Vehicles, Vaccine distributions**

I. Introduction

Recently, the world health organization (WHO) has collaborated with epidemic preparedness innovations (CEPI) in-effective deployments of novel coronavirus (COVID-19) vaccines global access (COVAX) [1]. COVAX-based accelerated COVID-19 tools are focused on strong capacity and immunity build in humans to fight against current COVID-19 and future pandemics. To fight the COVID-19 global pandemic, more than 50 major healthcare institutional stakeholders have worked towards vaccine production and 67 clinical trials are conducted. Recently, on November 18, 2020, Pfizer/BioNtech has proposed strong immune builds close to 95% against the COVID-19 phenotype structures [2]. With the initial success of vaccine builds, the focus has now transitioned towards large-scale production, manufacture, and massive distribution of COVID-19 vaccines. Fig. 1a shows the potential vaccine market for North America, Europe, Asia, and the rest of the world. As per the estimates, by 2024, USD 58.4 billion would be invested in vaccination against COVID-19 and future pandemics.

COVID-19 vaccines follow *cold-chain* process that maintains its effectiveness and stability. Owing to the standard operating procedures for *cold-chain*, COVID-19 vaccines are not allowed to ship for large distances through land, air, and water cargo shipments. Moreover, there are government regulations at national and international boundaries for cargo movements. Thus it might affect the vaccine stability and timely delivery owing to diverse climatic conditions [3]. The success of the *cold-chain* process of the vaccine depends on effective collaboration among governments and healthcare organizations, real-time vaccine shipments to nodal centers (NCs), and chronological record maintenance of vaccinated units to the priority groups [4].

Physical shipments through cargo units are expected to have high costs and might affect vaccine stability. To address the limitations and perform the last mile connectivity, unmanned aerial vehicles (UAVs) can speed up the distribution process, due to the shorter RTT delivery, optimal carrying payloads, and reduced shipping costs. It is estimated that UAVs assure $\approx 90\%$ vaccine deliveries to vaccine production warehouses (VPW) before expiration from *cold-chain* warehouses [7]. UAVs communicate with ground controller stations (GCs), and peer UAVs in proximity range to form a UAV-communication network (UAVCN), or a swarm of UAVs. Currently, UAV swarms communicate through global positioning systems, or 4G-long term evolution (4G-LTE) standards to combat the COVID-19 pandemic [8]. However, with the rise in massive device-to-device communications (D2D), 4G-LTE/LTE+ networks are less responsive and are not suitable for UAV drone control operations.

Thus, to address the requirements of vaccine delivery,

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