Hybrid Election System (HES)

Data Transmission and Network Architecture Documentation

Version 1.0_by_ed_millana

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1. Executive Summary

This document outlines the data transmission strategy for a proposed Hybrid Election System (HES). The system utilizes a distributed, mesh peer-to-peer (P2P) network topology to ensure the rapid, secure, and resilient transmission of election results from Voting terminals (nodes) to the Commission on Elections cloud (COMELEC) server. This architecture addresses the challenges of transmitting increasingly large datasets, including high-resolution ballot images, by leveraging the collective bandwidth of all connected devices, eliminating single points of failure, and expediting the public dissemination of results.

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2. System Architecture

2.1. Network Topology: Mesh Peer-to-Peer (Distributed Network)

The HES operates on a **mesh network topology**. In this model, every voting terminal and designated laptop acts as a **node**. Unlike a traditional client-server model where all clients connect to a central server, nodes in a mesh network connect directly to one or more other nodes.

- **Decentralized Relay:** Data does not need to travel back to a central point before being forwarded. It can hop from node to node, automatically finding the most efficient and fastest path to its destination (the server or another node).
- **Self-Healing & Resilient:** If one node fails or its connection is slow, the network dynamically reroutes data through alternative active nodes, ensuring high availability and fault tolerance.
- **Scalable Bandwidth:** As more nodes (laptops/terminals) join the network, the aggregate bandwidth and transmission capacity increase, rather than creating a bottleneck.

2.2. Data Components

Four primary sets of data are generated during and after an election. Their sizes and storage locations are strategically managed for efficiency.

1. **Election Returns (ER) Text Files with Metadata:** A lightweight, machine-readable summary of votes from each clustered precinct.
2. **Ballot Text File Results with Metadata:** A full text-based log of all votes cast by every voter.
3. **Digital ER Images:** A scanned image of the official, physically signed Election Return form for each precinct.
4. **Digital Ballot Images:** A high-resolution scanned image of each individual ballot cast.

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3. Data Storage and Distribution Strategy

The distribution of data is based on file size and intended use, ensuring optimal performance for both the on-site network and public access.

- **On Voting Terminal / Node:** Each node will only store and transmit the lightest and most essential dataset: **#1, ER Text Files**. This allows for rapid initial results transmission within the mesh without overwhelming the storage capacity of individual voting machines.
- **On COMELEC Storage Server & Public Website:** The COMELEC on-premise secured cloud storage will be the main repository for **all four datasets** (#1, #2, #3, and #4). This server aggregates all data from the mesh network and serves as the authoritative source for the public website, media, watchdog groups, and other stakeholders, providing full transparency and a means for comprehensive auditing.

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4. Data Volume Calculation

Below is the volume for each dataset, calculated based on the per-file sizes and quantities.

Note: Calculations use the standard 1,024 conversion factor: 1,024 kB = 1 MB, 1,024 MB = 1 GB, 1,024 GB = 1 TB.

#	Data Type	Per File Size	Quantity	Total Volume	Storage
1	ER's Text File + Metadata	5 kB	350,000 ERs	**1.67 GB**	Laptop + Comelec Cloud
2	Ballots Text File + Metadata	4 kB	70,000,000 voters	**267.03 GB**	Comelec Cloud
3	Digital ER Images	200 kB	350,000 ERs	**66.76 GB**	Comelec Cloud
4	Digital Ballot Images	150 kB	70,000,000 voters	**9.78 TB**	Comelec Cloud
	Total File Size			**~10.11 TB**	

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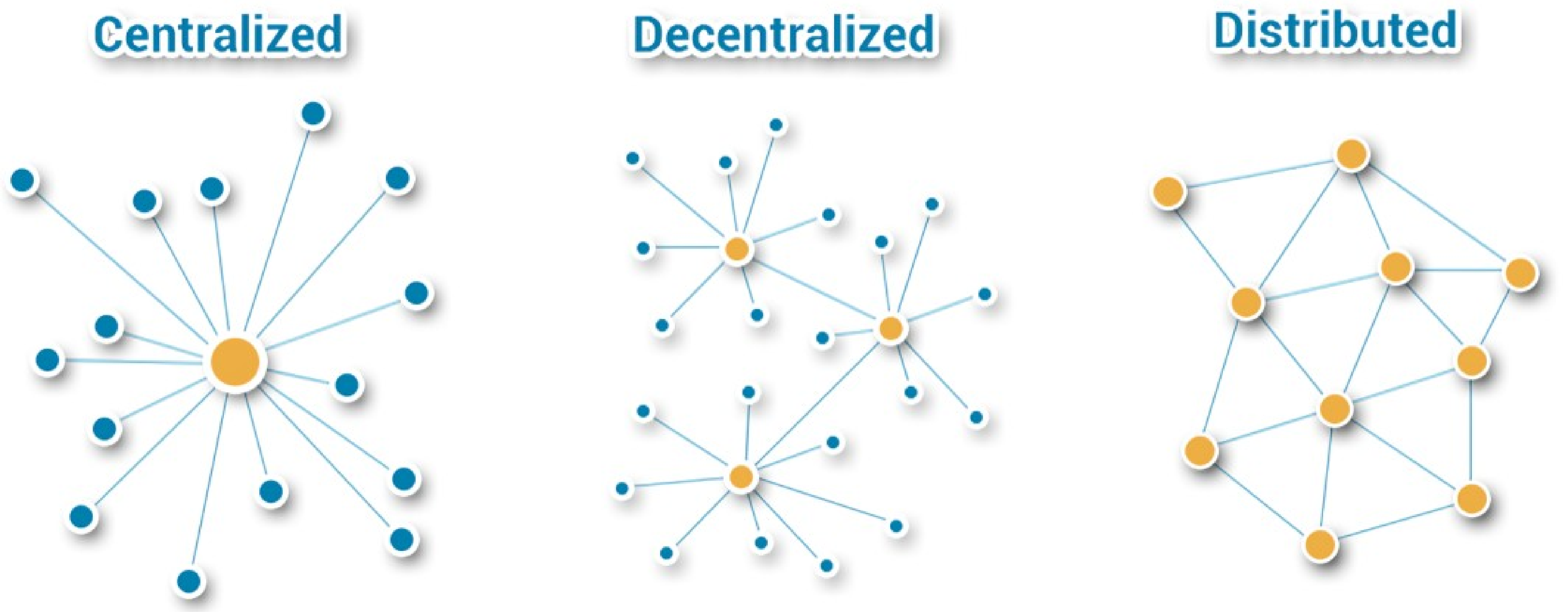
5. Data Transmission Workflow

1. **Local Mesh Formation:** As voting concludes, all laptops and terminals within a geographical area (e.g., municipality, city, province, region, nationwide) automatically detect each other and form a mesh network.
2. **Lightweight Data Propagation:** The ER Text files (est. 1.7 GB total) are created and instantly shared across the local mesh. Every node quickly obtains a copy of the results from all other local nodes.
3. **Heavy Data Transmission to Server:** Simultaneously, the heavy files (Ballot Text, ER Images, and Ballot Images) begin their transmission to the COMELEC storage server. The mesh network intelligently routes these large packets. Instead of 350,000 precincts trying to upload simultaneously over a single internet connection, the load is distributed. Data flows through the mesh, converging on nodes with the best external internet connectivity to be uploaded to the storage server.
4. **Aggregation & Public Dissemination:** The COMELEC server receives the data streams, verifies their integrity, and assembles the complete dataset. Once verified, the data is made available on the public website.

6. Comparison of Election System Network Topologies



H.E.S.

NETWORK TOPOLOGY

This chart compares the proposed HES model with the current centralized system and a theoretical blockchain-based system.

Feature	1. Centralized (Current AES)	2. Decentralized (Blockchain Model)	3. Distributed / Mesh P2P (Proposed HES)
Topology	Star topology. All Voting/Counting Machines (VCMs/ACMs) transmit data to a single central server.	Full-mesh where every node must store a complete copy of the entire ledger (all data).	Hybrid mesh. Nodes share data with each other and a storage server for file aggregation.
Data Flow	One-way, from precinct to server. Creates a bottleneck.	Multi-directional. Every new transaction (vote) must be broadcast to and validated by all major nodes.	Bi-directional and multi-path. Data flows peer-to-peer and to the server, using the fastest available routes.
Transmission Speed	**Slow to Moderate.** Severely bottlenecked at the central server and its internet connection, especially with large files.	**Extremely Slow.** Impractical for large files like ballot images. The consensus mechanism and data replication across all nodes is time-consuming.	**Very Fast.** Leages the aggregate bandwidth of all nodes. Heavy data is distributed and funneled through the best available connections, preventing bottlenecks.
Resilience / Redundancy	**Low.** A single point of failure. If the central server or its connection goes down, transmission stops for everyone.	**Very High.** No single point of failure. The network continues to function as long as some nodes remain active.	**High.** The mesh network is self-healing. If one node or connection fails, data is automatically rerouted. The central server is a single point for *aggregation*, but the peer-to-peer transmission is resilient.
Scalability	**Poor.** Adding more VCMs or increasing data size (e.g., higher-res images) worsens the bottleneck.	**Very Poor.** Data volume is a primary limitation. The blockchain size grows indefinitely, making it harder for new nodes to join and synchronize.	**Excellent.** Adding more nodes increases network capacity and bandwidth. The system scales naturally with the number of polling precincts.
Transparency / Auditability	**Moderate.** The public receives a copy from the central authority. Trust is placed in the central server's integrity.	**Very High.** The ledger is public and immutable. Anyone can verify the entire transaction history. However, verifying 13 TB of data is impractical for most citizens.	**High.** The comelec server provides an authoritative, easily accessible copy for public audit. The peer-to-peer transmission of raw data from the source allows for independent verification by stakeholders before aggregation.
Primary Advantage	simplicity and direct control.	Tamper-proof integrity and permanence.	**Speed, resilience, and bandwidth efficiency for large datasets.**
Primary Disadvantage	Bottleneck and single point of failure.	Impractically slow for large volumes of data; high resource consumption.	More complex to manage than a simple client-server network. Requires robust security for the mesh protocol itself.
Best Use Case	Transmitting small text-based results quickly.	Financial transactions, smart contracts where data volume per transaction is low.	**Modern elections requiring the rapid and reliable transmission of massive datasets (text, images, video) for transparency and auditing.**

7. HES Security & Integrity Features

- **Data Redundancy**: Mesh nodes store ER metadata to prevent single-point failures.
- **End-to-End Encryption**: All transmissions between nodes and COMELEC cloud are encrypted using AES-256.
- **Immutable Audit Trail**: Digital signatures are embedded in all files (items 1–4) for tamper detection.
- **Access Control**: Only authorized stakeholders (e.g., COMELEC, accredited observers) access the full datasets via multi-factor authentication.

8. Advantages of HES Distributed Mesh Architecture

1. **Fault Tolerance**: Multiple transmission paths ensure continuity during node failures.
2. **Lower Latency**: Adaptive routing prioritizes fastest available paths for heavy data.
3. **Compliance**: Dual storage (node + cloud) meets legal requirements for auditability.
4. **Cost Efficiency**: Lightweight ER files reduce local storage demands on end-user devices.
5. **Transparency**: Public access to full datasets (1–4) via secured cloud enhances trust in the process.

The hybrid mesh peer-to-peer system offers a robust balance of speed, security, and transparency, addressing critical limitations in legacy centralized and fully decentralized approaches. It ensures election integrity while enabling scalable, real-time monitoring for public trust.

This is a Preliminary document. All information is subject to change without notice due to the system's active development.

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