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(RESEARCH ARTICLE)

Integration of a Metropolitan Fiber Optic Ring for Telecommunications Network Convergence: A Feasibility and Impact Study in Mbanza-Ngungu

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Abstract

This study proposes the design and analysis of a metropolitan fiber optic ring for integrating the fragmented telecommunications networks in Mbanza-Ngungu, Democratic Republic of Congo. Faced with growing demand for high-speed connectivity and suboptimal existing infrastructure, the project aims to deploy a resilient, scalable, and open digital backbone. A field survey of 280 respondents (households, businesses, schools) reveals widespread dissatisfaction (≤23%) with current internet services but strong interest (62-70%) in fiber optics. The proposed architecture is based on a dual-feed ring using single-mode fiber with DWDM equipment, enabling operator interconnection, the creation of a local internet exchange point, and support for innovative services (telemedicine, online education, smart urban management). This neutral and scalable infrastructure represents a strategic lever for the city's digital transformation and its adaptation to smart city challenges.

Keywords: Fiber Optic; Metropolitan Ring; Mbanza-Ngungu; Network Integration; Urban Development; High-Speed Connectivity; Smart City

1. Introduction

The city of Mbanza-Ngungu, an economic and administrative hub in the Kongo-Central province of the Democratic Republic of Congo, is experiencing accelerated demographic and digital expansion [2]. However, its telecommunications landscape is characterized by pronounced fragmentation: siloed cellular networks, isolated institutional infrastructures, and disparate internet connectivity [1]. This fragmentation hinders the efficiency, reliability, and accessibility of digital services, thereby limiting the potential for local socio-economic development [10].

In this context, the implementation of a metropolitan fiber optic ring emerges as a structuring solution capable of unifying existing infrastructures and serving as a neutral integration platform [3]. This research aims to assess the technical and socio-economic feasibility of such a project, analyzing its architecture, potential impact, and user acceptance, in order to position Mbanza-Ngungu on the trajectory of smart cities [8].

2. Methodology

A mixed approach, combining documentary analysis, technical modeling, and quantitative field survey, was adopted. The methodological approach is structured in four phases:

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- Infrastructure diagnosis: inventory and mapping of existing networks (mobile operators, internet service providers, institutional networks).
- Architectural design: modeling of a dual-feed metropolitan ring, with definition of routes, points of presence (POP), and transmission technologies.
- Field survey: administration of a structured questionnaire to a sample of 280 stakeholders (households, businesses, schools) to assess satisfaction with current services and interest in fiber optics .
- Impact analysis: evaluation of technical (resilience, bandwidth), economic (transit cost reduction), and societal (access to digital services) benefits.

Survey data were processed using descriptive statistical analysis (frequencies, percentages).

3. Results and discussion

3.1. Survey Results: User Needs and Expectations

The survey reveals a critical connectivity landscape, with strong unmet demand.

Table 1 Distribution of Respondents

Category	Number	Percentage
Households	200	71.4%
Businesses	50	17.9%
Schools	30	10.7%
Total	**280**	**100%**

$Percentage = \frac{\text{Category count}}{\text{Total respondents}} \times 100$ (1)

Table 2 Satisfaction and Interest Rates by Category

Category	Satisfied	% Satisfied	Interested in Fiber	% Interested
Households	45	22.5%	132	66.0%
Businesses	9	18.0%	31	62.0%
Schools	5	16.7%	21	70.0%

$$Satisfaction\ rate = \frac{\text{Number satisfied in category}}{\text{Category count}} \times 100 \ (2)$$

$$Interest\ rate = \frac{\text{Number interested in category}}{\text{Category count}} \times 100 \ (3)$$

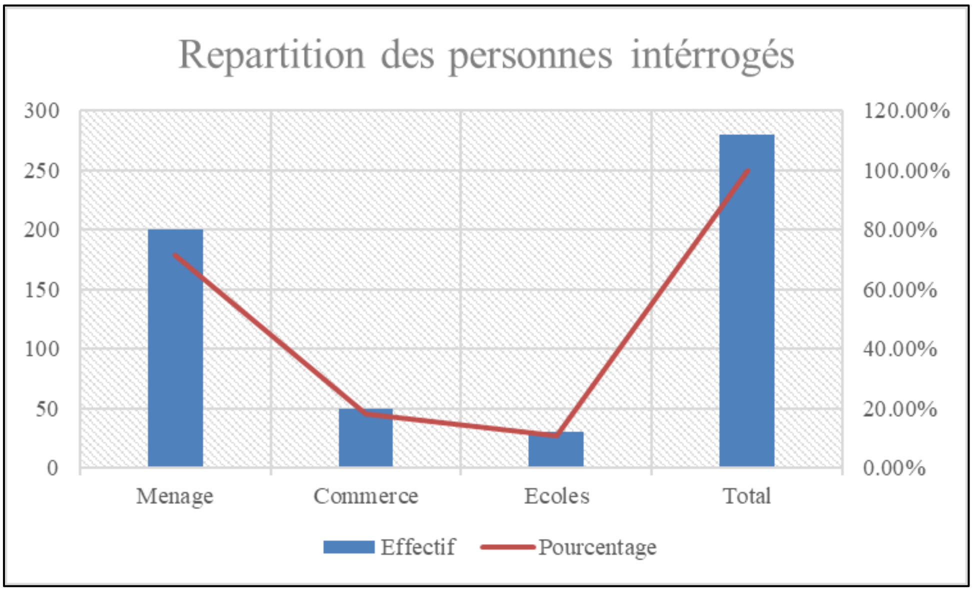

Figure 1 Distribution of Respondents

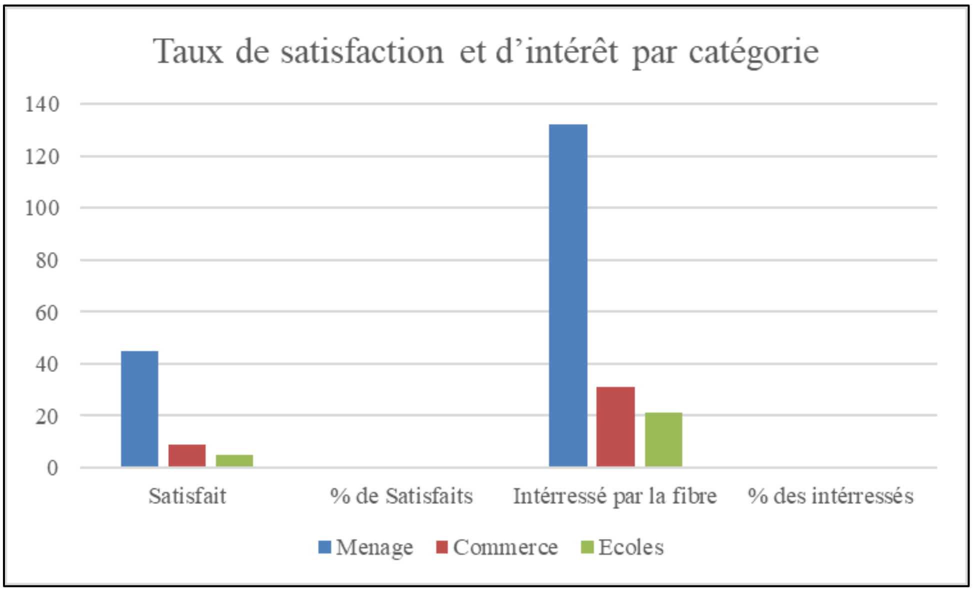

Figure 2 Satisfaction and Interest Rates by Category

3.1.1. Interpretation

The survey is predominantly based on households (71.4%), which is logical for a study on fiber optics. Businesses and schools represent a smaller but significant portion of the sample.

Generally Low Satisfaction

- The level of satisfaction with current internet is low across all categories, nowhere exceeding 23%.
- Schools are the least satisfied (16.7%), which could indicate that current bandwidths are insufficient for their educational and administrative needs.
- This widespread dissatisfaction reveals a clear need for improvement in internet infrastructure in the area concerned.

Massive Interest in Fiber Optics

- In total contrast to satisfaction, interest in fiber is very high across all three categories, ranging between 62% and 70%.
- Schools show the highest interest (70%). This corroborates their low satisfaction and highlights their pressing need for a more efficient and reliable high-speed connection.
- A large majority of households (66%) are interested, which represents a very significant potential market for an operator.

The results of this survey send a clear signal. The population and professionals are overwhelmingly dissatisfied with their current internet connection and are very interested in switching to fiber optics. This fiber deployment contribution would therefore meet a strong and justified expectation with a very high adoption potential, particularly among schools and households.

3.2. Proposed Technical Architecture

The designed metropolitan ring is based on a dual-feed closed-loop topology, encircling the strategic areas of the city. Its key characteristics are:

- Physical medium: G.652.D single-mode fiber, with dedicated conduits and secure cable pathways [9].
- Transmission layer: DWDM (Dense Wavelength Division Multiplexing) equipment enabling an initial capacity of 10 Gbps per channel, expandable to Terabit.
- Points of Presence (POP): located at critical nodes (city hall, university campus, reference health center, operator exchange zones).
- Governance: open access network model managed by a neutral entity, guaranteeing non-discriminatory access to all operators and institutions.

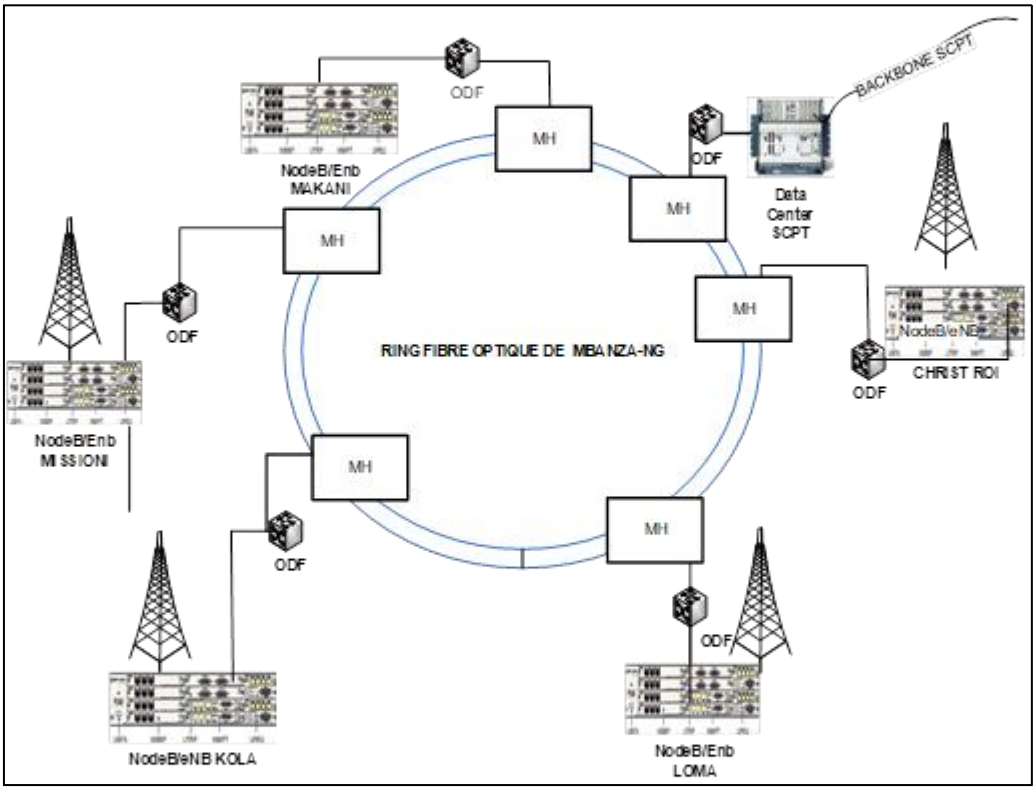

Figure 3 Physical Diagram of Proposed Architecture

3.3. Multi-dimensional Project Impacts

3.3.1. Network Convergence and Interoperability

The ring will serve as a neutral aggregation backbone, enabling :

- Direct interconnection of mobile operators (reduction of transit traffic, improvement of call quality).
- Fiber backhauling of 3G/4G/5G stations.
- Creation of a local Internet Exchange Point (IXP), reducing latency and international transit costs [6].

3.4. Catalyst for Innovative Services

The infrastructure will support the deployment of :

- E-education services (virtual classrooms, digital libraries).
- Telemedicine and telediagnosis platforms.
- E-government and smart urban management solutions (video surveillance, adaptive lighting).

3.5. Resilience and Quality of Service

The ring topology with protection (MSP type) offers availability greater than 99.99%, with re-routing time below 50 ms in case of failure.

3.6. Sustainability and Economic Optimization

The shared infrastructure model avoids costly duplications, reduces entry costs for new players, and represents a sustainable investment, preparing the city for future technological evolutions .

4. Challenges and operational recommendations

4.1. Identified Challenges

- Financial: high initial investment in civil works and active equipment [2].
- Institutional: complex coordination between multiple stakeholders (operators, municipality, landowners) [5].
- Technical-operational: acquisition of right-of-way, physical security of the network, sustainable maintenance.

4.2. Strategic Recommendations

- Strong institutional leadership: creation of a multi-party steering committee involving the municipality, operators, and civil society.
- In-depth feasibility study: including cost-benefit analysis, financial modeling, and phased deployment plan.
- Hybrid financing model: combining public funding, concessional loans, and private investment through PPPs (Public-Private Partnerships) .
- Incentive regulatory framework: adoption of a municipal charter facilitating deployment and guaranteeing open access.
- Awareness and inclusion: targeted communication campaign and integration of universal service clauses to reduce the digital divide.

5. Conclusion

The deployment of a metropolitan fiber optic ring in Mbanza-Ngungu goes beyond simple telecommunications infrastructure modernization. It represents a structuring investment with strong cross-cutting impact, capable of transforming the local digital landscape by integrating existing networks within a unified, resilient, and high-performance architecture. Survey results confirm massive user support, reinforcing the legitimacy and urgency of the project. By laying the foundations for a connected and smart city, this initiative could serve as a reference for the digital development of other secondary cities in the DRC, thus contributing to a sustainable reduction in digital access inequalities.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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