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Optimal sensor placement and leakage detection in water distribution networks

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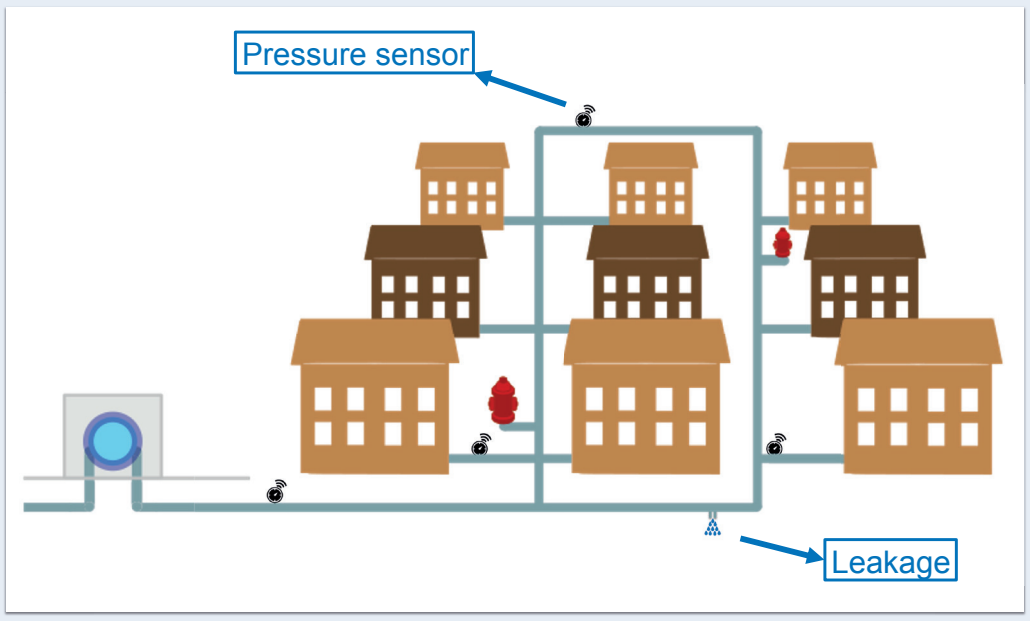
Motivation

Water distribution networks (WDNs) are essential systems that provide drinking water to various regions, yet water loss due to leakages remains a significant issue. Even in highly developed countries like the Netherlands, approximately 5% of drinking water is lost, while in countries like the UK, this can reach as much as 21% [1]. These figures highlight significant room for improvement. Reducing these losses is not just about conserving water—it also means minimizing financial strain, reducing environmental harm, and ensuring sustainable water management [2].

Innovative methods such as **digital twins** (virtual replicas of physical systems), **observers**, or **data-driven techniques** offer new ways to enhance leakage detection and localization. By advancing these technologies, WDN efficiency can be greatly improved, reducing water losses and supporting long-term sustainability.



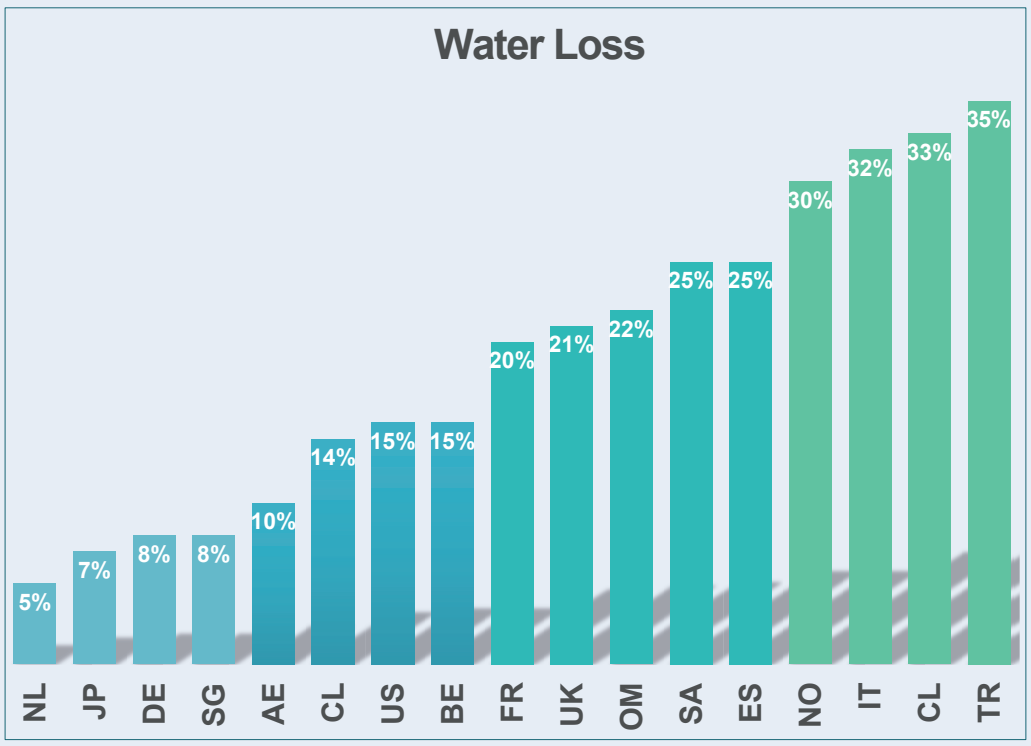
Technological challenge

In addressing leakage detection in water distribution networks (WDNs), several challenges need to be overcome:

1. **Leakage Detection**: Sensors and models are essential to detect leaks early before they grow into larger problems. Currently, leaks are often discovered through visible water pooling or user complaints, which are reactive and somewhat inefficient methods.
2. **Leakage Localization**: Once a leak is detected, its precise location must be identified to minimize excavation costs, water loss, and water contamination. Without accurate sensor data or validated models, localization can be time-consuming, inaccurate and costly.

To improve these two challenges, four technical challenges are formulated as follows:

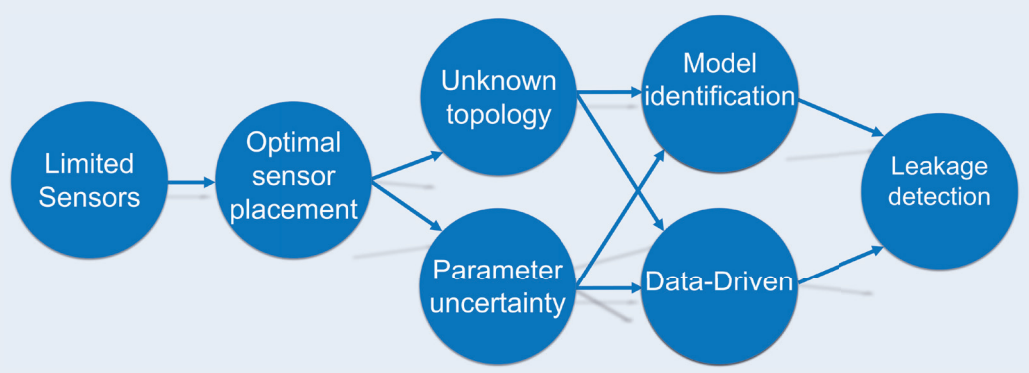
1. **High Sensor Costs and Limited Deployment**: Sensors capable of measuring pressure or flow are expensive, which results in a limited number of sensors in WDNs.
2. **Sensor Placement Optimization**: Determining the optimal number and location of sensors to balance cost and performance is a complex, unresolved problem.
3. **Limited Knowledge of Network Parameters**: Many parameters in WDNs, such as pipe roughness, valve settings, and pipe lengths, remain unknown or poorly defined. This uncertainty undermines the accuracy of available models.
4. **Inaccurate Structural Representations**: Often, the existing maps and schematics of water networks do not reflect the actual on-ground layout, further complicating model development.



Research goals

1. **Optimal sensor placement**: Develop strategies for optimal sensor placement that address uncertainties and support model validation, identification, and efficient leakage detection.
2. **Model validation and network structure identification**: Create innovative methods to validate models of WDNs and accurately identify the network structure.
3. **Leakage detection and localization**: Develop advanced methods for real-time detection and precise localization of water leakages within the distribution network.

[1] W. N. Europe, “Eu urges to monitor and reduce water leakages,” 2023, accessed: 2024-10-29.
[2] A. M. Annaswamy, K. H. Johansson, and G. Pappas, “Control for societal-scale challenges: Road map 2030,” IEEE Control Systems Magazine, vol. 44, no. 3, pp. 30–32, 2024.



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