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### Water LLM Architecture: Leak Detection in Water Networks

**#### Overview**

The architecture for the Water LLM project focuses on leveraging GenAI and machine learning to detect and manage leaks in urban and rural water distribution networks. It includes a strong integration with existing systems like SCADA, GIS, and work order systems, aiming to improve operational efficiency, reduce non-revenue water, and proactively address infrastructure issues.

**#### Core Components**

**1. \*\*Sensor Network\*\***

- \*\*Pressure Sensors\*\*: Minute-wise data collection per pipe segment.

- \*\*Flow Meters\*\*: Junction-based inflow/outflow readings.

- \*\*IoT Gateways\*\*: Protocols like OPC-UA, MQTT, Modbus for data transmission. Supports at least 10,000 sensors in parallel.

2. \*\*SCADA and IoT Integration Layer\*\*

- Manages telemetry data ingestion and connectivity.

- Real-time data processing <= 10 seconds latency for decision-making.

3. \*\*Water LLM Engine\*\*

- \*\*Leak Detection Model\*\*: AI/ML-based on flow-pressure anomalies using frameworks like PyTorch, TensorFlow.

- \*\*Data Integration Pipeline\*\*: Real-time ingestion of pressure/flow data for continuous monitoring.

4. \*\*GenAI Advisory Layer\*\*

- \*\*LLM\*\*: GPT-4 or a fine-tuned model for generating insights and recommendations.

- \*\*Summarization\*\*: Natural language output on leak causes, impact, and actions.

5. \*\*Work Order and Notification System\*\*

- \*\*Integration\*\*: Connect with systems like Maximo/SAP/IFS for work order management.

- \*\*Notification Services\*\*: Utilizes email, SMS, and mobile app push notifications for alerts.

6. \*\*GIS Platform\*\*

- Visual representation of network segments, terrain, and leak locations.

- Risk zones color-coded: Red for critical, Orange for moderate, Green for healthy.

7. \*\*Database and Storage\*\*

- \*\*PostgreSQL/TimescaleDB\*\*: Time-series database for sensor data storage.

- \*\*Cloud Storage (S3/Azure Blob)\*\*: For leak logs and training data archives.

**#### Workflow Overview**

1. \*\*Data Ingestion and Preprocessing\*\*

- Sensor data collected via SCADA and transmitted to the Water LLM Engine.

- Preprocessed for anomalies using rule-based and ML techniques.

**2. \*\*Leak Detection Process\*\***

- Anomaly scores computed every 15 minutes to identify potential leaks.

- Alerts generated and integrated with SCADA dashboard for real-time monitoring.

3. \*\*Insight Generation and Alerts\*\*

- GenAI generates summaries when anomalies are detected.

- Insights are relayed to respective stakeholders through notification systems.

4. \*\*Work Order Creation and Management\*\*

- Automatic generation of work orders for leaks with severity above threshold.

- Technician assignment based on AI suggestions factoring in location, skillset, and availability.

5. \*\*Risk Scoring and Proactive Measures\*\*

- Daily risk scoring for pipe segments based on historical data and environmental factors.

- High-risk zones trigger proactive inspection recommendations.

**#### Additional Functionalities**

- \*\*Technician Advisory System\*\*: Matches incidents with technician skills and safety measures.

- \*\*Data Export and Analytics\*\*: Historical data exportable for continuous improvement of ML models.

- \*\*Visualization and Mapping\*\*: GIS overlays for easy interpretation of terrain and network interactions.

**#### Non-Functional Aspects**

- \*\*Scalability\*\*: Supports 10,000+ sensors, leveraging cloud infrastructure for elastic scaling.

- \*\*Reliability\*\*: System uptime target 99.9%.

- \*\*Security\*\*: Compliance with GDPR, ISO 27001 for data protection.

- \*\*Latency\*\*: Alerts delivered 1 minute; data latency 10 seconds.

#### Integration and Ethics

- \*\*Integration Requirements\*\*: Connects with SCADA, GIS, work order systems, ensuring smooth data exchange.

- \*\*Ethical AI\*\*: Emphasis on bias avoidance, transparency, and explainability to maintain trust.

#### Readiness and Deployment

- \*\*Infrastructure Setup\*\*: SCADA system configuration, IoT gateways installation where necessary.

- \*\*Data Preparation\*\*: Archive of 6-12 months data, curated and validated.

- \*\*System Configuration\*\*: Work order systems and secure data access mandated for operations.

**### Conclusion**

The architecture for Water LLM is designed to support proactive, data-driven management of water distribution networks. By integrating real-time monitoring with cutting-edge AI technologies, this system aims to significantly improve the detection and resolution of leaks, reducing water wastage and enhancing overall service efficiency.