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Website-as-an-OS: Bridging the Indian Digital Divide through a Privacy-Oriented, Client-Side Runtime for STEM Education

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KEYWORD

W-OS, Artificial mainstream, Mainstream, *Deep Learning,* Statistical data

ABSTRACT

In an era where technology seems ubiquitous and everyone around seems to be have a access to it, there is a hidden reality beneath the surface, the "digital device gap" especially in India, where if you were to look at the statistical data of mobile owners and compare it against the household computer ownership, there is a sharp contrast where the former is almost a 95% and the latter is well under 10%, This Digital disparity of hardware ownership might not look like a problem at first but this disparity breed generations of a passive content consumer rather than a much needed people that could innovate and create digital products. The proposal of this paper - creating an OS that could be accessed just like any other app- is not a novel idea; versions of it exist, but what they fundamentally lack is the understanding of the needs of the end user who is the target demographic of their services. The current versions lack Speed, Efficiency and the productivity output that is required to bring this accessible OS to mainstream,This paper propose a evolved version of it "Website-as-OS (W-OS)" : a Client side,privacy -oriented web operating system built with React and Javascript to address the discrepancy of the what current-service provider provide and what the user needs, turning their browser into a complete decentralized workstation regardless of what device they are on.

1. Introduction

The Indian Digital landscape on surface level seems to be heading towards an ideal digital landscape where most of the population has access to a steady internet connection and owns some kind of device to access it, but beneath it lies the contrasting reality that is even with this unprecedented access of abundant knowledge and having access to hardware, the functional computing power - the ability to create, code, and produce digital artifacts remains concentrated to a privileged minority. As of late 2024, the mobile phone penetration among Indian youth(aged 15-29) has reached a near-universal ,approximately 97.1%,on the other hand, the ownership of household computers or laptops lingers below 10% and has been stagnant. This has created a different kind of digital literacy, where the average-Indian is proficient in consumption of digital content (social media, OTT streaming) but is deficient in technical production, a study found that 50% of Indians can send text messages, but only 10% can manage spreadsheets and only 25% can install software, a huge factor for this is the lack of access of the tools required to democratize the technical

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production. The conventional educational interventions to bridge the lack of digital education have been the "One laptop per child" model or establishing physical Computer labs. The biggest hurdle that these models face is the ability to shine in a resource-constraint environment. The capital expenditure alone for an average laptop/Computer is around ₹35,000 in a country where the average household income is around ₹32,000- ₹35,000 monthly in cities and less than ₹13,000 monthly in rural India, not to mention the additional cost of maintenance. Affording a Laptop/Computer would be considered a Luxury investment.

The obvious and technically feasible solution for overcoming this hardware disparity is to switch to a cloud based (Software-as-a service) working environment, no specific hardware requirement just a steady continuous internet connection and the user is good to go, but this again fails on the parameters of cost efficiency for an average Indian, introduces a technical overhead and with an average Internet speed in the urban parts and below average in rural parts is slower and does not give the required productivity yield. Furthermore, the shift toward cloud-based software-as-a-service (Saas) models has introduced a problem of data sovereignty and privacy. In India, the DPDP Act imposes a very strict requirement and guidelines for processing children's data (defined as anyone below 18 years of age) that include parental consent and prohibit behavioural tracking and targeted advertising, which is almost quite against the whole business models of the centralized cloud platforms, which monetize on these data profilings.

To address these shortcomings of conventional solutions, socio-economic disparity, and compliance with the law, this paper proposes a paradigm that is not novel but does require a functional overhaul of the current services to evolve into a mainstream app : A "Website-as-an-OS" (W-OS). This architecture utilizes the browser as more than just a remote content viewer, utilizing its full capacity to turn it into a complete, functional,decentralized Operating system. The proposed W-OS, built entirely in JavaScript and React, leverages the modern and high-performance browser APIs - IndexedDB for data persistence, WebAssembly (Wasm) for Code execution, and runs completely on the client side. Delegating the entire operating system to client side, the W-OS transforms any smart phone or device, budgeted or legacy, into a professional-grade workstation, with functionality like Code execution, file system, terminal and other utility applications without the need for local installation or server-side data storage, turning a only viable computing investment for an below-average Indian - a smart phone into a complete workstation that is free and accessible to all.

2. Literature Review:

The Evolution of Web-based Operating System(WebOS):

As stated earlier, the Idea of Website-as-an-OS is not new; it has been a concept for a while now. Early iterations such as EyeOS (2005), which utilized a two tier client-server model, where the application was hosted on a remote server, and when requested by the user, was pushed to the browser as a presentation layer. More recent projects like puter.com offer desktop-style GUIs, but require a steady, continuous Internet connection and account creation, which hampers the speed,efficiency, productivity yield, and privacy concerns. So even though there has been a fundamental shift in the architecture, it has not yet evolved to be resource-constrained and customer-centric.

The Indian Digital Divide: The "Device Gap" Paradigm :

The Technological topology of India Market is unique, and we need to analyze it to understand the necessity of a browser-based OS. The Internet users (exceeding 900 million users in 2025) and mobile phone owners (95% of Indian households) have outpaced the growth of the Computer and Laptop market (below 10%) by order of magnitude, and this is exacerbated further by even less computer ownership in the rural parts

of the country, around 4%. Research by UNESCO and NITI Aayog suggests that traditional ICT interventions fail because they ignore the reality that a smartphone is the only computing investment most Indian households can afford.

Technical Foundation: Local First Architecture and Browser APIs:

The Technical feasibility of this paper's proposed system is supported by the emergence of "local-first software principles, unlike the current services, which rely heavily on the cloud-first approach and consider that as the source of truth. The "local-first" approach treats users' devices as the primary source of truth.
IndexedDB - A NoSQL, transactional Database which allows for persistent storage of data across sessions, all within a browser. Eliminating the need to do network round-trips.
WebAssembly (Wasm) : The hero behind the ability of compilers to execute code with near-native speeds in a sandboxed environment, providing security and lightning speed, and enabling terminal utilities without local installation.

Legal Frameworks : The DPDP Act of 2023 and Data Sovereignty:

A significant driving force for client-side OS development is the legal requirement for data sovereignty. India's Digital Personal Data Protection (DPDP) Act 2023 defines any user under 18 as a child and strictly prohibits behavioral tracking and "harmful profiling" in EdTech. Traditional cloud-based platforms often struggle with "function creep," where student data is used for secondary analytics or marketing. The "Zero-Knowledge" architecture in W-OS inherently stores entire user data on client-side. IndexedDB storage provides a technical solution to these legal hurdles, as nothing ever leaves the user's device.

Multidisciplinary Impacts : Pedagogy and Sustainability:

Pedagogy Empowerment: Mobile-first strategies have been shown to improve student engagement by 20% on platforms that prioritize creation over consumption. Case studies of Shuren Jingrui Primary School of China demonstrates that providing production tools on existing portable hardware can significantly raise its schools overall academic standing, in the case of Shuren Jingrui Primary School of China, they saw a jump from eighth to first place within their district with this integration.
Environmental Circularity: Repurposing legacy hardware can help to cut down costs and environmental damage. standard OS demands frequent hardware upgrades, leading to software-induced "software-induced obsolescence". In contrast, a browser-based OS is lightweight and can run on older devices that do not receive native OS support.

Methodology (Proposed):

Research Framework: Design Science Research (DSR): The research should employee the Design Science Research Methodology process, to create and evaluate the artifact.

The research should be driven by these two questions:

RQ1: Can a browser-based, client-side architecture provide a performant development environment on budget mobile hardware?

RQ2: to what extent does a local-first storage model satisfy the data sovereignty requirements of India's DPDP Act 2023?

1. The artifact must measure up to following strict standards to be truly considered as Website-as-an-OS:
    a. Zero Setup Desktop like Development Environment on any Hardware
    b. Ensuring "Local first" Privacy Environment.
    c. support all legacy hardware and extend its life.

   d. compliance under DPDP Act 2023.
2. Proposed Artifact Design and Development :
   a. The Development can utilizes React 19 and Javascript concurrent rendering
   b. IndexedDb for offline persistence Virtual file system
   c. WebAssembly(Wasm) to run compilers and terminal utilities at near native speed with security
3. Evaluation Stragery:
   a. The system should be evaluated through a Mixed-Methods approach.the product needs to be tested both in Quantitative Performance (Time to first frame, Interaction To Next Paint, Memory Growth (Δ Memory)) and Qualitative Assessment (Nielsen's Heuristics testing, teacher and student regarding feedback on pedagogical utility).
   b. The parameter to measure the efficacy of the artifact should be demonstrated through a controlled "proof-of-work", which involves deploying the W-OS on budget Android devices (representative of Indian Market) and documenting the successful execution of the common STEM task like plotting graphs, ability of run code and shell navigation and giving a familiar GUI for user to migrate or adapt to a actual OS.
4. Legal Compliance and Privacy Audit : A privacy audit will be conducted to verify that the "Zero-Knowledge" architecture maintains all structured data in origin-isolated IndexedDB. This audit will explicitly map data flows to ensure compliance with the verifiable parental consent and data residency mandates of DPDP.

3. Expected Results:

The Technological Performance Benchmarks:

The study expects to demonstrate that a client-side W-OS can achieve a "snappy" user experience even on budget Android hardware (< ₹ 7,000).

Response Latency: By utilizing IndexedDB and a local Virtual File System, we anticipate sub-millisecond query response times for local files, eliminating the overhead of 100ms+ network round-trips required by cloud-first IDEs like Replit, GitHub Codespaces or puter.com

Rendering Stability: Using React-19 and concurrent rendering optimizations the OS must adhere to a strict processing model of $T_{total} = T_{script} + T_{layout} + T_{paint} < \sim 16.47ms$

Execution Speed: Preliminary analysis suggests that WebAssembly (Wasm) modules will execute compiled code at roughly 60–80% of native speed, providing a viable terminal environment for STEM education without local installation.

II. Data Sovereignty and Privacy Compliance

The proposal anticipates a "Zero-Knowledge" outcome when network traffic gets audited and that it will be verified that 100% of user-generated data stays within the browser's origin-isolated storage. DPDP Compliance: The system is expected to provide inherent compliance with India's Digital Personal Data Protection (DPDP) Act 2023, specifically regarding the strict mandates for processing children's data (<18 years old) by ensuring no behavioral tracking or third-party data transit occurs.

III. Multi-Disciplinary Socio-Economic Impact

The Consumption-Production Shift: We expect a measurable increase in the "Production Ratio" among mobile-first students, transitioning them from passive media consumption to active digital creation (coding, document management, STEM activities)

Environmental Circularity: Although we are not creating a rigid system to measure environmental circularity, we expect that users using legacy hardware can extend their device' s life which has lost the native support for a few more years using the W-Os.

Conclusion

The proposal research addresses a critical "device gap" in India, where 95% mobile ownership exists alongside computer ownership rates below 10%,. By shifting the computing paradigm from the cloud to client side browser the "Website-as-an-OS(W-OS) model offers a scalable, sustainable and privacy oriented solution for democratizing STEM education.1.Technological Innovation: It validates the browser as a complete, decentralized runtime environment capable of replacing native OS functionality for educational purposes. 2. Legal blueprint and Standards: The proposed W-OS has inherent privacy built in by design thus aligning perfectly with data sovereignty laws not just in India but around the world providing a significant leap in the legal standards for software development. 3.Educational Equity: By democratizing the tools that enable people to build and learn for free help them to reach their potential and bring educational utility in true sense,especially to rural parts of the country. In conclusion, the W-OS is a little more than a software artifact; It is an intervention designed to ensure that anyone regardless of their background, financial or hardware constraint has access to tools that help that supports and builds their potential.

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