CHAPTER 1

Introduction

Context and objective

This thesis reports a project consisting of the development of a sizing model for public IoT networks, explicitly designed to support smart city (Albino et al., 2015) coverage planning. As urban environments increasingly rely on connected sensors, meters, and actuators, ensuring a reliable and scalable communication infrastructure becomes critical for municipalities and public authorities. The proposed model addresses this challenge by providing a structured, assumption-driven approach for initial network dimensioning, enabling planners to generate rapid, transparent, and defensible estimates of coverage, capacity, and resource requirements. By focusing on public IoT deployments within azesmart city contexts, this work aims to bridge the gap between conceptual planning and actionable design, providing a practical methodology for early-stage decision-making. Conventional network design toolchains tend to be either (i) sophisticated but closed and time-consuming to configure, or (ii) ad-hoc spreadsheets whose logic is difficult to audit or reuse. Public authorities and project teams often face a gap at the outset: they need a structured, assumption-driven sizing method that is lightweight enough for rapid iteration and rigorous enough to reveal key drivers and trade-offs. This gap is especially critical in public IoT deployments—such as city-wide, district, or municipal networks—where technology choices (e.g., LPWAN versus cellular), propagation conditions, device density, and duty-cycle constraints interact in complex and often unpredictable ways. (Zaman et al., 2024) (Kanellopoulos et al., 2023) (NIST Wireless SuperCluster, 2019) (Azevedo & Mendonça, 2024)

This project, conducted within an industry–academia collaboration between ISCTE and KPMG, details the development of a spreadsheet-based framework for dimensioning public IoT networks, with a focus on smart-city (Albino et al., 2015) coverage analysis. The proposed template uses formula-based estimations (e.g., for throughput) and explores macro automation for its workflow. It adopts an assumption-driven approach, aiming to demonstrate a streamlined methodology for initial network sizing and planning. The work benefited from supervision by KPMG—primary advisor Tomás Santos and secondary advisor Rúben Silva—and academic supervision at ISCTE by João Silva.

The primary objective of this work is to develop and validate a reusable, spreadsheet-based template that facilitates the initial planning of public IoT networks for smart-city scenarios. Specifically, the project aims to: (1) define what type of inputs a planner needs to provide; (2) develop formula-based estimates for path loss (ETSI & 3GPP, 2022), link budget (Sharma et al., 2016) and throughput (Shannon, 1948); (3) organize the workbook so that dependencies are clear and easy to change; and (4) use macro-level automation (VBA) to handle common tasks—such as scenario setup, toggling assumptions, and generating standardized reports and charts.

These objectives lead to the following research questions:

(RQ1) What are the essential parameters required to develop a practical dimensioning template for public IoT networks?

(RQ2?) How does an assumption-driven modeling approach impact the feasibility and utility of the dimensioning tool for initial network planning?

(RQ3) What are the main practical challenges and limitations encountered when automating network-analysis processes within a spreadsheet environment?

(RQ4) How can the complex process of public IoT network dimensioning be simplified and modeled into a reusable template for rapid, first-pass coverage analysis?

Methodology

This thesis is implemented as an Excel macro workbook (project.xlsm) that operationalizes first-pass dimensioning through a structured set of input and output sheets. The macro "CreateTablesFromInput" (in the workbook) reads declarative instructions from the sheet "Model Configurator" and builds auditable tables for scenarios. Key inputs are provided via: "Study Years" (planning horizon), "Regions" (geographical partition), "Verticals_Sectors" (use-case taxonomy), "Network Parameters" (e.g., Busy-Hour contention ratio, headroom), "Throughput Formulas" (device counts and traffic profiles), "Base Stations Sites" (site categories), "Base Stations Profiles" (per-site capacity: simultaneously active users, downlink throughput), "Base Stations Parameters" (RF parameters for link budget and spectral-efficiency calculations, including bandwidth, sectors, MIMO layers, SNR, antenna gains, path-loss, other losses, carrier frequency, base-station height, and interference margin), and "Sites per Region" (initial siting estimates). Outputs are generated in "Output Formulas" and consolidated in "Model Output" for screening-level coverage/capacity and cost.

The work proceeds by (i) requirements elicitation with practitioners; (ii) definition of a canonical, technology-agnostic structure for the workbook; (iii) decision of compact formulas for key estimations; and (iv) implementation in Microsoft Excel using cell formulas for traceability and VBA for workflow automation. Attention is paid to separating input assumptions from computed layers, tagging each dependency, and enabling scenario replication with minimal manual steps.

Contributions

The contributions of this project are threefold. First, it proposes a minimal yet complete set of parameters and structural components for a practical IoT dimensioning template, organizing inputs, calculations, and reporting so that the logic remains auditable. Second, it codifies a set of formula-based estimations for the early sizing of public networks and shows how these can be combined to obtain coverage and capacity screens under explicit service targets. Third, it assesses the benefits and pain points of spreadsheet automation for network analysis—documenting where VBA macros streamline repetitive tasks and where the language and host environment impose limitations, maintenance overhead, or brittleness.

An assumption-driven model is both a strength and a limitation. It forces transparency about what is known versus what is asserted, enabling stakeholders to test sensitivity to radio margins, traffic distributions, or retry policies. At the same time, simplifying assumptions—such as homogeneous propagation classes, stationary traffic, or ideal scheduling—can overstate feasibility if taken too far. To enhance reliability, the template incorporates structured validation mechanisms. These include explicit scenario labeling for traceability, predefined parameter ranges to prevent unrealistic inputs, and summary dashboards that highlight deviations from expected performance thresholds.

The thesis also documents the practicalities of automating a dimensioning workflow in a spreadsheet. Where appropriate, macros help (re)initialize scenarios, validate inputs, calculate batches, and render standardized charts and summaries. However, experience indicates that non-trivial automation in VBA is not only labor-intensive but also prone to fragility when workbook structures evolve, due to its tight coupling with sheet layouts and lack of modular design. (Power Streamline, 2024).

From an industrial perspective, the template aims to shorten the time from idea to first-order network plan, allowing consultants and municipal teams to triage options and focus detailed engineering where it matters most. By constraining the problem to declared assumptions and well-scoped estimations, organizations can create repeatable analyses across districts or use cases and build a library of comparable scenarios.

Structure of the report.

The remainder of this thesis is organized as follows. Chapter 2 reviews the background on public IoT networking and the planning considerations relevant to smart-city deployments. Chapter 3 specifies the requirements and overall design of the dimensioning template. Chapter 4 details the formula-based estimations and their integration in the workbook. Chapter 5 describes the automation layer and discusses its benefits and limitations. Chapter 6 presents scenario experiments and validation results. Chapter 7 synthesizes findings, highlights limitations, and outlines future work.

The work benefited from supervision by KPMG—primary advisor Tomás Santos and secondary advisor Rúben Silva—and academic supervision at ISCTE by João Silva.

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