The GAINAfrica approach to smart communities

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***Abstract*—This paper proposes a participatory and context-driven framework for the adoption of GenAI in low-resource *smart environments and communities* and investigates two alternative technology transfer pathways: mediated transfer through innovation intermediaries and direct end-user uptake. The framework is operationalized through living labs and evaluated across four application domains in African countries.**

***Index Terms*—Generative AI, Socio-technical smart systems**

I. Motivation

In recent years, the imperative to conceptualize frameworks for the design and deployment of AI systems that are responsive to heterogeneous realities and contextual specificities has grown increasingly important [1]. This is particularly pertinent in politically and culturally sensitive contexts, which entail different configurations of needs and, consequently, different modalities of AI use, underlining the urgency of locally adapted tools designed and implemented to address specific requirements. The realization of a project of this nature requires a clear understanding and the ability to recognize factors such as social, linguistic, and economic diversity, as well as a clarification of how to address these issues ethically. The research investigates how participatory design, living-lab experimentation, and alternative technology transfer mechanisms can support the sustainable adoption of GenAI solutions in low-resource smart environments and communities. Particular attention is devoted to comparing mediated and direct transfer pathways in terms of adoption, sustainability, and local ownership.

II. Approach

The methodological framework adopts a participatory and context-driven approach to innovation. Rather than treating GenAI systems as fully developed technological artefacts that can be transferred across regions without modification, it views innovation as a socio-technical process shaped through iterative interaction between technology, users, and institutional environments. This approach promotes co-creation, integration of local knowledge, contextual adaptation, and the mitigation of biases and language barriers. Living labs constitute the main environment for experimentation, data collection, and technology validation. They bring together users, researchers, industry, and public institutions to explore, develop, and evaluate technological solutions in real-world settings. By embedding innovation within everyday contexts, living labs enable the observation of social, organizational, and infrastructural dynamics that influence adoption and usability [2], also incorporating robust ethical governance mechanisms. A governance baseline is also established to ensure accountability and transparency in system operations. This includes structured management procedures, audit logging mechanisms, and traceability protocols that enable monitoring of system behavior and data processing activities. Furthermore, a risk and safety register is maintained to systematically document potential ethical, operational, and technical risks associated with system deployment. The methodology consists of three phases: (i) needs assessment and stakeholder engagement, (ii) co-design and development within living labs and (iii) deployment and validation in real-world settings.

A. Technology transfer process

The novelty of this work lies in the comparative analysis of two technology transfer mechanisms through which AI-based solutions may transition to real-world implementation. This analysis evaluates *mediated* and *direct* transfer in terms of effectiveness, sustainability and local ownership. The first pathway corresponds to a mediated technology transfer model, in which technologies based on EU solutions will be introduced in Egypt, Tunisia and Morocco through intermediaries such as start-ups and incubators. This model reflects established patterns of academic technology transfer in which commercialization entities play a key role in bridging the gap between research and market deployment. The second pathway explores a direct end-user uptake model, where technological solutions are adopted directly by healthcare practitioners, institutions, or public service providers without the mediation of dedicated actors.

B. Technological architecture

At the core of the system lies a GenAI component based on Small Language Models (SLMs) to support natural language interaction between users and the system. To improve the reliability and transparency of the generative outputs, the system integrates a Retrieval-Augmented Generation (RAG) architecture. User queries are first matched against curated knowledge repositories, ensuring that responses remain grounded in the relevant body of knowledge for each use case. The retrieved information is provided as contextual input to the SLM, allowing it to generate responses grounded in verifiable sources. The framework integrates contextual data from distributed sensing infrastructures relevant to each deployment context. When available, these data streams can enrich the analytical pipeline with real-time information, enabling AI models to incorporate up-to-date contextual evidence into their reasoning processes. To support this integration, the system includes a data processing layer that harmonizes heterogeneous information sources. Beyond the adoption of standard GenAI technologies, the architectural contribution lies in enabling deployment in multilingual, data-scarce, and resource-constrained environments through contextual adaptation, lightweight integration mechanisms, and locally governed knowledge repositories.

III. Positioning

GAINAfrica operationalizes the proposed methodology through four use cases: healthcare, smart cities, smart agriculture, and digital skills and learning. Each use case applies the same methodological framework and contributes empirical evidence to evaluate the technology transfer pathways.

- The first use case, *healthcare*, responds to a gap noted in the literature: most validated systems target high-resource, EHR-integrated settings, while rural and remote facilities require offline-capable architectures. The use case grounds its generative outputs in curated clinical guidelines and locally adapted protocols through the RAG architecture, directly responding to limitations of unconstrained SLM reasoning in complex clinical scenarios and to performance degradation observed under real-world distribution shift.
- The second use case targets *smart cities*, which face seasonal peaks from tourism and events. The solution pairs a multilingual City Visitor Assistant that provides crowd-aware itineraries, real-time alerts, and accessibility features for women, families and the elderly.
- In the third use case, *smart agriculture* addresses crop losses among farmers who lack timely agronomic support, particularly in rural regions. The use case combines computer vision-based disease diagnosis from smartphone images with soil, satellite, and weather data to support decision-making. Based on these inputs, it provides natural-language treatment recommendations and precision farming alerts, such as irrigation and harvest timing in farmers' local languages.
- The fourth use case, *digital skills and learning*, focuses on applying GenAI to enhance digital literacy and personalized learning in African and EU university contexts. The system integrates SLMs into digital tutoring platforms to support students in ICT, entrepreneurship, and STEM courses. Through conversational tutoring, adaptive content generation, and multilingual explanations, it provides on-demand academic assistance, bridging gaps in access to qualified instructors.

This positioning is further supported by ongoing academic contributions addressing the constraints of African deployment contexts, such as lightweight adaptation techniques that avoid costly full model retraining (e.g., model compression [3]). The broader GAINAfrica initiative has also been presented to the research community as a project-level contribution [4].

IV. Conclusion

The key idea of this research is that participatory and context-driven methodology is not just an ethical preference but an epistemic necessity. The project will provide empirical evidence on the effectiveness of alternative technology transfer strategies and on the role of participatory methodologies in improving adoption, trust, and long-term sustainability of GenAI solutions in low-resource environments.

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