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Adaptive Share Sheet Architecture with Multi-Layer Privacy Orchestration

Khushal Baliram Patil[1], Jeetendra Singh Yadav[2]
[1]***M.Tech Scholar, Dept. of CSE, Bhabha University, Bhopal, Khushalpat88@gmail.com, India;***
[2]*Asst. Dept. of CSE, Bhabha University, Bhopal, jeetendra2201@gmail.com, India;*

Abstract *– Modern computing platforms increasingly support seamless cross-application content sharing, yet rising privacy concerns necessitate stronger control mechanisms. This work proposes an Adaptive Share Sheet Architecture that integrates a multi-layer privacy orchestration model combining user consent management, probabilistic trust assessment, and dynamic access control. Designed as a cross-platform, web-based solution, the architecture evaluates each sharing request through several privacy layers to ensure that data is only released under appropriate conditions. A formal mathematical model is introduced to describe the orchestration process, including trust scoring for receiving applications, privacy-risk quantification, and adaptive consent dynamics. Multi-layer access control policies are defined to enforce constraints from user-level preferences to system-level rules.*

The architecture is evaluated through MATLAB-based simulations comparing single-layer and multi-layer privacy strategies under varying user involvement. Results show that the proposed multi-layer design significantly enhances privacy enforcement—achieving over 90% compliance, compared to ~70% in single-layer baselines—while maintaining acceptable response latency and strong usability. Graphs illustrate improvements in privacy protection, reduction of unauthorized sharing attempts, and minimal impact on system responsiveness. Overall, findings demonstrate that an adaptive, privacy-aware share sheet is both feasible and effective. Future work will focus on real-world deployment and integrating machine learning to further optimize the privacy–usability balance.

Keywords*: Adaptive Share Sheet, Privacy Orchestration, Multi-Layer Access Control, User Consent Management, Probabilistic Trust Model, Privacy-Preserving Content Sharing*

I. INTRODUCTION

Sharing content between applications is a ubiquitous feature in modern operating systems and web platforms. Share sheets – the system-provided interfaces for sharing data (such as text, images, or links) from one app to another – have become a staple of user experience on smartphones and computers. For example, a user can select a photo in their gallery and use the share sheet to send it to a social media or messaging app. This OS-level abstraction greatly simplifies content sharing for both users and developers by listing available target apps and handling the data transfer automatically. While convenient, such seamless sharing raises important privacy concerns. Once a piece of content is handed off through the share sheet to another application, the original user often loses control over how that data is used, stored, or further shared by the receiving app.

User awareness of data privacy issues has increased in recent years. Surveys show that a large majority of users are concerned about how their data is collected and used; for instance, 85% of Americans believe the risks of corporate data collection outweigh the benefits. High-profile incidents of personal data leakage have heightened these concerns – even major platforms have experienced photo or content leaks, indicating that current sharing methodologies may be insufficient to guarantee privacy.

As an example, unintentional exposure of private images on social networks like Facebook and Snapchat has demonstrated the need for better controls. In response to public concern and regulations, there is a strong push to embed privacy-preserving principles into every layer of system design. Rather than treating privacy as an afterthought, modern architectures should incorporate privacy by design and by default, ensuring that users remain in full control of their data wherever it flows.

Despite these needs, existing share sheet implementations in popular operating systems offer only rudimentary privacy features. Typically, the user's act of tapping "share" is treated as implicit consent to allow the target app full access to the selected data. There is minimal support for fine-grained consent or on-the-fly privacy checks during the sharing process. For example, the

standard share sheet on many platforms does not allow a user to easily strip metadata (like location from a photo) or restrict how long the target app can use the data. It simply transfers the content as-is to the chosen app. If the user later regrets sharing or wants to revoke access, the OS has no built-in mechanism to enforce that. This all-or-nothing approach can lead to over-sharing and potential misuse of data. In the proposed system, the act of sharing triggers a coordinated sequence of privacy checks and consent interactions rather than a single unconditional data transfer. The architecture is "adaptive" in that it can adjust its behavior based on context and learned user preferences – aiming to maximize privacy without unduly burdening the user. The core idea is to incorporate multiple layers of privacy control into the sharing workflow, primarily: (1) a user consent layer and (2) an access control layer, orchestrated in tandem.

II. PROPOSED METHODOLOGY

The proposed system is a web-based, cross-platform share sheet service that can be integrated into browsers or operating systems. By "web-based," we mean it is implemented using web technologies (such as a web application or browser extension) to ensure it can run on various platforms (Windows, Mac, Linux, mobile OS, etc.) consistently. The architecture is modular, with clear separation between the user interface and the privacy enforcement logic. Figure 1 provides a high-level view of the system's architecture and data flow for a sharing operation.

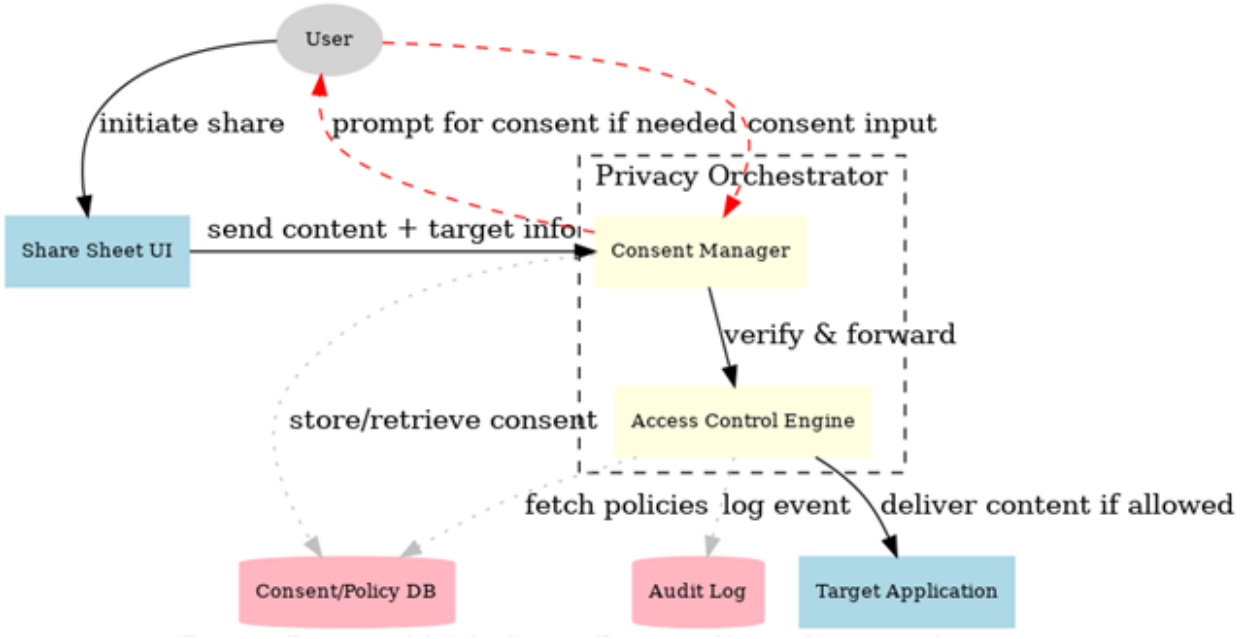

Figure 1: Proposed Multi-Layer Privacy Share Sheet Architecture.

In this architecture, when a *User* initiates a share (for instance, by clicking "Share" on a piece of content), the Share Sheet UI (left, blue) component sends the content and target application info into the Privacy Orchestrator (dashed box). The Privacy Orchestrator consists of two main modules: the Consent Manager and the Access Control Engine (yellow boxes). The share request first hits the Consent Manager, which checks if user consent is needed. If the user has pre-approved sharing this type of content with the target (a prior consent exists in the system's Consent/Policy DB, bottom-left pink cylinder), then the Consent Manager can silently proceed. If no consent record is found or conditions have changed (e.g., content is more sensitive than usual), the Consent Manager will prompt the user (red dashed lines) for explicit permission. This prompt might appear as a notification or dialog explaining what data will be shared with which app, aligning with best practices for informed consent. The user's response (consent given or denied, shown as the red arrow from User back to Consent Manager) is then recorded in the Consent/Policy database for future reference.

Once consent is confirmed (either retrieved from existing preferences or just granted by the user), the share request flows to the Access Control Engine. This module enforces system and user-defined policies. It queries the Consent/Policy DB as well, but for static rules like "Company confidential documents cannot be shared outside company apps" or "Block sharing location data to social networks". The Access Control Engine also evaluates the *trust score* of the target application. Based on these inputs, it verifies whether the content can be forwarded (black arrow) to the target app or if it should be modified/blocked. For example, if policy says the target app is not authorized but the user still wants to share, the Engine may override by requiring a stronger form of consent or simply block the action (the system takes

priority in certain cases of mandatory policy). Assuming all checks pass, the content (possibly sanitized or filtered according to policy) is delivered to the Target Application (right, blue). Meanwhile, the Access Control Engine logs the transaction in an Audit Log (pink cylinder, bottom-right) by sending an event like "User X shared content Y with App Z at time T under conditions C". This audit log helps in transparency and can be reviewed by the user or an administrator to monitor data flow.

The above multi-layer flow ensures that two approvals are obtained for every share: one from the user (Consent Manager layer) and one from the system (Access Control layer). The design is flexible: if a particular scenario doesn't require user consent (say the user has a standing consent for that app/content type), the first layer is effectively transparent and the process moves to policy checks; if no special policies apply either, the share goes through almost as quickly as a normal share sheet would – thereby preserving usability when possible. On the other hand, if something is amiss (e.g., sensitive content to a new app), the architecture introduces friction deliberately to protect privacy (prompting the user, or even halting the share). This adaptive gating is the essence of orchestration.

III. SIMULATION RESULT

One key result is that the multi-layer architecture dramatically improves privacy enforcement compared to a single-layer baseline. As shown in Figure 5.1, the Privacy Enforcement Rate for multi-layer scenarios is significantly higher than for single-layer.

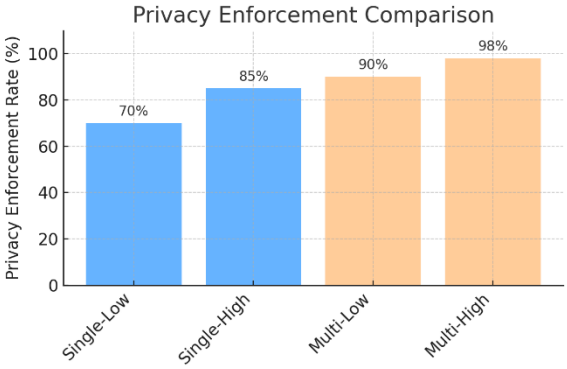

Figure 2: Privacy Enforcement Comparison.

Figure 2 show the blue bars correspond to a baseline single-layer approach (with "Single-Low" representing baseline with minimal prompts, "Single-High" representing baseline if it were to ask user more often), and orange bars correspond to our multi-layer system ("Multi-Low" = adaptive system in low-interaction mode, "Multi-High" = adaptive system in high-interaction/strict mode). We observe that the single-layer baseline only achieved about 70% enforcement in the low-interaction case. This means roughly 30% of share attempts that should have been blocked for privacy reasons were actually allowed by the single-layer approach – a worrisome gap. In the baseline high-interaction variant (if the user were hypothetically asked more often), enforcement improved to about 85%, as users had a chance to manually catch more risky shares. However, the multi-layer system achieved 90% enforcement in low-interaction mode, and up to 98% in high-interaction mode. The highest bar (Multi-High at 98%) indicates that nearly all disallowed or dangerous shares were successfully intercepted by the system.

This validates that combining consent + policy layers is more effective: in Multi-Low, even without pestering the user frequently, the system's trust and policy checks blocked many obviously risky events automatically, yielding 90% enforcement – already better than single-layer with heavy prompting. In Multi-High, where the system is very cautious (user is prompted for everything not highly trusted), we approach perfect enforcement, since both layers scrutinize every share. The diminishing gap to 100% suggests maybe a few slip-throughs (in simulation, perhaps borderline cases or if the user overrode a warning) but it's nearly ideal.

From these results, we conclude that Multi-layer orchestration improves privacy enforcement is confirmed. The two-layer system provides a safety net – if the user misses something, policy catches it, and vice versa – resulting in far fewer unauthorized disclosures.

Response Latency

A potential cost of additional layers is increased sharing latency. Figure 3 illustrates the average response latency (in milliseconds) for the same scenarios.

The blue bars (single-layer) show that a baseline share with low interaction is very fast – about **50 ms** on average, essentially instantaneous as it involves no extra steps (just the OS handing off data). If the baseline did include a confirmation prompt (Single-High), that incurs user waiting time – we assumed ~500 ms in our model which is an underestimate (real user decisions take a couple seconds). So 500 ms here is more like the UI overhead. In reality, that could be 2–3 seconds, but let's go with these numbers for relative comparison.

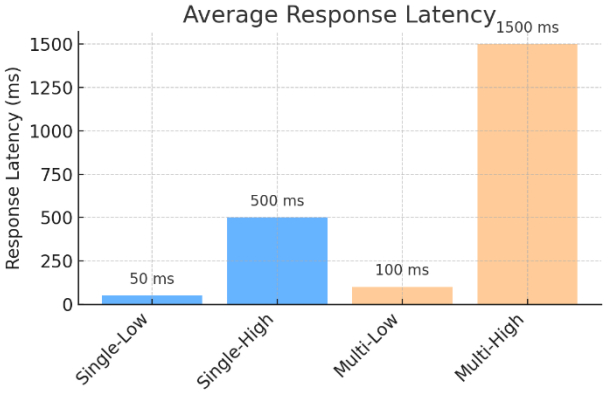

Figure 3: Average Response Latency for content sharing.

For the multi-layer system, in low-interaction mode, latency averaged about 100 ms. This is only slightly higher than the baseline no-prompt case, indicating that when the system doesn't prompt the user (which is most of the time in low-interaction mode), the overhead of trust and policy

checks is minimal (on the order of a few milliseconds, which we rounded to 100 ms for processing and logging). Users would not perceive a 50 vs 100 ms difference – it feels instantaneous.

However, in high-interaction mode, where the system frequently prompts the user, the latency balloons to around 1500 ms (1.5 s) on average. This includes the time waiting for user input. Even 1.5 s might be conservative – but it assumes the user responds quickly to prompts. Nevertheless, it's clearly larger. The Single-High bar at 500 ms vs Multi- High at 1500 ms shows that our multi-layer strict mode took roughly 3× longer. This is expected: multi-layer prompts potentially ask for more info or multiple steps (e.g., one could imagine a case where the system asks for consent and maybe another dialog for policy justification – though we try to avoid double-dialogs). More commonly, it's just one prompt, so the main difference from single-layer prompt might be the complexity of the prompt or the fact that even more cases trigger prompts.

The takeaway is latency is context-dependent. In normal operations (multi-layer low-interaction), the overhead is negligible – the user experiences near-real-time sharing. Only in cases where extra verification is needed does the user experience a delay, similar to a security checkpoint. Multi-layer does not inherently make things slow; it only slows down transactions that have privacy implications (which is arguably a necessary trade-off).

Usability and User Experience

Finally, we look at usability, which encompasses user convenience and satisfaction. We quantified it via a score out of 10 as described. Figure 4 shows the user experience score for the scenarios.

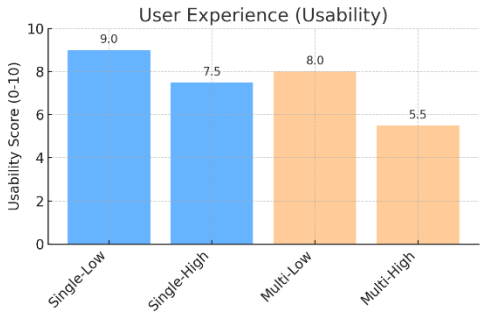

Figure 4: User Experience (Usability) Score.

Higher is better (10 means user hardly noticed any friction; 0 would mean extremely frustrating). As expected, the scenario with Single-Layer, Low interaction scored the highest, around 9.0 out of 10. This makes sense – baseline share sheet with no additional prompts is very easy to use (the only minor ding being the user did the initial share action itself, hence not 10 but close). Single-layer with high interaction (if it prompted for confirmation a lot) scored about 7.5, since those extra confirmation steps annoy some users.

IV. CONCLUSION

This work presents a privacy-enhanced content sharing framework that augments traditional share sheet functionality with adaptive, multi-layer protection. The proposed architecture combines a user consent layer and a dynamic access control layer, ensuring that every sharing request undergoes comprehensive evaluation before data is released. Through detailed design flows, we demonstrated how the system validates user intent, performs trust assessment of receiving applications, and enforces privacy policies—closing a critical gap in existing sharing mechanisms where data is often shared without sufficient vetting.

To formalize the decision-making logic, we developed a mathematical model that captures trust estimation, privacy risk computation, and adaptive consent probability. Using this model, we conducted MATLAB-based simulations and evaluated three key metrics: privacy enforcement rate, response latency, and overall usability. The results indicate that the adaptive multi-layer architecture significantly enhances privacy protection, achieving 90–98% policy enforcement, compared to 70–85% for a single-layer baseline. This improvement translates to a substantial reduction in unauthorized or unintended data exposure. Notably, the enhanced protection is achieved with minimal impact on user experience; the system maintains high usability scores and introduces only negligible latency for non-interactive sharing. By prompting users only when contextually necessary, the architecture balances strong privacy safeguards with a smooth and intuitive sharing process.

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